# SUMMARY OF STOCK ASSESSMENTS

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by

RESOURCE ASSESSMENT DIVISION

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# STOCK ASSESSMENT SUMMARIES

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

# INTRODUCTION

Assessments of about 25 species - stocks are made annually by members of the Resource Assessment Division of the Northeast Fisheries Center. In previous years, such assessments were made in conjunction with or reviewed by scientists of other countries within STACRES (the Standing Committee on Research and Statistics). The results were reported to ICNAF (International Commission for Northwest Atlantic Fisheries) Commissioners, who agreed on catch limitations for the upcoming year. The assessments were published in ICNAF Redbooks. The following assessment summaries have been conducted by members of the Resource Assessment Division using all available commercial and recreational landings and sampling data and research vessel survey data through 1976. Details of the assessments are available at the Northeast Fisheries Center.

## COMMERCIAL FISHERY TRENDS

### Gulf of Maine, Georges Bank and Southern New England Area

Total commercial catches of all species declined from 791,000 tons in 1975 to 646,000 tons[1] in 1976 (18%). Total catches of groundfish species declined from 221,000 tons in 1975 to 198,000 tons in 1976 (10%). The greatest decline occurred in silver hake (20%), the catches of other groundfish species being approximately the same as, but in total slightly below, those in 1975. Total catches of pelagic species declined from 380,000 tons in 1975 to 248,000 tons in 1976 (35%). Declines occurred in herring catches (48%) and mackerel catches (39%), although catches of other pelagics increased by 51% due to increases in catches of menhaden. Total commercial catches of other fish declined by 50% mainly due to decreases in dogfish, skates, and non-specified finfish catches. Total invertebrate catches increased from 148,000 tons in 1975 to 177,000 tons in 1976 (20%), due in part to increases in squid catches (41%). Catches of shrimp declined from 5,300 tons in 1975 to 1,000 tons in 1976.

### Middle Atlantic Area

Total commercial catches of all species in the Middle Atlantic were almost identical in 1975 and 1976 at 895,000 tons. Declines in catches of silver hake (56%), red hake (27%), squid (34%), and other invertebrates (13%) were offset by increases in catches of mackerel (26%) and other pelagics (mainly menhaden) (43%).

## RECREATIONAL FISHERY TRENDS

National marine recreational angling surveys have been conducted in 1960, 1965, and 1970. Additionally, a regional survey was made for the northeastern states in 1974, and a local New Jersey party and charter boat recreational survey

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[1]Tons in this report refers to metric tons

was conducted during 1975-76. Although survey methodologies and sampling techniques differed somewhat between studies, several trends in the marine angler harvest in North Atlantic waters are discernable. The total number of finfish caught by marine recreational anglers (Maine through Virginia) increased 8% between 1965 and 1970 (2.65 million fish in 1965 vs 2.85 million fish in 1970), but declined 51% from 1970 to 1974 (1.40 million fish in 1974). Similarly, the weight of finfish caught by marine anglers in this region increased 16% between 1965 and 1970 (4.45 million pounds in 1965 vs 5.14 million pounds in 1970), but declined 30% from 1970 to 1974 (3.57 million pounds in 1974). Overall, between 1965 and 1974, the number and weight of finfish harvested by marine recreational fishermen decreased 47% and 20%, respectively. A review of survey methodology to provide more reliable estimates is currently in progress; this will be completed in late 1977.

## COD

Several cod stock complexes have been proposed for the Georges Bank, Gulf of Maine and Middle Atlantic areas.

The largest component is the Georges Bank stock. The 1976 commercial catch from this stock dropped to 17,400 tons from 24,000 in 1975, primarily as a result of lower Spanish and Soviet catches. The autumn bottom trawl surveys provide an index of abundance of this stock. The 1976 total abundance indices were about equal with those preceding it. The number of pre-recruits was relatively high compared to catches from earlier surveys.

Mortality rate estimates indicate that the Gulf of Maine stock is being fished beyond the $F_{max}$ level. Commercial catches of 11,900 tons in 1975 in the Gulf of Maine were the highest catches ever recorded. This stock also sustains the Gulf of Maine recreational fishery.

The southern component of the Georges Bank stock complex was examined separately from the Georges Bank data in the bottom trawl surveys. This component is the basis of the Middle Atlantic commercial and recreational fisheries. The New Jersey component of this fishery, covered in the July 1974 to June 1976 NEFC creel survey, has been very poor. Spring bottom trawl survey indices indicated a pronounced drop in overall abundance in 1976. The relatively high 1977 index, however, suggests some improvement in stock abundance. Further study is required before hypotheses can be developed to explain these changes in the Middle Atlantic area.

## HADDOCK

Haddock have been managed as a single unit in the Georges Bank - western Gulf of Maine area since 1970, although separate spawning stocks exist on Georges Bank, off Nantucket Shoals, and in the western Gulf of Maine. To date, analytical assessment work has been performed only for the Georges Bank stock.

Preliminary data for 1976 indicate a catch of 6,300 tons for Georges Bank and the western Gulf of Maine, down somewhat from the 1975 total of 6,700 tons. Albatross IV autumn bottom trawl survey data indicate a continued decline in abundance from 1967-1974 (with autumn indices for weight and numbers being the lowest on record); 1975 values increased somewhat. For 1976, numbers and weight per tow increased sharply coincident with appearance of the strong 1975 year-class, although adult spawning stock size remained at a very low level.

The 1975 year-class should increase spawning stock size considerably in 1978 if it is not subjected to excessive fishing pressure. Under the current incidental catch limitation of 6,000 tons and average recruitment levels observed in recent years, stock size will stabilize at approximately half of the pre-1960 level in the mid-1980's, again provided that incoming year-classes are not overfished.

## REDFISH

The 1976 redfish catch in the Gulf of Maine - Georges Bank area was 10,750 tons, marking the third successive year that catch remained between 10,000 and 11,000 tons. The standardized commercial catch per unit effort index declined from 1.9 to 1.8. The survey index was the lowest since the series started in 1963. Previously, the survey length frequency data had shown an abundance of small fish from the 1971 year-class, but in 1976 these fish were missing. Concurrently, smaller fish (probably from the 1971 year-class) increased considerably in the 1976 commercial landings. Furthermore, the survey length frequency data indicate a lack of any substantial recruitment other than the 1971 year-class for at least the next five years. Further analyses are being conducted but the current information indicates a decline in abundance from 1977 to 1978.

## SILVER HAKE

### Gulf of Maine Stock

The 1976 catch of 9,746 tons was the largest catch since 1970 and was taken entirely by the US. Commercial catch-per-day increased from 7.8 tons in 1975 to 16.7 in 1976, the highest catch rate since 1968. The 1976 autumn survey catch-per-tow index was the highest since 1963. The 1975 and 1976 spring survey abundance indices were the highest in the 1968-77 time-series. The spring index, however, dropped sharply from 1976 to 1977. This drop may be due to changes in distribution or availability since other evidence suggests improving stock abundance.

The relationship between fishing effort and fishing mortality indicates an F of 0.21 in 1976 for ages 3 and older (M = 0.4) compared to $F_{0.1}$ = 0.3 and $F_{max}$ = 0.6. Stock biomass (age 2+) in 1977 was about 73,000 tons; stock size has increased steadily from a low of only 16,000 tons in 1971. The highest level of biomass (age 2+) during 1955-77 was about 180-185,000 tons in the late 1950's.

Recent year-classes have been much stronger than those produced in the late 1960's. The 1973 year-class appears to be the strongest since 1964, followed in strength by the 1974, 1976, and 1972 year-classes.

A catch of 9,000 tons in 1977 (the total allowable catch) will leave an estimated stock (age 2+) in 1978 of 81,400 tons. This stock appears to be rebuilding. If the catch in 1978 varies between 6,500 and 15,500 tons (F = 0.12 - 0.30), the stock (age 2+) in 1979 will range between the 1978 level (81,400 tons) and the 1976 level (72,000 tons).

### Georges Bank Stock

The 1976 catch was 42,500 tons (the total allowable catch was 50,000 tons) compared to 63,000 tons in 1975 and was the lowest catch since 1970. The USA catch

was 3,800 tons. USA commercial catch-per-day increased from 22.8 tons in 1975 to 46.1 tons in 1976, the latter being the highest catch rate since 1959. The 1976 USA autumn survey catch-per-tow index was the highest observed during the 1963-76 time-series, and the spring survey index increased sharply from 1976 to 1977 which was the highest observed during 1968-77.

Fishing mortality in 1976 was estimated to be 0.35 for age 3 and older (M = 0.4) based on a relationship between fishing effort (calculated using USA catch-per-effort) and fishing mortality from virtual population analysis (VPA) for this stock, $F_{0.1} = 0.30$ and $F_{max} = 0.45$.

Autumn survey abundance indices at age 0 and spring survey abundance indices at age 1 are not consistent with each other or with year-class estimates at age 1 from VPA. Therefore, it is difficult to predict the size of the incoming year-classes. However, using the spring indices which have been the most consistent in predicting year-class size, the 1974 year-class appears to be fairly strong, although a little weaker than the 1972 year-class, which was the strongest since 1963. The 1975 year-class appears to be about as poor as any observed, while the 1976 year-class is about twice the size of the 1975 year-class but still below the average of the 1954-73 year-classes.

Stock biomass (age 2+) at the beginning of 1977 was estimated at 260,000 tons, down from 305,000 tons in 1976. The stock has increased in recent years from a low of 131,000 tons (age 2+) in 1971. The high during 1955-77 was 593,000 tons in 1964. Stock size projections for 1978 will be made as soon as 1977 catch projections are available. Although a TAC of 70,000 tons was set for 1977, it is unlikely that the total catch will be taken. The USSR allocation was 46,050 tons, but through March their catch was only 3,900 tons and the window is closed after 30 June.

Southern New England - Middle Atlantic Stock

The 1976 total catch was 23,700 tons compared with 43,000 tons in 1975 and 59,500 and 66,000 tons in 1974 and 1973, respectively. The USA commercial catch was 9,054 tons in 1976, the highest since 1966, and the estimated recreational catch was only about 1,000 tons.

USA commercial catch-per-day increased from 5.3 tons in 1975 to 6.6 in 1976, the highest since 1970. The USA autumn survey abundance index increased markedly from 1974 to 1976; however, the spring survey index declined from 1975 to 1977.

Fishing mortality was estimated to be 0.45 in 1976 for ages 3 and older (M = 0.4), which is about the $F_{max}$ level. Recent year-classes appear to be quite good based on the 1969-73 relationship between autumn survey catch-per-tow at age 0 and VPA year-class sizes at age 1. The 1976 year-class is estimated to be the strongest since 1965 followed by the 1974 year-class which is about the size of the strong 1971 year-class. The 1975 year-class is below average but still stronger than those produced in 1966-70 and 1972-73.

Stock biomass (age 2+) in 1977 was estimated as 148,000 tons, the highest since 1968. Peak biomass was 368,000 tons in 1965. The stock has generally been rebuilding since a low of 59,000 tons in 1971, although there have been fluctuations between 1971 and 1977.

The stock appears to be in good condition now with good year-classes entering the fishery. Exact stock size and catch projections for 1978 will be estimated, pending the availability of 1977 catch estimates.

Stock Identity

There is some evidence to indicate that several discrete stocks of silver hake exist off the eastern USA coast (SA 5-6). Conover et al. (1961) reported the existence of two separate stocks, one in the Gulf of Maine and one south of Cape Cod, based on an analysis of various morphometric measurements. This study did not reveal any significant differences between inshore Gulf of Maine fish

and offshore fish from the northern part of Georges Bank.

Tagging studies conducted in 1957-58 (Fritz, 1959, 1962, 1963; and unpublished data) produced only a 4.3% rate of recapture. Most of the tagged silver hake were recaptured fairly close to the site of tagging, with the greatest movement being about 65 km. These results did not indicate any movement of silver hake between the Gulf of Maine and the area south of Cape Cod.

Nichy (1969) examined first year growth patterns on otoliths from young silver hake and found a difference in otolith zonal formation and length at age between Gulf of Maine and southern New England fish using 41°30'N latitude as the division line.

Konstantinov and Noskov (1969) reported that serological analysis had distinguished two stocks: (1) Georges Bank and (2) Cape Cod - Cape Hatteras. A division between these two stocks was suggested to be in the Nantucket Shoals area (70°W longitude), with some mixing occuring during autumn and winter.

Although some USA studies suggest distinct stocks in the Gulf of Maine and south of Cape Cod, and USSR studies distinguish between Georges Bank and Cape Cod - Cape Hatteras stocks, definitive data are still lacking to establish the stock identity of silver hake occupying the Gulf of Maine - Georges Bank area. There is some evidence which suggests that fish from the Gulf of Maine and the northern part of Georges Bank may belong to the same stock. Plots of station catches of silver hake during USA bottom trawl surveys illustrate the seasonal distribution of the species and may provide some insight concerning the possible delineation of stocks. Winter and spring surveys indicate that silver hake are generally absent from the shoal portion of Georges Bank at those times but are present in the deep water of the Gulf of Maine, along the northern slopes of Georges Bank and along the continental shelf south and west of the Bank. Summer and autumn surveys indicate a widespread distribution in both shoal and deep water. Fish which inhabit the northern part of Georges Bank during the warm months appear to retreat to the deeper waters north of the Bank during the cold months. Similarly,

those inhabiting the southern part of Georges Bank during water periods appear to move offshore during cold periods to overwinter. It is, therefore, possible that two stocks exist on Georges Bank. The fish which occupy the northern part of Georges Bank and the shoal areas of the Gulf of Maine in summer and autumn may overwinter in the same or adjacent grounds in the central deep-water basin of the Gulf. This being so, then either two separate stocks mix or segments of a single stock migrate in various directions during the warm months. Previous work (Conover et al., 1961) indicated no morphometric differences between silver hake from these two areas which supports, to some extent, the concept of a single stock. However, similarity in morphometric characteristics is not sufficient basis for such a conclusion.

Winter and spring bottom trawl surveys document the concentrations of silver hake along the continental shelf slope from Georges Bank to the Hudson Canyon vicinity with greater numbers evident towards the southern end of that range. There appears to be no clear-cut demarcation between a Georges Bank stock and a Cape Cod - Cape Hatteras stock. Summer and autumn surveys particularly show a continuous distribution of fish from Georges Bank to Hudson Canyon.

It is possible that only two completely discrete stocks exist in SA 5-6. Some evidence suggests that silver hake from the Gulf of Maine and the northern part of Georges Bank comprise one stock, while the ambiguousness concerning any definite division between southern Georges Bank and Cape Cod - Cape Hatteras fish, as evidenced by bottom trawl survey catch distribution plots and by the suggestion of a zone of mixing between the two proposed stocks (Konstantinov and Noskov, 1969), could infer that a single stock is continuous from southeastern Georges Bank to Cape Hatteras.

The uncertainty associated with silver hake stock delineation in SA 5-6 has resulted in stocks defined by ICNAF divisions and subdivisions: (1) Gulf of Maine (Div. 5Y), (2) Georges Bank (Subdiv. 5Ze), and (3) southern New England - Middle

Atlantic (Subdiv. 5Zw and SA 6). Most important, for the purposes of assessment, is the fact that all non-USA catch data have been reported on the above basis, and to define stocks by geographical areas which would not coincide with the above areas would create serious problems and potential errors in assigning catches to stocks. Therefore, until such time as more definitive data are available (e.g., from tagging studies) and, if necessary, catch statistics could be accurately apportioned to stocks, the present stock boundaries should be continued.

## RED HAKE

### Georges Bank Stock

The total catch in 1976 was 18,850 tons compared to 15,000 tons in 1975 and 9,500 tons in 1974. The USA catch was only 37 tons. The 1977 TAC was set at 16,000 tons.

The USA spring survey catch/tow index increased steadily from a low in 1974 until it dropped in 1977. Stock biomass of age 2+ fish from cohort analysis (data base = 1968-76) reached a high of 88,000 tons in 1971 and decreased to 45,000 tons in 1974; it has remained at about that level in 1975-77. The spring survey index and the cohort analysis results agree very well in describing the recent changes in this stock.

Fishing mortality in 1976 at ages 3+ was estimated as 0.79 (M = 0.4) compared with 0.55 in 1975 and 0.35 in 1974. $F_{max}$ = 0.70 and $F_{0.1}$ = 0.35 for this stock.

The 1971-73 year-classes were about 40% smaller than the 1967-70 year-classes. However, the 1974 year-class appears to be good, nearly the same size as those of 1967-70. Recruitment estimates based on survey data have not been consistent with results from the fishery (cohort analysis). The 1975-76 year-classes were assumed equal to the poorest seen since 1967.

The 60-mm mesh regulation effective for the foreign fishery, beginning in 1977, changes the partial recruitment coefficients from an estimated 4%, 50%, and 100% at ages 1, 2, and 3+, respectively, in 1976 to 4%, 36%, 82%, and 100% at ages 1, 2, 3, and 4+, respectively. Projections for 1977 indicate that an F of 0.85 will be required to produce a catch of 16,000 tons (the TAC) leaving a stock biomass (age 2+) in 1978 of 41,700 tons, a 6.5% decrease from 1977. If 13,000 tons (a more realistic estimate, assuming the USSR takes its allocation and other countries fish at levels comparable to past years) is taken, an F of 0.65 will be generated, leaving the same stock biomass (age 2+) in 1978 as in 1977.

Southern New England - Middle Atlantic Stock

Total catches (commercial plus estimated recreational) declined steadily from 40,125 tons in 1973 to 11,043 tons in 1976. Recreational catch was about 300 tons in 1976 and averaged 372 tons for 1960, 1965, 1970, 1974, and 1976. The USA commercial catch was 3,829 tons in 1976, the highest since 1970. A TAC of 28,000 tons was set for 1977.

Stock biomass (age 2+) declined from 133,000 tons in 1971 to about 58,000 tons in 1976 and increased slightly to 64,000 tons in 1977. This trend was also shown by the survey data, although the spring index decreased from 1976 to 1977.

Fishing mortality was estimated to be 0.25 in 1976 for ages 3+ compared with 0.39, 0.70, and 0.84 in 1975, 1974, and 1973, respectively. The 1971-75 year-classes all appear to be approximately the same size and are about half of the size of the 1967-70 year-classes.

The partial recruitment coefficients determined for 1976 were 6% at age 1 and 100% at ages 2+. With a 60-mm mesh in effect for the foreign fishery, beginning in 1977, partial recruitment is estimated to be 1%, 17%, 83%, and 100% for ages 1, 2, 3, and 4+, respectively.

If the full TAC of 28,000 tons is taken in 1977, an F of 1.2 will be required, leaving a stock biomass (age 2+) of 50,500 tons in 1978 (21% decrease from 1977). If only 23,000 tons is caught, F would be 0.89 leaving a stock biomass of 55,000 tons in 1978 (14% decrease).

## POLLOCK

This stock has been assessed as a unit in the Georges Bank, Gulf of Maine, and Nova Scotian areas. Commercial samples and US and Canadian research vessel survey data indicate that the 1972-1974 year-classes are weaker than preceding ones which supported the fishery in recent years. Assuming that 30,000 tons is taken in 1977 (the ICNAF TAC) and that the 1975 and 1976 year-classes are equal in strength to the preceding three, stock size (age 4+) would be 80,000 tons in 1978 compared to approximately 84,000 tons in 1977 (stock sizes for 1975 and 1976 calculated from cohort analysis were 104,000 tons and 93,900 tons, respectively). Fishing at $F_{max}$ in 1978 would provide a catch of 28,100 tons with a 1979 stock size of 78,900 tons; fishing at $F_{0.1}$ would provide a catch of 17,700 tons with a 1979 stock size of 90,500 tons.

## YELLOWTAIL FLOUNDER

Yellowtail flounder has been assessed as four units in the Gulf of Maine, Georges Bank, Southern New England and Middle Atlantic areas. A small stock off Cape Cod has supported a localized fishery of about 2,000 tons for a number of years and while no analytical assessment is yet available for this stock, some declines in recent years are evident from the commercial catch-per-tow data.

The Georges Bank stock has been the largest in recent years but has declined considerably in the past few years as recruitment in the 1970's averaged only half that in the last half of the 1960's, while removals remained at 15,000 to 20,000 ton levels. In 1976, the survey indices, both total and pre-recruit, were the lowest on record. The 1976 commercial age composition data is only partially analyzed but indicates an increasing dependance on two year old fish.

The Southern New England yellowtail stock was for many years the mainstay of the fishery, however, there have been no strong year-classes since 1968. The index for the 1975 year-class in the fall 1976 survey was up from the previous three years but was roughly only half the 1971-1972 average and one sixth the average of the 1962-1968 year-classes. The survey indices for all age groups were also up in 1977 from the previous three years but still only a fraction of early years. Recent management has been designed to harvest the surplus yield awaiting the occurrence of a huge year-class to begin rebuilding the stock. Although no good year-classes have appeared, the stock seems to have stabilized at a very low level.

In the area west of Block Island, a small yellowtail flounder fishery traditionally existed until 1972 and 1973 when the catch doubled that of preceding years, reaching almost 9,000 tons. By 1975, the fishery had collapsed to less than 1,000 tons. Survey indices dropped drastically after 1972. The 1976 values remain very low and recruitment appears to be very poor, likely resulting in further stock declines.

## FLOUNDERS EXCEPT YELLOWTAIL

Provisional statistics indicate a 1976 catch in the Georges Bank, Gulf of Maine and Middle Atlantic areas of all other major flounders (winter flounder, summer flounder, American plaice, witch and windowpane flounder) of 27,461 tons of which 27,381 tons were taken by USA vessels. Since 1963, the total commercial catch of these flounders (predominantly winter flounder and summer flounder) has generally varied between 20,000 and 30,000 tons. In addition, recent angler surveys have indicated substantial recreational catches of winter flounder and summer flounder. The 1974 regional survey estimated 34,900 tons of summer flounder and 18,884 tons of winter flounder harvested from Maine to Virginia. Using these figures as approximations for the 1976 recreational catch, the total catch of other flounders may be in excess of 81,000 tons in 1976.

USA autumn research vessel surveys show recent increases in abundance of summer flounder in the Southern New England and Middle Atlantic areas. The recreational catch remains the dominant fishery, accounting for about three fourths of the landings (1974 northeast regional survey statistics). In the commercial fishery, New England landings have been increasing from 6% in 1971 to 35% in 1976. Reported foreign catches increased from less than 1% to an average of 20% in the early 70's but with none reported after 1974. Age-length data are currently being prepared and length frequency samples from commercial landings will be aged for further analysis of summer flounder.

The winter flounder abundance index for Southern New England has steadily declined since the mid-1960's. This decline has also been noted in recent studies of inshore winter flounder abundance in Narragansett Bay from 1966 to 1974 (Jeffries and Johnson, 1974) and in Nantucket Sound from 1970 to 1974 (Howe, 1975). The authors of both studies suggest that climatic trends and natural cyclic fluctuations may be responsible, in part, for the observed decline since the

mid-1960's. On Georges Bank, winter flounder abundance appears to have remained relatively stable since 1963.

In 1975 and 1976, USA vessels landed approximately 2000 tons of windowpane flounder annually. About 75% of this catch was taken from the Georges Bank area. Samples from the 1975 landings suggest a modal length of between 30 and 34 cm and an extremely high female to male sex ratio. Research survey catch-per-tow indices and length frequency data showed a substantial increase in the number of small windowpane flounder (less than 11 cm) on Georges Bank in 1974. The overall abundance of this species appears to be up in recent years despite the modest increase in landings. Abundance of windowpane flounder in the Southern New England area has been relatively stable from 1963 to the present.

In the Gulf of Maine, the two most abundant flounders are American plaice and witch flounder. Abundance of witch flounder has declined in recent years, while the index for American plaice has remained relatively stable. The fishery for these two species in the Gulf of Maine is conducted almost exclusively by USA vessels.

# HERRING

Herring catches on Georges Bank declined by 71% during 1976 from the catches of 1975 and 1974. In 1976, the catch of 42,000 tons was due, at least in part, to the reduction in total allowable catch from 150,000 (which held from 1972 to 1975) to 60,000 tons. The catch from the adult fishery (20,200 tons) in the Gulf of Maine has remained relatively stable compared with 1974 (18,000) and 1975 (21,500 tons). The catch from the Gulf of Maine juvenile fishery, however, increased dramatically from 15,200 tons in 1975 to 30,200 tons in 1976. The 1974 year-class accounted for a 13,200 ton catch in 1976 compared with age 2 catches of 2,800, 8,100, and 9,000 tons for year-classes 1969, 1971, and 1972, respectively. The 1973 year-class accounted for a 12,000 ton catch in 1976 compared with age 3 catches of 833, 5,500, and 2,500 tons for the 1969, 1971, and 1972 year-classes, respectively.

These catches suggest that the 1973 year-class was more abundant at age 3 than the 1969, 1971, and 1972 year-classes and that the 1974 year-class may be a strong year-class. The 1973 year-class, therefore, was assumed equal to one-half of the 1966 year-class at age 3 and the 1974 year-class was assumed equal to the 1966 year-class at age 3 in all assessments. In previous assessments, the 1973 and 1974 year-classes were assumed to be equal in size to the 1969, 1971, and 1972 year-classes.

## Maine juvenile fishery

This fishery depends on age 2 and 3 herring primarily which are the 1975 and 1974 year-classes in 1977 and the 1976 and 1975 year-classes in 1978. No index of abundance is yet available to predict recruitment to the juvenile fishery but estimates of larval abundance of the 1975 and 1976 year-classes are very low (ICNAF Res. Doc. 76/VI/123 and G. Lough, personal communication).

Gulf of Maine adult herring fishery

Estimates of year-class size of both the 1973 and 1974 year-classes at age 3 were revised upward from the earlier assessments: 64-91 million fish revised to 133 million for the 1973 year-class and 64 million fish revised upwards to 269 million fish for the 1974 year-class. While the previous assessment (1976 ICNAF Redbook, p35-50) predicted that the stock size (age 4 and older) would decrease during 1976 to 43,000 (from 60,500 tons) if a catch of 20,000 tons were taken, it now appears, due to the change in recruitment assumptions, that the stock size only decreased to 52,800 tons at the beginning of 1977. Assuming a 20,000 ton catch during 1977 would give a stock size at the beginning of 1978 of 67,600 tons (a 28% increase). Under these conditions and assuming that the 1975 year-class is a poor one, 7,000 tons can be taken in 1978 with no decrease in stock size. If a 10% increase in stock size (by weight) is desired during 1978, only 1,000 tons should be taken in 1978. A catch of 20,000 tons during 1978 would produce a fishing mortality rate of 0.58 on the stock and decrease the stock size (age 4 and older) from 67,600 tons to 54,000 tons (a 20% decrease).

Georges Bank adult herring fishery

The same assumptions as to year-class sizes are applied to this stock as were used in the Gulf of Maine herring assessment. To date, there has been a good correlation of year-class strengths between these two adult fisheries. The assumption, as to the 1973 year-class size at age 3, was revised upwards from 550-620 million fish to 781 million. The size of the 1974 year-class at age 3 was revised upwards from 550 million to 1561 million fish (the size of the 1966 year-class at age 3). It is further assumed that the 1977 catch will be 28,000 tons; the total allowable catch is 33,000 tons with a 12,000 ton quota for the US. The US probably will not catch more than 7,000 tons in 1977.

With the low catches in 1976 and 1977 and the improved estimates of year-classes 1973 and 1974, the estimated stock size (age 4 and older) was estimated to increase to 270,000 tons (from 209,000 tons) at the beginning of 1977. The assumed catch in 1977 of 28,000 tons would mean an increase during 1977 of the stock size (age 4 and older) to 456,000 tons at the beginning of 1978 (a 69% increase).

To maintain the stock at 456,000 tons in 1978 implies a fishing mortality rate of 0.20 and a catch of 67,000 tons in 1978. To increase the stock by 10% during 1978 implies a catch in 1978 of 22,000 tons. Catches of 75,000 and 100,000 tons in 1978 requires fishing mortality rates of .22 and .31 and would reduce the stock size by 2% and 8%, respectively, to 446,000 and 420,000 tons.

It should be noted that the year-classes 1971 through 1974 make up 98% of the 1978 stock size by weight and the 1973 and 1974 year-classes make up 73% of the 1978 stock size by weight in the Georges Bank fishery. If the assumption of the 1974 year-class is wrong and is equal to the conventional poor year-class size (85,000 tons) instead of 219,000 tons, then the stock size in 1978 will not be 456,000 tons but 318,000 tons. If both the 1973 and 1974 year-classes are poor (85,000 tons at age 3) then the stock size in 1978 will only be 292,00 tons. The assessment, therefore, is critically dependent on the assumptions concerning the 1973 and 1974 year-classes.

Pooled assessment

To deal with the problem of herring movements and seasonal intermixture of spawning stocks, the catches of herring from all areas from Chedabucto Bay (Northeast Nova Scotia) south were combined into one assessment. This assessment includes all herring caught in juvenile as well as adult fisheries. There are six fisheries involved, all with different recruitment selection rates and mean weights at age. The changes in stock size during 1978 were calculated with a variety of assumed catches in 1978 from the various fisheries.

If the catch of herring in Canada remains at 117,000 tons in 1978, 30,000 tons of herring could be taken in the Maine juvenile fishery and 90,000 tons could be taken in the Georges Bank - Gulf of Maine area adult fisheries with little decrease in stock size. To achieve an increase in abundance of 10%, catches of 20,000 tons in each of the juvenile and adult fisheries in the Gulf of Maine - Georges Bank area can be taken (providing that 117,000 tons is not exceeded in Canada).

Changes in abundance from 1978 to 1979 are related to the proportion of the total Gulf of Maine - Georges Bank catch taken as adults and as juveniles. For example, a 70,000 ton catch in this area broken down as 20,000 tons juvenile fishery - 50,000 tons adult fishery gives a 20% greater increase in stock in 1979 than a 30,000 ton juvenile fishery catch and a 40,000 ton adult fishery catch.

With the present juvenile fisheries combined with the adult fisheries, the $F_{0.1}$ is 0.20 and $F_{max}$ is at 0.38. If management is at the $F_{0.1}$ level, the average recruitment selection coefficients indicate that the mortality on age groups 1 to 4 should be .02, .15, .10, .15 and .2 for ages 5 and older. An equilibrium total annual catch (Chedabucto Bay, Canada, to Cape Hatteras, North Carolina) at $F_{0.1}$ of 240,000 tons could be taken from a stock size of 1.7 million tons if recruitment is poor (average size of 1967, 1968, 1969, 1971, 1972, and 1973 year-classes at age 3). If recruitment is fair (equal to the size of the 1964, 1965, and 1974 year-classes) and $F_{0.1}$ is employed, the annual catch could be 377,000 tons. These are equilibrium conditions and require a rebuilding of the stock to the proper level.

While a combined assessment may provide guidelines of the total mortality that can be placed on the overall abundance, it says nothing about the effects of the distribution of this mortality on the spawning stocks which are of different sizes. To prevent severe reductions in individual spawning stocks, the total mortality allowed for the combined assessment should be proportioned on the spawning stocks according to the size of the spawning population.

# MACKEREL

Mackerel migrate extensively in the area between Cape Hatteras and Newfoundland and as a result have been assessed and managed as a unit stock in the Northwest Atlantic. Total international catch decreased from 431,606 tons in 1972 to 243,033 tons in 1976. USA commercial and recreational catches in 1976 were 2,345 and 4,947 tons, respectively. A TAC of 105,000 tons was set for the commercial fishery in 1977. The provisional reported catch for January-March 1977 was 52,114 tons. The best estimate for the total 1977 commercial catch is about 87,000 tons. A USA recreational catch of 5,000 tons is estimated for 1977, giving a total estimated catch in 1977 of 92,000 tons.

The USA spring bottom trawl survey has shown a continuous decline since 1968, and decreased 37% from 1976 to 1977. There was also a marked decrease in the number of age 1 mackerel caught during the 1976-77 spring surveys.

Fishing mortality in 1977, assuming a total catch of 92,000 tons, was estimated to be 0.39 from a regression between a fishing effort index (total catch divided by the spring survey abundance index) and fishing mortality from cohort analysis. This level of F is nearly 50% less than in 1976 and is the lowest since 1972.

The 1974 year-class is the strongest since 1969, while the 1975 and 1976 year-classes appear to be very poor. Partial recruitment in 1978 was assumed to be 9% at age 1, 39% at age 2, and 100% at age 3 and older.

Total stock biomass (age 1+) increased from about 600,000 tons in 1962-66 to 2.4 million tons in 1969 and then declined to 525,000 tons in 1977. Spawning stock size (50% of age 2 and 100% of age 3 and older) increased from around 500,000 tons in 1962-67 to 1.8 million tons in 1970-72 and then decreased to 435,000 tons in 1977. Given the assumptions of catch and recruitment in 1977, the spawning stock will be reduced further to 402,000 tons in 1978.

A zero catch in 1978 would result in a 6% increase in spawning stock biomass in 1979. A catch of 23,500 tons (F = 0.07) would maintain the 1979 spawning stock at the 1978 level. Fishing at $F_{0.1}$ = 0.35 would produce a catch of 104,000 tons but would reduce the spawning stock by 21% in 1979. Since the overall mackerel stock comes under the jurisdiction of both the USA and Canada, these catch options must apply to both countries collectively. The Canadian catch in 1976 was 15,700 tons and in the present assessment was estimated to be 20,000 tons in 1977.

## OTHER FINFISH

The "other finfish" group off the northeastern coast of the United States consists of a variety of species which are usually caught incidentally to commercial fishing for other species or in mixed industrial catches (e.g., dogfish, butterfish, scup, ocean pout, goosefish and skates) although some (e.g., argentine and alewife) have been subject to intensive directed fisheries. Many are also of considerable recreational importance (e.g., bluefish, weakfish, and striped bass).

For the 1964-1976 period, commercial landings for this stock have averaged 148,400 tons, of which an average of 77,600 tons was taken by the USA. Total landings have declined since 1973, apparently in response both to reductions in individual species TACs and to the overall "second-tier" TACs imposed from 1973-1976 by ICNAF. Nominal commercial catches for 1974, 1975, and 1976 were 131,800 tons, 120,400 tons, and 82,600 tons, respectively; USA catches have fluctuated between 60,300 and 62,00 tons during this period. Combined USA recreational landings of "other finfish" species in the 1965 and 1970 saltwater angling surveys and the 1974 NMFS regional survey were 126,900 tons, 141,500 tons, and 106,500 tons, respectively.

There is no evidence that this group of species, as a whole, is declining under current catch levels. Combined indices for selected species in USA autumn bottom trawl surveys indicate relative stability during the past 5 years; the calculated value for untransformed data was similar to the 1975 value while values calculated from retransformed data (logarithmic scale) increased somewhat. Furthermore, abundance indices for individual species of major commercial or recreational significance in selected strata usually increased over 1975 values, or at least fell within the range of values observed within the last three years. See other sections for separate treatment of alewife and blueback herring, butterfish, scup and weakfish.

## SQUID (Short-finned-*Illex* and Long-finned-*Loligo*)

During 1976, the total catch of squid remained at about the same level as has occurred since 1972 with *Loligo* landings decreasing and *Illex* landings increasing. The USA catch of squid was about 4,000 tons, nearly double the average level in recent years. USA catch per day was also about double the average level since 1970. The catch per day of squid by Japan and Spain was slightly higher and sharply lower respectively.

*Illex* were very abundant in the autumn 1976 bottom trawl survey while the abundance of *Loligo* remained at about the same relatively high level that had occurred in the previous two years. The abundance of pre-recruit *Loligo* and *Illex* was sharply lower in autumn 1976 than in the preceding year, but comparable to the levels observed during earlier years. Preliminary analysis of the spring survey from 1977 indicates that both species of squid were very scarce. It should be noted that the abundance of squid in the spring survey has been more variable than the abundance in the autumn survey, thus the latter is usually used as an index of population size, particularly for *Loligo*.

The preliminary catch estimate of *Loligo* for the first quarter of 1977 (all nations) was about 11,000 tons (16,477, 14,965, and 12,794 tons for 1974, 1975, and 1976, respectively). Although this catch is lower than in the first quarter of recent years, *Loligo* are abundant enough to support an active offshore fishery. The low abundance of both species in the spring survey may reflect cooler water temperatures which might have delayed the movement of *Loligo* inshore and the movement of *Illex* from the continental slope onto the shelf.

At present, the biological bases for the 44,000 ton quota for *Loligo* for 1977 still appears valid. This catch quota was based on a conservative estimate of recruitment of 1.5 billion *Loligo*, applying an exploitation rate of 40% (over the life span of the species) which corresponds approximately to the maximum sustainable

exploitation rate assuming a moderate stock recruitment relationship and ignoring random fluctuations in production. If the autumn 1977 bottom trawl survey indicates that recruitment for 1978 is likely to be poorer than has been indicated in the past, then the situation should be re-examined.

The model on which the 1977 quota for Loligo was based did not quantify the trophic importance of the species. Nevertheless, other components of the ecosystem should not be significantly impacted if regulations protect Loligo against severe changes in stock size.

There is no quantifiable scientific basis for a pre-emptive quota of 35,000 tons for Illex (which has never been caught). The abundance of Illex increased sharply from 1974-1976. During 1970-1974, catches increased from less than 1,000 tons to 20,000 tons and have remained at about the 1974 level in the two years that followed. It appears that catches have been related to population abundance and there is no evidence that catches as high as 20,000 tons have had an impact on Illex production when the population is large. It is impossible to predict the impact of a catch of 35,000 tons, particularly if the abundance of Illex is sharply lower in 1977 and 1978 than during recent years.

Squid are shortlived animals that vary widely in abundance. Management of Loligo and Illex would be more effective biologically if decisions were made and data gathered more in time with the annual productive cycle of these species. The biological bases for optimum yield should be based on the abundance of Loligo in the USA autumn bottom trawl survey immediately preceding the regulated fishing season. For Illex, neither of the present research surveys are particularly useful for management. The autumn survey indicates the abundance of Illex at the end of the summer fishing season, presumably just before they migrate offshore to spawn and die. A high abundance of pre-recruit Illex in the autumn survey might indicate good fishing the next year (as the autumn 1975 survey indicated in retrospect),

but this is a rare event. The spring survey appears to be too early in the year (water temperature still cold) to give a good indication of the abundance of Illex during the following summer and autumn. Summer surveys and special cooperative research during 1977 should indicate a strategy for estimating Illex abundance.

While the USA catch of squid increased in 1976 (during a year of very high squid abundance), it was still only a fraction of the estimated capacity for 1977. The USA catch during the first 3 months of 1977 (prior to the start of the inshore squid fishing season) does not indicate any increase in domestic fishing pressure.

## TOTAL FINFISH AND SQUID IN THE GEORGES BANK - MIDDLE ATLANTIC AREA

Clark and Brown (1977) calculated catchability coefficients for all stocks from Georges Bank to the Middle Atlantic using USA commercial and autumn bottom trawl survey data. These coefficients were applied to USA autumn bottom trawl survey data (stratified mean catch per tow values) for 1964-1975 to obtain total biomass estimates by year. To reduce the effects of anomalous fluctuations in survey catches, data were transformed to logarithms and retransformed values calculated; linear (untransformed) values were also calculated for comparative purposes. Note also that (1) catchability coefficients were calculated by relating autumn survey data to stock size estimates at the beginning of the following year and (2) coefficients were applied to autumn bottom trawl survey data; consequently, computed estimates are considered to represent stock size at the beginning of the year following the survey.

Resulting estimates indicate a decline in total biomass to an apparent all-time low in 1975, followed by an increase to the beginning of 1977. However, short-finned squid (Illex) estimates for 1977 were anomalously high, possibly due in part to changes in catchability in recent years. USSR summer surveys indicate minimum biomass levels of 197,000 tons and 258,000 tons for Georges Bank area in 1975 and 1976, respectively (Knostantinov and Noskov, 1977). Consequently, it would appear logical to assume a modest rate of increase based on the USSR surveys, i.e., from 200,000 tons in 1975 to 250,000 tons and 300,000 tons in 1976 and 1977, respectively.

Applying the above Illex biomass estimates for 1976 and 1977, the total biomass estimates for untransformed and retransformed data, respectively, are 2338 - 2656 x $10^3$ tons for 1976 and 3121 - 3414 x $10^3$ tons for 1977. The 1977 estimates are substantially higher than for 1976 (33% and 29% for untransformed and retransformed data, respectively).

## RIVER HERRING

The river herring fishery, composed primarily of alewife (Alosa pseudoharengus) and blueback (A. aestivalis), is one of the oldest in North America, and was exclusively a USA inshore fishery until 1967, when the distant water fleet began catching river herring. With the advent of the foreign fishery, USA catches dropped to approximately half the 1969 level by 1971, although fishing effort remained relatively constant (Street, 1976). These catches have continued to decline to an all-time low of 6,480 tons by 1976 (provisional statistics), and averaged 10,518 tons annually from 1971 to 1976. This decline in USA catch has been accompanied by a similar decline in the foreign fishery. After a rapid increase from 1967 to a high of 36,154 tons in 1969, total catches have steadily declined to a low of 3,775 tons in 1975.

An indication of stock decline in the USA fishery is the increased dependence on a single year-class of fish. In 1972, four year-classes were well represented in the landings, but in 1973, only three year-classes were represented. USSR catches were predominantly age 4 and older but with a few age 1 and 2 fish represented. In 1974 and 1975, the USA began to catch only a single year-class of first-time spawners (Street, 1976). This trend, accompanied by large quantities of small immature fish in the foreign catches, suggests a reduction in recruitment of juvenile fish, although Hoagman et al. (1973) state that there were indications of a good year-class in 1973, after a drop in strength between 1970 and 1972.

Abundance indices for alewife from USA spring research vessel surveys for the Southern New England and Middle Atlantic areas reflect the decline in catches since 1969 with the exception of a short resurgence in 1973. This increase may be an artifact associated with changes in fishing power of a

higher opening trawl net introduced in 1973 (conversion factors for this species are still preliminary).

The smaller alewife fisheries within the Gulf of Maine do not appear to have been affected by foreign fishing and increased abundance has been noted in many rivers in recent years.

## SCUP

Commercial scup landings by the USA have increased steadily since 1971, from 4,000 tons in 1971 to 7,000-8,000 tons in 1976. However, present levels of catch are well below the 18,000-20,000 ton catches of the 1950's. The foreign catch for 1976 was only 26 tons, well below the foreign catch of 672 tons for 1975. No new data were available on the USA recreational fishery in 1976, but assuming the catch to be about 30% of the total scup catch, the 1976 total catch was 10,300 tons, a decrease from the 11,800 ton catch in 1975.

Catch per effort for the New England otter trawl fishery during 1967-1976, (using trips for which landings consisted of at least 80% scup) indicates a steady increase in abundance from 1971 to 1975, when the index dropped from 6.33 tons/day in 1975 to 5.57 tons/day in 1976. Such a decline was also evident in the catch per tow data of autumn groundfish surveys in the Southern New England area where the 1975 value was 5.3 kg/tow and the 1976 value 1.8 kg/tow.

In the Mid-Atlantic area the groundfish survey indicates a substantial increase in scup abundance during 1975; catch per tow values increased from 1.6 kg/tow in 1975 to 14.8 kg/tow in 1976. For the entire area occupied by scup, an increase from 3.6 kg/tow in 1975 to 7.77 kg/tow in 1976 was observed.

# WEAKFISH

The range of the weakfish extends from Massachusetts to Florida; evaluation of racial studies and tagging information indicates the probable existence of a discrete stock from Cape Cod to Cape Hatteras. Commercial landings from Massachusetts to North Carolina have historically undergone considerable fluctuation; landings declined from 19,000 tons in 1945 to 1,338 tons by 1967 but subsequently rose to 9,133 tons in 1976. Estimates of recreational landings parallel the dramatic increases in the commercial fishery since 1967; thus, total USA landings (commercial and recreational) have increased from 2,837 tons in 1967 to 18,266 tons in 1976. Most commercial landings came from North Carolina, Virginia, and New Jersey, while the majority of sport fish landings occurred in New Jersey, Delaware, and New York.

The average length of fish taken during inshore surveys has increased; nevertheless, a strong 1976 year-class was evident in the autumn survey. Length frequency analysis of trawl survey data and creel census information indicate that young-of-year fish are only partially recruited to the recreational fishery. Total mortality rates (Z) calculated for fish of age 4 and older ranged from 0.47 to 0.75. A yield per recruit analysis was conducted assuming natural mortality rates (M) of 0.2, 0.3, and 0.4, which indicated that an increase in the minimum age landed from age 1.0 to 2.0 would result in a 29-32% increase in yield in weight per recruit at $F_{max}$.

## BUTTERFISH

Nominal butterfish landings increased from 11,047 tons in 1975 to 11,419 tons in 1976. Japan (69%), USA (13.4%), and Poland (13.3%) accounted for most of the production. Catches by the USA, however, decreased by 560 tons from 1975 to 1976.

Catches of butterfish discarded by Spain and Italy during the squid fishery have never been reported, but are estimated to equal 25% of the squid catch based on by-catch ratios and USA surveillance reports. If nominal landings are adjusted to include Italian and Spanish discards, the total catch of butterfish in 1976 increases to 15,823 tons.

Autumn survey abundance indices (kg/tow) remained stable from 1975-1976, but were below the levels of 1968-1974. The recruitment index (no. of age 0+ fish per tow) in the autumn 1976 survey was, however, the largest since 1973, and third largest in the period 1968-1976.

## NORTHERN SHRIMP

The northern shrimp fishery of the Gulf of Maine expanded dramatically during the 1960's and reached a peak in 1969, when 12.8 thousand tons (28.3 million lbs) were landed. Since that time, landings have declined drastically and in 1976 totalled 1.1 thousand tons (2.3 million lbs). Stock size estimates calculated from commercial and research vessel survey data, and NMFS and State of Maine survey indices of abundance, all agree in indicating a decline in stock abundance in the order of 80% since 1969. Further projections (assuming that present rates of decline continue) indicate stock sizes of 3.1 thousand tons (7 million lbs) and 1.4 thousand tons (3 million lbs) for 1977 and 1978, respectively. Recovery potential appears to be limited by unfavorable environmental conditions and by-catch in the Gulf of Maine silver hake fishery.

## NORTHERN LOBSTER

Small lobsters in coastal areas of New Brunswick, Nova Scotia, Prince Edward Island, and the Gulf of Maine are, in general, nonmigratory.

Lobsters of the outer shelf region, however, are rather mobile, exhibiting lateral movement along the shelf edge as well as seasonal shoalward migrations in spring and summer with a return to deeper water in fall and winter (Cooper, 1971). Lobsters move from offshore canyon areas (Hudson, Block, Atlantis, Veatch) into the inshore fishing grounds southwest of Cape Cod where they are taken in the coastal fisheries during spring and summer.

The USA fishery for offshore lobsters (>12 miles seaward of the coast) is presently being conducted from Georges Bank to Virginia and is centered in Rhode Island and Massachusetts with approximately 81% of the 1975 catch and 82% of the 1976 catch being landed in these two states.

Historically, landings of offshore lobsters were first reported in 1950 (136 tons) and during the following decade landings increased gradually to 544 tons (1960). By 1969, the annual catch had increased to 3,138 tons. Landings peaked at 3,983 tons in 1972 and have since declined to 2,512 tons for 1976.

Stratified mean catch per tow values (in numbers and weight) from USA research vessel surveys were averaged for the period 1964-1966 (Southern New England, Georges Bank), and the period 1967-1969 (Middle Atlantic) and compared with corresponding values for 1974-1976. Mean weight (kg/tow) declined 75%, 72%, and 67% for Southern New England, Georges Bank, and the Middle Atlantic, respectively, while stratified mean numbers per tow have declined 68%, 53%, and 56%, respectively.

Commercial indices also indicate a decline in offshore lobster abundance. The pot index has declined from 1.64 kg/trap haul set over day in 1969 to 0.36

in 1976, and otter trawls show a general decline from 680 kg/day fished in 1964 to 510 kg/day in 1976.

A State-Federal lobster mortality yield-per-recruit workshop indicated that current fishing mortality rates are excessive and minimum size limitations too low in all areas for maximum yield-per-recruit.

## RED CRAB

The red crab (Geryon quinquedens) occurs along the continental slope from Nova Scotia to Brazil at depths of 20 to 1,200 fathoms (Rathbun, 1937). From the Gulf of Maine to Cape Hatteras red crabs inhabit depths between 60-800 fathoms, with large concentrations occurring between 175-350 fathoms (Gray, 1970; Meade and Gray, 1973; Haefner and Musick, 1974; Wigley et al., 1975). High densities and quantities of crabs are found where water temperature is between $5^{o}$-$8^{o}$ C (Wigley et al., 1975).

Directed commercial exploitation of the red crab began during 1973 (Rathjen, 1974, 1977).

Trawl and trap survey cruises for red crab (McRae, 1961; Anonymous, 1971, 1973; Murray, 1974; Wigley et al., 1975; Ganz and Hermann, 1975) indicate striking differences in size between male and female crabs, with males being generally larger in carapace width and heavier in weight. The sexes appear also to be bathymetrically isolated; females are common at depths between 175 and 275 fathoms and relatively rare at other depths, while males are sparse in shallow water (<175 fm) but rather uniformly abundant in depths from 175-700 fathoms (Wigley et al., 1975). An inverse relationship between depth and crab size (i.e., young crabs in deep water and large crabs in shallower water) was documented by Wigley et al. (1975) and postulated as evidence for size-related, long-term, up-slope migration.

In May and June 1974, a red crab tagging program was undertaken by the National Marine Fisheries Service, to obtain further information on the movements and growth of this species. A total of 7,825 red crabs were tagged with labelled spaghetti tags tied around the carapace and released in the slope area between Hudson and Veatch Canyons in about 200 to 500 fathoms. To date, 467 tags have been recovered (F. Lux, personal communication).

Preliminary analysis of the tags recovered during 1974 (Ganz and Hermann, 1975) indicated that most recaptures were taken less than four miles from their release site. Recoveries made in 1976 and 1977, however, showed that some crabs moved between 30 and 40 miles from the release location and that some were at large for as much as three years (F. Lux, personal communication). Since this type of tag is lost during molting, molting had obviously not occurred in two years in many of the crabs and in at least three years in others. This would suggest that a slow growth rate is characteristic of the species, a pattern generally observed in other deep-water, decapod crustaceans.

Red crab landings in 1976 were the highest in the short history of the fishery. A total of 1,394,000 pounds was landed in Massachusetts and Rhode Island ports, an increase of over a million pounds from 1975. Landings consist only of male crabs with a minimum carapace width of 4½ inches (115 mm). Females and small male crabs are culled from the catch at sea.

The size frequency of commercially harvested crabs shows little temporal variation from the size frequency distributions obtained from research and exploratory fishing cruises, indicating that fishery activities, at present, have not significantly affected population structure.

A total of 182 million crabs, of all sizes, and 43 million of commercial sizes, was estimated to inhabit the four geographic zones surveyed during the 1974 NMFS red crab survey based on photographic analyses. Commercial size crabs were most abundant at intermediate depths (175-350 fm) and were less populous in both shallower and deeper water with none taken in water depths greater than 500 fathoms.

Estimates of standing crop biomass (weight) of commercial size red crabs were calculated from density estimates provided by the photographic analyses

combined with the average weight of trawl-caught crabs. This latter equates to 59 million pounds of commercial size crabs.

A first approximation of annual maximum sustained yield (MSY) from the red crab fishery can be determined using the commercial biomass estimate and assuming the instantaneous rate of natural mortality to be 0.2 (similar to that suspected for king crab (Eldridge, 1972) and using Gulland's (1971) procedures this value is 5.9 million pounds. This estimate would be identical to that derived by using the ratio between virgin biomass and maximum sustainable yield of 10:1 estimated by Caddy et al. (1974) for slow-growing, long-lived, offshore crustaceans.

Although biomass estimates for red crabs in the Gulf of Maine are not available, surveys conducted by the Rhode Island Division of Fish and Wildlife in the southern Gulf of Maine during 1974 indicated an absence of large crabs (over 115 mm) (Hermann, 1974). Hence, this region is not expected to contribute to the commercial red crab fishery.

Preliminary analysis of the red crab tag returns in 1974 (Ganz and Hermann, 1975) indicated that 4.84% (379/7,825) of the tagged crabs had been accounted for. All but 25 of the recaptures were recovered by a single vessel (F/V MARS), in the course of seven fishing trips (4.52% return by this vessel).

If the rate of recovery of tagged crabs by the F/V MARS is representative, then theoretically a single fishing trip would yield 0.646% of the population. A single vessel, fishing forty trips a year, could conceivably capture 25.83% of the sample population. As noted by Ganz and Hermann (1975), theoretically, four such vessels, fishing forty trips per year, could capture the entire tagged population.

## SURF CLAMS

The National Marine Fisheries Service has conducted research cruise surveys of surf clam populations since 1965. The primary purpose of many of the surveys was exploratory fishing and not population monitoring; nevertheless useful analyses of trends can be made. Although the entire surf clam population can be considered one stock as the larvae are subjected to distribution by currents, once the beds are established they can be subjected to differing fishing mortality rates and thus surf clams can be analyzed on an areal basis.

A catch per tow index was obtained from NMFS surf clam survey data for offshore northern New Jersey, offshore southern New Jersey, and offshore Delmarva.

Pre-recruit indices were obtained by applying the percentage of sample length frequency distributions in the recruiting size classes from the surveys to the total survey indices.

The survey indices remain stable off the Delmarva Peninsula with yields averaging 20 million pounds (plus the landings from this area which are made north of Maryland). Considering the stable recruitment indices as well as overall survey catches, yields in the neighborhood of 20 million pounds for the area south of New Jersey would result in a stable fishery for the next few years. This allows for a small catch off North Carolina-southern Virginia, which has at present only a limited fishery; and based on the 1976 survey of the few resources off Long Island, the survey index has also remained stable with catches in the neighborhood of 3-4 million pounds.

In New Jersey the catches have declined drastically, paralleling the survey indices. From 1965 to 1967 cruise indices averaged 43 clams per tow and catches of 30 million pounds. In 1969 to 1970 the indices averaged 26 and the catches 13. The indices for 1976-1977 average 7.8. Adjusting the

mortality to be equivalent to the early periods results in catches between 3.9 and 5.4 million pounds. Recruitment indices have been low in recent years, indicating that no recovery would be possible with these catches although the stock might not decline further. However, the clam kill resulting from 1976 low oxygen levels was devastating in the northern area as can be seen by the decline in the index for that area from 7.8 to 2.5. The overall New Jersey average did not decline as a greater number of samples were taken from the southern area in an attempt to delineate the southern boundary of the kill area. If the north Jersey index were weighted equally with the southern one the equivalent catches would be between 2.6 and 3.6 million pounds. If the means were approximately weighted by area, i.e. twice as much weight given to northern New Jersey, the resulting values would be 2.3-3.2 million pounds. Values lower than these would be needed if a good probability of stock build-up is desired.

The New Jersey inshore stocks are not thoroughly covered in the surveys, but the limited number of stations examined supported the conclusions of lower populations and lower numbers of pre-recruit sizes in recent years (Haskin and Starypan, 1975).

## OCEAN QUAHOG

Landings of ocean quahogs increased from 664 thousand pounds (meat weight) in 1944 to 1510 thousand pounds in 1946, then declined to a low of 45 thousand pounds in 1967. During the 1970's, ocean quahog landings once again increased averaging 1450 thousand pounds annually during 1970-1975, and sharply increased to 5545 thousand pounds in 1976. Most of this increase was attributable to the development of the New Jersey fishery. The traditional Rhode Island ocean quahog fishery has remained virtually stable since 1970, averaging 1300 thousand pounds of meat annually.

Results of the 1976 shellfish assessment cruise (NMFS, 1976) indicated a biomass (standing crop) of ocean quahogs of 5.4 billion pounds (meats) from Long Island south to Virginia. Population abundance was estimated by the area swept method (Baranov, 1918) stratified by quahog density, depth range, and geographical region. Abundance declined southward of Long Island, although concentrations of quahogs were generally found in all areas between 20 to 30 fm (37-55 m). This geographical trend in abundance was further corroborated in the results of the 1977 shellfish assessment survey which indicated that ocean quahogs were generally outside of this range of the deoxyginated water.

Annual sustainable yield of 108 million pounds (meats) of commercially harvestable ($\geq$ 3.5 inches) ocean quahogs south of Long Island was estimated using Gulland's procedures (Gulland, 1971) for virgin stock exploitation. This estimate would be identical to that derived by using the ratio between virgin biomass and maximum sustained yield of 10:1 postulated by Caddy et al. (1974) for slow growing, long-lived, offshore species. This assessment whould be interpreted with caution, however, due to the preliminary nature of the biomass estimate and the uncertainty of the natural mortality estimate used in the yield determination. Reports of substantial (25%) quantities of very old (100 years old) ocean quahogs (Dr. Ida Thompson, Princeton University, pers. comm; Anonymous, 1977;

Stanley, 1977) imply that natural mortality may be much lower than 10% annually. If the instantaneous rate of natural mortality is 0.014 (which it would be based on 25% of the population surviving to 100 years old), the $Y_{max}$ would equal 15 million pounds.

Underwater observations of clam dredge performance (Medcof and Caddy, 1971) on ocean quahog beds showed that dredging mortality losses are substantial (>80% of the uncaught clams). This mortality source should be considered in any management measures adopted for the ocean quahog fishery.

## SEA SCALLOPS

USA landings of sea scallops doubled from 4,422 tons (meat weight) in 1975 to 8,711 tons in 1976. Georges Bank landings increased during this period from 907 to 1,770 tons, while Mid-Atlantic catches rose from 2,769 to 6,575 tons. Canadian catches from Georges Bank rose from 7,387 tons in 1975 to 9,675 tons in 1976 (highest Canadian landings in the history of the scallop fishery). Total scallop landings in 1976 were 18,386 tons, a 56% increase from the 1975 catch of 11,809 tons. Preliminary analysis of USA catches for the first few months of 1977 suggests that a doubling of the USA commercial harvest from the 1976 level may be achieved.

Stock size estimates for the Georges Bank and Mid-Atlantic scallop populations are lacking due to an inability to obtain reliable measures of fishing effort and incomplete data on age composition of the catch. USA and Canadian survey cruise and commercial catch/hour indices for 1961-1971 (Georges Bank) indicated high stock abundances in the early 1960's and subsequent decreases through 1971. Survey indices do not exist after 1971.

Yield-per-recruit analyses for both the Georges Bank and Mid-Atlantic scallop populations indicate that maximum yield occurs at a mean age of first harvest of 5.0-7.5 years for all levels of fishing mortality. Little gain in yield, however, is realized by allowing F in excess of 0.3. Although the current fishing mortality rate on either scallop stock is not known, it is highly probable that it is considerably in excess of 0.8.

Analysis of USA commercial length frequency data indicates that the frequency of scallops less than 95 mm (about age 5) has increased in the landings in recent years. For Georges Bank, the percent of scallops less than 95 mm rose from 9.9% in 1975 to 43% in 1976. Similarly, the frequency

of small scallops harvested from the Mid-Atlantic population increased from 25% in 1975 to 59% in 1976. For both areas, these increases imply recent declines in the average age of first exploitation.

Stock-recruitment relationships for sea scallop populations are unknown. The current USA scallop fisheries, however, are dependent on only one or two year-classes. Since irregular recruitment is characteristic of sea scallops, the probability of future recruitment failure cannot be discounted.