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United States Research Report for 1990

by

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A.Status of the Fisheries (Subareas 3-6 inclusive)

Brief summaries are provided on the status of fisheries for major species of finfish and shellfish. More detailed information on these and other species is included in a report entitled **"Status of the Fishery Resources off the Northeastern United States"** prepared annually by the Northeast Fisheries Center of the National Marine Fisheries Service (NMFS).

1. Atlantic Cod

USA commercial landings from Subarea 3-6 increased 22% from 35,620 t in 1989 to 43,505 t in 1990. Compared to 1989, landings in Subarea 3 decreased (7 t vs 111 t), landings in Subarea 4 increased (209 t vs 16 t), landings in Subarea 5 increased (42,989 t vs 34,968 t), and Subarea 6 landings decreased (300 t vs 525 t).

Landings in 1990 from the Georges Bank fishery [Div. 5Z + 6] totaled 28,144 t, 12% higher than in 1989 (25,097 t). Ottertrawl effort (days fished) increased 3% from 1989 and was slightly below the record-high 1988 level. USA commercial CPUE increased sharply (+20%) in 1990 to its highest level since 1984. USA research vessel indices indicate that stock abundance is high due to strong recruitment from the 1987 and 1988 cohorts. Cod age composition data indicate that landings in 1990 were dominated by the strong 1985, 1987, and 1988 year classes.
Gulf of Maine [Div. 5Y] landings in 1990 were 15,145 t (a record-high) and 46% greater than in 1989 (10,397 t). Otter trawl effort, which accounted for 69% of the 1990 landings, increased 7% from 1989 but was still second lowest since 1981. USA commercial CPUE in 1990 increased sharply to its highest level since the early 1980s. Research vessel survey indices indicate that stock abundance remained at a relatively high level in 1990 due to above-average recruitment from the 1986 and 1987 year classes. USA landings in 1990 were dominated by these two cohorts, which together accounted for 86% of the Gulf of Maine cod catch, by number, and 69% by weight.

2. Haddock

USA landings from Subareas 3-6 in 1990 increased to 2,468 t, 740 t more than in 1989, but still the second lowest total ever. Landings from Georges Bank [Subdiv. 5Ze] increased 39% from 1,435 t in 1989 to 2,001 t in 1990. Abundance of the Georges Bank stock continues to remain at a record-low level despite some modest recruitment from the 1987 year class. Landings from the Gulf of Maine [Div. 5Y] haddock stock in 1990 were 433 t, slightly higher than the record-low 263 t landed in 1989. Commercial CPUE and research vessel indices in 1990 indicate that Gulf of Maine stock abundance remains at historically-low levels.

3. Redfish

Subarea 4

USA landings of redfish from Division 4X totaled only 9 t in 1990.

Subarea 5

USA landings of redfish from Subarea 5 declined from 628 t in 1989 to 590 t in 1990, marking the eleventh consecutive year of decline. Landings in 1990 were the lowest since 1934. Redfish are taken primarily as by-catch in the Gulf of Maine mixed species otter trawl fishery. Stock biomass has declined by over 80% since the late 1960s and is currently between 20,000 - 25,000 t. The 1978 year class remains the only significant year class in the fishery. All subsequent year classes have been poor.

4. **Pollock**

Subarea 4

USA landings from Subarea 4 increased from 35 t in 1989 to 213 t in 1990.

Subarea 5

USA landings from Subarea 5 in 1990 were 9,330 t, 10% less than in 1989 (10,510 t), and the lowest annual catch since 1975. USA commercial CPUE has declined consistently since 1983. Commercial fishery age composition data for 1990 indicate that the last strong year class, the 1982 cohort, no longer dominates the landings. Stock biomass continues to decline as a result of high fishing mortality.

5. **Yellowtail Flounder**

Subarea 3

USA landings from Subarea 3 declined from 319 t in 1989 to 6 t in 1990.

Subarea 5

USA landings in 1990 were 13,995 t, 3X higher than in 1989 (4,731 t), and the highest since 1984. Landings from the Georges Bank stock increased to 2,769 t (from the record-low 1989 catch of 1,134 t), while landings from the Southern New England stock increased to 8,133 t (from 2,478 t in 1989). In both stocks, landings in 1990 were dominated by fish from the strong 1987 year class. Research vessel survey indices indicate that stock abundance increased markedly in 1989 (due to the strong recruitment from the 1987 cohort), but declined sharply during 1990 due to high fishing mortality. The fisheries on both stocks remain dependent heavily upon incoming recruitment, although all cohorts since 1988 have been poor.

Subarea 6

Landings declined from 527 t in 1989 to 360 t in 1990.

6. **Other Flounders**

USA landings of flounders [other than yellowtail flounder] from Subareas 3 - 6 in 1990 totaled 15,784 t, 32% lower than in 1989. Compared to 1989, landings from Subarea 3 declined by 99% (10 t vs 1,429 t); landings from Subarea 4 increased by 10 t (14 t vs 4 t); landings from Subarea 5 declined by 17% (12,879 t vs 15,436 t); and landings from Subarea 6 declined by 54% (2,881 t vs 6,262 t). Winter flounder (43% of total), summer flounder (19%), American plaice (16%), windowpane flounder (12%), and witch flounder (9%) accounted for 99% of the 'other flounder' landings. Winter flounder landings remained unchanged (+0.3%) between 1989 and 1990, summer flounder declined 62%, American plaice fell 29%, windowpane flounder declined 26%, and witch flounder landings declined by 38%. Survey indices for nearly all of the 'other flounder' stocks declined in 1990.

7. **Silver Hake**

USA commercial landings from Subareas 5 and 6 in 1990 were 20,187 t, a 13% increase from 1989 (17,820 t). Landings from the Gulf of Maine - Northern Georges Bank stock increased to 6,373 t (+37% from 1989), while landings from the Southern Georges Bank - Middle Atlantic stock (13,813 t) (+5% from 1989) were the highest since 1965. Research vessel survey indices in 1990 indicate increased abundance of the Northern stock due to strong recruitment from the 1988 year class, but little change in the Southern resource where stock size has been relatively low

since 1986.

8. **Red Hake**

USA 1990 commercial landings from Subareas 5 and 6 were 1,758 t, a 13% increase from the record-low 1989 catch of 1,556 t. Landings from the Gulf of Maine - Northern Georges Bank stock in 1990 were 825 t (+6% from 1989), while landings from the Southern Georges Bank - Middle Atlantic stock totaled 931 t (+19% from 1989). In both stocks, fishing mortality is low and stock levels have increased due to good recruitment from the 1985 and 1988 year classes.

9. **Atlantic Herring**

USA landings from Subarea 5 in 1990 were 50,761 t, 25% higher than in 1989 (40,542 t). Landings from the Gulf of Maine (Div. 5Y) in 1990 were 50,534 t, the highest annual catch since 1981. Gulf of Maine spawning stock biomass (SSB) has increased continuously since 1982 and is currently near the high SSB levels observed in the late 1960s. Stock size has increased due to recruitment from the strong 1983 and good 1987 year classes, and reduced fishing mortality rates, particularly on juvenile herring. Landings from Division 5Z in 1990 were 227 t, primarily from Subdivision 5Zw (207 t). There has been no directed herring fishery in Subdivision 5Ze since the collapse of the fishery in 1977. There is evidence of continuing recovery of the Georges Bank population based on research vessel survey results and reports of incidental catches by commercial vessels. Herring landings in Subarea 6 in 1990 were 538 t.

10. **Atlantic Mackerel**

USA commercial landings in 1990 from Subareas 5 and 6 totaled 31,527 t, twice as large as in 1989 (14,516 t), and the highest USA annual catch since 1944. Total stock biomass (Subareas 2-6) has been increasing since 1980 and is presently comparable to the record-high levels (2 million t) observed in the late 1960s. Rebuilding of the stock has resulted from low fishing mortality rates coupled with strong recruitment from the 1981-1982 and 1984-1986 year classes.

11. **Butterfish**

USA landings in 1990 from Subareas 5 and 6 were 2,395 t, 25% lower than 1989 (3,192 t), and the second lowest USA commercial catch since 1978. The 1990 catch was divided about equally between Subarea 5 (1,199 t) and Subarea 6 (1,196 t). Research vessel survey indices indicate that stock abundance is relatively high due to strong recruitment from the 1989 year class.

12. **Squid**

USA landings of long-finned squid, *Loligo pealei*, from Subareas 5 and 6, were 15,469 t, 33% lower than the record-high 1989 catch (23,007 t), but still the fourth-highest ever. Of the 1990 USA total, 45% was from Subarea 5 (6,902 t) and 55% from Subarea 6 (8,567 t). Survey abundance indices indicate that stock abundance remain moderately high, although lower than the very high levels observed in 1988 and 1989.

USA landings of short-finned squid, *Illex illecebrosus*, from Subareas 5 and 6 were 11,316 t, a record-high, and 66% greater than in 1989 (6,802 t). Of the 1990 USA total, 9% was from Subarea 5 (1,003 t) and 91% from Subarea 6 (10,313). Survey abundance indices indicate that *Illex* abundance continues to remain at a relatively high level.

13. **Sea Scallops**

USA commercial landings from Subareas 5 and 6 increased from 14,776 t (meats) in 1989 to a record-high 17,174 t in 1990. Compared to 1989, Georges Bank [Div. 5Z] landings (10,125 t) increased 74%, Gulf of Maine [Div. 5Y] landings (574 t) declined by 11%, while Mid-Atlantic [Subarea 6] landings (6,475 t) declined by 22%.

USA commercial CPUE indices increased in the Georges Bank fishery in 1990 but declined in the Mid-Atlantic and Gulf of Maine regions. The 1990 Georges Bank CPUE index was the highest since 1982, while the 1990 Mid-Atlantic CPUE index was the lowest since 1985. Total USA scallop effort [days fished in all areas] in 1990

increased 19% from 1989, which was a record-high.

Abundance indices from the USA 1990 sea scallop survey indicate that scallop abundance in the USA sector of Georges Bank has increased markedly from the record-low 1989 level, while scallop abundance in the Mid-Atlantic area has remained at a historically high level. In both areas, the 1990 survey abundance indices were the second-highest in the 1975-1990 survey time-series. On Georges Bank, recruitment of the 1987 year class is outstanding in the South Channel region, above-average in the USA Northern Edge and Peak region, but poor in the Southeast Part of the Bank. In the Mid-Atlantic resource, recruitment of the 1987 year class is regionally variable, being exceptionally strong in the Virginia-North Carolina region, moderately strong in the New York Bight, and weak in the Delmarva region.

B. Special Research Studies

1. Environmental Studies

(a) Hydrographic Studies

Hydrographic surveys of the Georges Bank region were conducted in January, February, October, November and December in conjunction with a study of the recovery of the herring stock on Georges Bank. Additional hydrographic surveys of the Bank occurred in April and May during studies of predation by the migrating mackerel population.

Reports were compiled for 1989 summarizing environmental conditions in the shelf and slope waters off the northeastern U.S.A., dealing with the movements and paths of the Gulf Stream warm-core rings, the position and variability of the shelf/slope front, and water column temperature structure across the New York Bight.

Two studies were conducted to examine the spatial and temporal variability in water column stratification over southern Georges Bank. Hydrographic data were analyzed to define the mean seasonal cycle of stratification and the differences between depth zones, and in relation to physical forcing. In the second project, temporal changes in stratification were inferred from short time-scale fluctuations in sea surface temperature (SST) using satellite infrared data. The SST fluctuations were found to be correlated with the spring-neap changes in tidal current mixing which occurs on the Bank.

A report was issued summarizing the temperature observations made in connection with the Northeast Fisheries Center spring and fall bottom trawl survey program. Average surface and bottom temperatures were calculated for four regions of the shelf - Gulf of Maine, Georges Bank, northern Middle Atlantic Bight and southern Middle Atlantic Bight - for each spring since 1968 and fall since 1963. Interannual temperature anomalies were also calculated for the same regions. The anomalies were correlated significantly between the regions in each season.

(b) Plankton Studies

Collaborative studies with Los Alamos National Laboratory investigated the mechanisms by which marine phytoplankton develop increased tolerance to heavy-metal pollutants after prolonged exposure. Five algal species were induced over several years to tolerate cadmium concentrations that had been lethal upon initial exposure; strains have been maintained in high cadmium concentrations for over ten years. The possibility that cadmium-adapted strains tolerate the metal by means of cadmium-binding polypeptides similar to those produced by higher plants was investigated using Sephadex G-50 liquid chromatography, ICP analysis of cadmium in chromatographic fractions, and HPLC amino acid analysis. The most cadmium-tolerant species studied,

Dunaliella tertiolecta and Phaeodactylum tricornutum, showed clear evidence of poly(gamma-glutamylcysteinyl)glycine [(gamma-EC)$_n$G] production. P. tricornutum had been maintained in three cadmium concentrations, and production of (gamma-EC)$_n$G was positively correlated with cellular cadmium content on a dry weight basis. By contrast, Isochrysis galbana, Pavlova lutheri, and Tetraselmis maculata showed no evidence of (gamma-EC)$_n$G production, although I. galbana polypeptide composition was altered by long-term cadmium stress. These findings suggest that differences in the ability of various algal species to compete in polluted environments may be related to the metabolic tolerance mechanisms possessed by each species. Further, detection of (gamma-EC)$_n$G in natural phytoplankton assemblages has potential as a bio-marker of cadmium stress in the first level of the food web.

A technique developed at the Narragansett Laboratory of the NEFC to assess recent growth, condition, and health of individual fish larvae utilizing automated flowthrough fluorescence to determine RNA/DNA content, was presented at the international symposium on Development and Aquaculture of Marine Larvae held in Bergen, Norway. Details of the technique are currently in press.

Herring egg beds and their ecology were studied on northern Georges Bank using a Navy submersible vehicle. Historic sea herring spawning beds were surveyed and subsequent sediment analysis showed that herring prefer pebble gravel on which to spawn.

1990 marked the 30th year of measuring monthly variability in the species composition and relative abundance of phytoplankton and zooplankton across the Gulf of Maine. The sampling began in 1961 as part of the North Atlantic Continuous Plankton Recorder Survey by the Oceanographic Laboratory in Edinburgh, Scotland, with NEFC joining the research effort in 1972. This time-series for planktonic organisms is the longest for any area in the Western Atlantic Ocean, and one that is of great importance given current concern about the possible effects of global warming.

Comparisons between abundance of zooplankton in the Northeast and Northwest Atlantic based on the data from Continuous Plankton Recorder surveys show differing trends, possible related to different climatic regimes over the past three decades. Zooplankton abundance declined in the Northeast Atlantic with no observable upward or downward trend in the Northwest Atlantic, except for an apparent increase in one copepod species, Calanus finmarchicus. Collection of Continuous Plankton Recorder data and the analysis of the plankton time-series in relation to oceanographic and climatic conditions within the U.S. Northeast Continental Shelf ecosystem is continuing.

The automated plankton analyzer, developed in cooperation with the University of Rhode Island is currently being tested with samples from Georges Bank. The system is based on a 386 class personal computer and a flow-through sampler. It can count, measure and identify preserved zooplankton to major taxonomic group. With the flow through sampler, it is designed to run with minimal operator attention, processing a sample of 300 animals in 90 minutes or less.

Results of a study of effects of temperature on spawning adults, embryos, and larvae of winter flounder showed that both adult acclimation temperature and embryo and larval incubation temperature had an effect on larval size and biochemical composition. Larvae produced by adults acclimated to a low temperature (2°C) were better suited for growth at low temperatures, while larvae produced by adults acclimated to a higher temperature (7°C) were better suited for growth at higher temperatures. At first feeding, larvae were larger (higher standard length) and in better condition (high protein and RNA

content) when incubated at lower temperatures.

The Northeast Fisheries Center completed the third year of a study to measure the changing status of Atlantic herring and sand lance in the Nantucket Shoals/Massachusetts Bay/Georges Bank area by tracking interannual changes in the distribution and production of larvae. Six cruises were conducted at monthly intervals from October 1990 through March 1991. The program includes fecundity estimates on mature females collected during the late summer and early autumn period and the preservation of some larvae in ethanol for otolith and biochemical analyses. Samples from the 1990-91 spawning season are being processed at the Polish Sorting Center in Szczecin. Preliminary observations indicate that the principal spawning grounds of herring remain on Nantucket Shoals with less significant spawning occurring in Massachusetts Bay and on Georges Bank as far east as Cultivator Shoals. By December, larvae are spread throughout the study area. The 3-year study has yet to produce evidence of major spawning concentrations of herring occupying the historical spawning beds on eastern Georges Bank, although some recently hatched larvae have been observed in samples taken in the Northeast Peak Region. The areal extent of the dense concentrations of sand lance larvae is now more limited than in the early 1980s but they remain extremely abundant around Nantucket Shoals and, to a lesser extent, over central Georges Bank in January, or about two months after the peak abundance of herring larvae.

(c) Benthos Studies

Analysis continued of benthic macrofauna responses to phase out of sewage sludge dumping in the inner New York Bight. Three years after dumping ended, only limited recovery was evident, e.g., numbers of species in the area most affected by sludge approached those at a reference site, but the faunal assemblage remained sparse, with little resemblance to the reference area fauna.

An attempt was made to re-establish eelgrass, Zostera marina, in Raritan Bay (where it had once been abundant). Survival and growth of the transplants was poor, probably due to factors such as wave action, turbidity, shading by macroalgae and fouling by invertebrates.

About 120 tons of clam shell were spread over six plots in two New Jersey bays. Densities of hard clams, Mercenaria mercenaria, in shelled and unshelled areas will be compared to test the theory that the shells reduce predation on young clams. In laboratory experiments, young-of-the-year winter flounder held under constant low dissolved oxygen (2.2 mg/l) for 11-12 weeks grew only about half as much as in water high in oxygen (6.7 mg/l). There was intermediate growth when oxygen fluctuated between high and low concentrations.

A three-year flounder tagging study in the Hudson-Raritan estuary and inner New York Bight showed that in addition to regular, localized seasonal migrations, there is intermixing among New Jersey, New York and points further north.

Manuscripts were completed on: preliminary findings concerning responses of a) benthic macrofauna and b) the overall ecosystem, to phaseout of sewage sludge dumping in the inner New York Bight; c) metal concentrations in eggs of winter flounder from Boston Harbor; d) effects of dissolved oxygen on growth of young-of-the-year winter flounder; e) winter flounder movements in the inner New York Bight; and f) a biography of pioneer shellfish biologist Ernest Ingersoll. Also, an extensive "Guide for enhancing estuarine molluscan shellfisheries" was published, detailing ways in which "shellfish production specialists" might work with local shellfishermen, citizens, managers, and politicians to improve shellfish habitats and increase yields.

(d) Other Environmental Studies

Research groups have continued to process, analyze, and report on results of a three-year monitoring study conducted during the phaseout and cessation periods of sewer sludge dumping at the 12-mile site in the New York Bight. The Third Annual Report (final) will be published in June. Hydrographic studies, including current-meter data from one meter over the bottom, have elucidated bottom flow dynamics and erosion models have been developed based on shear, grain size, and porosity values. Measures of seabed oxygen consumption, as a measure of benthic community metabolism, indicated that stations under the influence of dumping maintained high consumption rates, especially during summer. As dumping phased out, the oxygen consumption rates declined to background levels typical of New York Bight stations not influenced by sludge disposal.

Biologically labile carbon concentrations in surface sediments at sludge-influenced stations continued to decline and the redox potential has generally increased -- both trends followed a predictive model of sediment biochemistry. Analyses of benthic invertebrate communities indicate numbers of crustaceans, molluscs and total species have increased, with greater increases occurring at stations presumably influenced by sludge.

A pollution-indicated polychaete was scarce in the last two study years. Increases in finfish biomass taken in the post-dumping period were largely due to spiny dogfish, a reflection of a general increase of elasmobranchs in offshore waters, probably unrelated to dumping. No short-term change has been observable in the finfish biomass during the study. Gross pathology observations of winter flounder suggest reduction in the incidences of finrot, cysts, Glugea, and lymphocystis. A symposium in which all participants will present a summation of results in mid-June will be followed by a technical publication of individual studies. Drafts are in final preparation for review.

At the "12-mile" site in the New York Bight, cessation of oceanic sewage sludge dumping produced changes in sediment biogeochemistry that were related to reduced labile carbon input. Redox potential (E_H), which had been lowest at stations nearest the dumpsite, increased and values across the study area converged as the amplitude of seasonal cycle decreased following cessation. Concentrations of reduced substances in the sediment (e.g. acid soluble sulfide) decreased while secondary water quality variables such as dissolved oxygen improved. A mathematical model of sediment biogeochemistry which considers temperature, dissolved oxygen, and labile carbon forcing successfully emulates the record of E_H. E_H was, in turn, highly correlated with benthic macro-invertebrate diversity.

Personnel planned and participated in an August cruise to the 106 Mile Dumpsite. Megafaunal samples were sent to sister laboratories for organic and inorganic body burden analyses.

A cooperative sea-sampling program has been conducted to collect American lobster and red crab shell disease incidence. Programs are being written to integrate catch/effort data with the disease observation data set.

Growth potential of toxic dinoflagellate. The discovery in recent years of widespread presence of the toxic dinoflagellate Gonyaulax tamarensis in Long Island embayments suggested the necessity for assessment of its growth potential elsewhere in the New York Bight. A bioassay study examined the possibility that chemical water quality, apart from the usual growth limiters including nutrients, metals and vitamins, is a factor in the apparent absence of the species in Great Bay, NJ, one of the state's most important shellfish areas. The results indicate that Great Bay water can at times be very detrimental to growth of G.

tamarensis. The overall incidence of inhibitory water quality has not been determined, so whether or not this is a major determinant of suitability of the habitat for the species remains a question.

Algorithms established to relate remotely sensed images with pigment concentrations in turbid coastal waters were tested in coastal waters of New Jersey. Comparisons were made between surface pigment concentrations (Chlorophyll a and phaeophytin) and remotely sensed data collected by the Landsat 5 Thematic Mapper and MSC-02 used aboard a helicopter. Data collected during the initial stage of the project on August 30, 1990, show good correlation between remotely sensed data and the ground truth. Work continues to improve the correlation. This is the first attempt to test existing algorithms using Thematic Mapper and MSC-02 data in this area.

A monitoring survey was conducted in the mid Atlantic Bight in August 1990 to determine whether any effects of sewage sludge dumping at the 106-Mile Dumpsite were detectable in mid-water fish, using contaminant metal concentrations to indicate possible exposure to sludge. Sample collections were made at 34 stations situated in and around the dumpsite. Over 1300 specimens were collected; the myctophids, Benthosema glaciale, Hygophum spp and Lobianchia dofleini were most abundant. Mid-water fish, are potentially good sentinels for monitoring the introduction into the food web of contaminants derived from sewage sludge discharged at the 106 MDS. The rationale is that they are relatively abundant throughout the slope water area; they migrate vertically, moving to the surface layer at night to feed and returning to 200-700 m depths before daylight, thus bringing them into contact with any contaminated water or forage that may be present in the upper water column each time; and they prey on zooplankton, and may concentrate any pollutants that might have been taken up by phytoplankton and zooplankton that have been exposed to a sludge discharge.

Results of a reconnaissance survey conducted in June 1989 showed that levels of Cr, Cu, Ni, Pb, Zn, Fe and Mn in B. glaciale collected in the dumpsite were significantly higher than metal levels found elsewhere. Since these metals are generally present in sludge at highly elevated levels, the findings suggested that specimens had been exposed to a sludge plume; fish collected "downstream" either had not been exposed to sludge or did not retain elevated levels of metals long enough to show increased body burdens at the "downstream" station, about 185 km (approximately 42 days drift) away. No such pattern has so far been observed in preliminary analyses of samples collected in 1990. Metal levels have generally been comparable to or lower than those found in samples collected during the reconnaissance survey, but effects due to sludge dumping have not been as clearly perceptible; metal concentrations were statistically similar at almost all stations. The only significant differences found were: higher concentrations of silver in samples of B. glaciale from near the dumpsite and higher concentrations of lead in samples of B. glaciale from shoreward of the Gulf Stream.

2. Biological Studies

Studies of the Effects of Heavy Metals on Immune Defenses in Sea Scallops. Sera of sea scallops were examined for the presence of both agglutinins (i.e. substances that cause bacteria to aggregate) and opsonins (i.e. substances which coat and aid in ingestion of bacteria by blood cells). An opsonic factor was demonstrated for Vibrio but not Bacillus; coating of bacteria with serum significantly enhanced the ability of scallop cells to attach and/or ingest a marine Vibrio species but not Bacillus cereus. Upon exposure of scallops for six weeks to 20µg/liter of Cu^{++} or Cd^{++}, the opsonin no longer enhanced bacterial uptake by the cells; however the ability of cells to take up both bacterial strains (with or without opsonin) was significantly increased.

The data indicate activation of phagocytes by heavy-metals. Serum agglutinins were demonstrated against all five bacteria that were tested. Exposure of a scallop population from coastal New Jersey to a combination of Cu^{++} (10µg/liter) and Cd^{++} (17.7µg/liter) significantly reduced agglutinins to three of the five bacteria. Agglutinins in a scallop population from coastal Maine were unaffected by the heavy-metal exposure.

Winter Flounder Reproductive Success. In a 3-year study, late pre-spawning winter flounder were collected from various stations in Long Island (3 of them heavily urbanized) and spawned in the laboratory. For comparative purposes, flounder from 2 sites in the Boston Harbor area were similarly treated in 1987 and 1988. Of the stations in Long Island Sound, New Haven Harbor alone consistently produced low percent viable hatch and small larvae. Boston Harbor produced the smallest larvae of all sites. There were no significant station-to-station differences in lipid utilization during larval development; yolk reserves at stations showing a low percent viable hatch, small larvae, and low embryonic development rate were probably used in part or stress metabolism. No significant differences in PCB concentrations for collections from Long Island Sound were found either in livers of spawned fish, in sediments, or in eggs of winter flounder.

Biotechnology. Monoclonal antibody research has produced several hybridoma cell lines which produce species, specific antibodies, and antibodies which react to groups of species. Although the major thrust of this research is the identification of species in processed fishery products, these antibodies may be valuable tools for biological research. Studies are being carried out to test the feasibility of using monoclonal antibodies to identify and quantify prey in stomach samples.

PSP Toxins in Mackerel. Since it was discovered that liver tissues of Atlantic mackerel contain significant levels of PSP toxins, we are continuing to collect and analyze mackerel samples to determine if there is a systematic pattern of toxicity. To date, after three years of sampling, we continue to find varying amounts of PSP toxicity in mackerel livers throughout the migratory range of the species. Neither edible flesh nor roe have shown to be toxic.

PSP on Georges Bank. In 1989, PSP was observed in all molluscan shellfish species on Georges Bank resulting in a closure of the surf clam fishery and an advisory to scallop fishermen concerning ROE (on scallops). In 1990, there appeared to be a major PSP bloom on Georges Bank with extremely high levels of toxins in scallop viscera, surf clams, ocean quahogs, mussels and moon snails. The surf clam and ocean quahog fishery was again closed and advisories are still in effect warning fishermen not to land anything but scallop adductor muscles and not to consume shellfish by catch. Through contractual agreements, shellfish on Georges Bank and Nantucket Shoals are being monitored for PSP and Domoic Acit (ASP).

Food Chain Studies. An analysis was completed of mackerel predation on 0-group fish on Georges Bank in the Spring of 1986. High mortality of larval cod and haddock in April/May 1986 on Georges Bank was attributed to the migration of mackerel across the southern flank of the bank. Consumption rates observed along the leading-edge of the migration appeared sufficient to account for the larval mortality. This evidence together with the lack of overlap between the mackerel distribution and larval gadids (and 0-group sand lance) supports the hypothesis that mackerel predation was largely responsible for the observed larval mortality. If this phenomenon of very rapid predation over small scales of time and space can be confirmed, it will provide one explanation of why direct evidence of predation in the field is often difficult to obtain. This study also identifies a probable mechanism which could explain the inverse correlation observed between mackerel and sand lance populations in the Georges Bank region.

Two cruises were conducted on southern Georges Bank during the period April 23-May 18, 1990, to investigate predation on pelagic 0-group fish.

A 50-station grid was replicated four times, with a trawl haul and bongo tow at each station to document the density distribution of both predators and prey. More than 6000 stomachs were examined at sea and principal predators of 0-group fish included mackerel, herring, silver hake, spiny dogfish and sand lance. The most common 0-group fish observed in predator stomachs included sand lance, Atlantic herring and cod. A pattern of relatively little overlap between predators and prey was observed in 1990 similar to that observed in 1986. Analysis of the joint density distribution of predators and 0-group fish, in relation to consumption estimates based on stomach analysis, will be used to test the hypothesis that the discontinuities in distribution are a direct result of predation. This is particularly important during the April/May period when mackerel are migrating across Georges Bank in relation to seasonal warming. This warming and the associated stratification are processes affecting the growth and vulnerability of their prey (0-group gadids and sand lance) as well as the distribution of the predators; thus the predator-prey interactions could be profoundly affected by any significant change in vernal warming.

Data were summarized from observations on 3500 mackerel stomachs examined on commercial vessels by Foreign Fisheries Observers during the winter the spring of 1990. Total food consumption by mackerel was low during January-March while mackerel were in the middle Atlantic Bight region, and then increased significantly during April and May as the fish migrated northward into southern New England and onto Georges Bank. Predation on age - 0 fish, primarily sand lance, occurred chiefly during April and May. However the bulk of the mackerel diet consisted of invertebrate zooplankton throughout the study.

Examination of gut contents at sea continued on the demersal trawl surveys in 1990. More than 15,000 stomachs were examined with a focus on major fish predators including spiny dogfish, cod, silver hake, and other hake. Principal prey fish observed were small silver hake (0-group and some 1-year olds) in stomachs of cod, larger silver hake, and red and white hake. Also herring (25 cm) were found in stomachs of spiny dogfish and larger cod and white hake. Sand lance appeared to be in low abundance (in both catches and predator stomachs) compared with the early 1980's.

Joint work was conducted with researchers from the Marine Biological Laboratory (MBL) Ecosystems Center on linking food habits analyses with stable isotope ratios. Archived scale samples were analyzed to determine whether changes in trophic structure and feeding dynamics of haddock and six species of flounders have occurred on Georges Bank during the last several decades. Results to date are described in a draft manuscript.

A new multispecies model was developed based on a delay-difference formulation. The objective of the model is to tailor an analysis of multispecies interactions around the types of data available from NEFC archives. The model allows aggregation of age and or size classes of post-recruits and can use information from research surveys or commercial fishery statistics. The parameters of the model will be estimated based on trends in population size and independent estimates of some parameters (e.g. consumption rates). The model allows a non-linear functional feeding response.

Age and Growth. Approximately 22,000 age determinations were completed for 15 species of finfish and shellfish.

A study of the compensatory response of witch flounder, *Glyptocephalus cynoglossus*, in the Gulf of Maine region to increased exploitation during 1977-1990 was completed.

A computerized, interactive data entry, audit and summarization system for age data was developed and implemented.

A workshop to review the reproductive biology of summer flounder, *Paralichthys dentatus*, and criteria for determining ages was conducted and report prepared.

Apex Predator Studies. A record number of fish, 5,464, representing 34 species of sharks and 14 species of teleosts was tagged by the Apex Predators Investigation's ongoing cooperative tagging program in 1990. The majority of sharks tagged were blue (47%), sandbar (14%), and tiger sharks (12%). This is more than the number tagged in 1989. The difference is primarily due to an increase in tagging of blue sharks by anglers and tiger sharks by Florida commercial fishermen.

Anglers accounted for 70% of the total releases followed by commercial fishermen (15%), NMFS and other biologists (15%). NMFS biologists tagged 69 fish while on board two commercial longline vessels. Approximately 100 blue sharks were tagged by Italian sport fishermen in the Adriatic Sea, some of which were recaptured this year.

Other highlights of 1990 efforts include: (a) record times at liberty were reported for sandbar (25 years) and tiger sharks (8 years); (b) the longest distances recorded for sandbar (2,039 mi.), scalloped hammerhead (402 mil.), and bull sharks (231 mil.); (c) a tagged white shark traveled 384 miles from Virginia to Massachusetts; (d) a tagged swordfish traveled a record distance of 2,357 miles between the Flemish Cap and Cuba.

Three hundred and eighty-five fish, including 19 species of sharks and 4 teleosts, were recaptured in 1990. Tags from blue sharks (34%), sandbar sharks (23%) and tiger sharks (20%) were the most commonly returned. This is the largest number of fish recaptured in any year since the beginning of the Cooperative Tagging Program in 1962. The increase in the number of returns in 1990 compared with 1989 is primarily due to the large number of tiger shark recaptures.

Anglers (59%), commercial fishermen (19%), NMFS and other biologists (14%), and Foreign Fisheries Observers (6%) tagged the sharks returned in 1990. The fishing gear used was rod and reel, longline, handline, trawl net, and gill net. A few were also tagged free swimming. Recaptured fish were originally tagged from vessels representing the U.S., Japan, Poland, Italy, Spain, and Mexico.

The sources of the recaptures were primarily commercial fishermen (69%) and recreational anglers (30%). Returns came from vessels from the following 15 countries and island territories: U.S. (326), Spain (19), Mexico (11), Canada (9), Cuba (9), Taiwan (2), and 1 each from Italy, Venezuela, Yugoslavia, Greece, Colombia, Japan, Malta, Barbados, and England.

Major reports for 1990 include "Elasmobranchs as Living Resources: Advances in the Biology, Ecology, Systematics, and the Status of the Fisheries." NOAA Tech. Report NMFS 90. This 518 page book edited by project staff includes three reports by our personnel in "Shark reproductive strategies as a limiting factor in directed fisheries, with a review of Holden's method of estimating growth parameters," and two papers on recommendations for future research.

Marine Mammals. Research on marine mammals increased further in 1990 with the creation of a new group of six scientists and technicians dedicated to the study of fishery by-catch and ecological interactions of these species in the Northwest Atlantic. The research agenda of the group is primarily an expansion of the research effort done in the past two years, and the principal projects are outlined here. In addition, the program of placing observers aboard domestic and foreign vessels has been continued and expanded, and is providing valuable information on the by-catch of marine mammals, primarily small cetaceans. The several projects addressed in 1990 are described below.

Significant by-catch of several species of marine mammals has been demonstrated in waters between Cape Hatteras and the Bay of Fundy, occurring primarily in three fisheries: Gulf of Maine sink-gill net fishery, Mid-Atlantic and S. New England swordfish gillnet fishery, and the Mid-Atlantic and S. New England mackerel trawl fishery. Observer sampling of domestic fishing activities was begun in 1989, and was expanded in this year. Observer sampling of foreign fishing activity

continued, having been begun in 1977.

Observer sampling of domestic fishing activity is handled under this data collection contract. The intensity of sampling of different fishing fleets is adjusted to meet a complex set of objectives, including monitoring marine mammal by-catch. Several types of data are collected focusing on all aspects of the fishing operations and catches. The data are collected using standardized forms and computer software, edited, and made available to the NEFC for analysis. Marine mammal by-catch was observed in the Gulf of Maine sink gill net fishery and the swordfish gill net fishery this year. Fisheries data are collected by observers placed aboard foreign fishing vessels funded under a reimbursable arrangement with foreign fishing countries. Data on marine mammal by-catch and sightings collected by these observers are received and handled by this project, and made available to the NEFC for analysis.

Several species of cetaceans which are killed during commercial fishing operations in both the winter and the summer-fall period are distributed in the Mid-Atlantic Bight and Southern New England from the continental shelf seaward to at least the Gulf Stream. The distribution patterns at any season are poorly known because few systematic sighting surveys have been conducted seaward of the 1000 m depth in this region, and ideas about seasonal movements are derived from only nearer shore surveys. A series of simultaneous fishery resource and cetacean sighting surveys will be required over the next several years to defining the seasonal distribution and the factors determining cetacean habitat. In 1990 an initial survey was conducted in July along the Gulf Stream from Cape Hatteras north to Georges Bank, and along the southern edge of Georges Bank in areas fished by the swordfish gill net fleet.

The endangered North Atlantic right whale population has been the subject of an intensive, coordinated, multi-institution study since 1986 which focuses on detecting changes and causes of changes in the population size. The overall coordination of this study has facilitated the organization of individual identification and sighting survey data that had been collected by numerous organizations over the past decade, and the integration of that data into comprehensive data bases. Additional studies will be required to implement a pending Endangered Species Recovery Plan.

The harbor porpoise in the Northwest Atlantic has been subject to levels of by-catch in a sink-gill net fishery in U.S. and Canadian waters for several years. The levels of by-catch may be biologically significant. To determine the significance of the by-catch, studies are conducted to estimate total abundance, and to determine seasonal distribution patterns, especially relative to the distribution of fishing activity and fishery resource species. This information is synthesized along with estimates of total by-catch and estimates of vital rates to determine the biological significance of the by-catch, and to determine possible approaches to reducing by-catch levels.

The endangered North Atlantic humpback whale population has been the subject of a series of research projects over the past several years, both within the Gulf of Maine and more generally across the North Atlantic and in the Caribbean. The NMFS is nearing finalization of an Endangered Species Act Recovery Plan for this species. Projects on the distribution and habitat requirement and on maintaining a centralized photographic catalog were supported this year. Overall coordination of research on this species is needed to ensure that the status of the species is considered in the appropriate spatial context, and especially that the complex breeding and social behavior of this species is properly accounted for. A series of international meetings were held among scientific researchers with interest and with active projects studying this species, and a two year research plan was developed that involves sampling all known winter and summer grounds for both photographic and biopsy sampling for estimating total and regional abundance, and for genetic studies.

3. **Gear and Selectivity Studies.**

A cruise designed to study the relative fishing power of trawl doors currently used, with trawl doors used prior to 1985 was conducted between January 31, and February 9, 1990. The study was conducted at specific sites on eastern Georges Bank and in the Gulf of Maine aboard the R/V DELAWARE II. Ninety four stations were completed during the cruise.

Analyses of data designed to study the relative fishing power of the R/V's ALBATROSS IV and DELAWARE II have nearly been completed. Species specific differences were noted for several species, and for all species combined in terms of both weight and number. Coefficients and confidence interval remain to be calculated. Manuscripts describing analysis techniques and preliminary results of earlier work were completed.

4. **Miscellaneous Studies.**

Fisheries economics. An economic overview of the Northeast Region's major fisheries and fleets was developed as a contribution to the first round of Stock Assessment and Fishery Evaluation (SAFE) Reports. Individual vessel time series data were provided to management councils as background to a variety of limited entry and rights allocation discussions. Initial analysis of sea-sampled data on by catch and discards undertaken. Fish market news service privatized and made available in print, by phone and by computer. Estimations made of dissipated consumer surplus, inframarginal and resource rents in the groundfish fishery.