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HADDOCK:

A REVIEW OF THE RECORD AND A FORECAST

by

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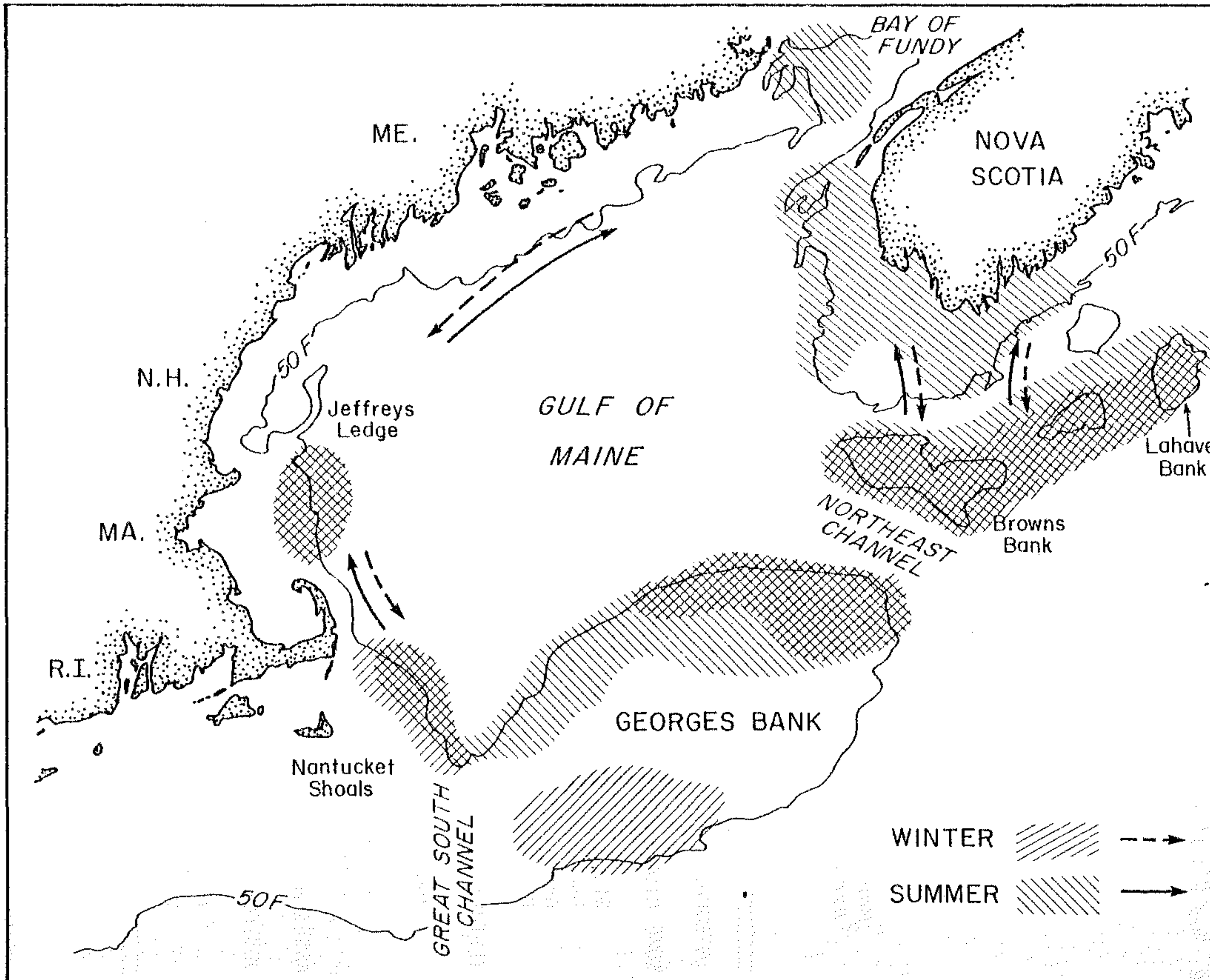

[Figu]re 1. Principal concentration areas and mi[gration] routes for haddock in the New England region.

INTRODUCTION

Haddock, which live on both sides of the North Atlantic, have historically been abundant on the eastern side from the southern British Isles to Norway and Iceland, and on the western side from the Grand Banks to Southern New England, straggling from there as far as the Middle Atlantic states. These fish are highly valued in the New England groundfishery and in markets nationwide, but in recent years their numbers have declined considerably. The outlook for our domestic haddock fishery for the next few years is worrisome. Before taking up this assessment, however, let us review some aspects of haddock biology and the history of New England's haddock fishery which should help in understanding present circumstances.

SOME BIOLOGICAL ASPECTS

Stocks

Fish populations are often made up of subgroups or stocks existing more or less in isolation. These must be identified before a fishery resource can be scientifically managed for exploitation. Haddock stocks have been given close attention for this reason. Tagging studies and analysis of certain physical characteristics of haddock caught on various Northwest Atlantic grounds reveal distinct stocks or subpopulations. Differences in growth rate from one place to another, in certain anatomical characters, and in the proportion of fish of different ages in one population compared with another, all support this inference.

In the Northwest Atlantic, clearly defined stock boundaries exist for haddock between Newfoundland and Nova Scotia, and between Nova Scotia and the New England region, the latter including the Gulf of Maine and Georges Bank. Haddock shun very deep water; the Northeast Channel at the eastern tip of Georges Bank is deep enough to bar their passage between Georges Bank and western Nova Scotia waters (Figure 1). There is also little if any movement across the deep central basin of the Gulf of Maine.

Three stocks have been identified in the region: the western Scotian Shelf stock, the Georges Bank stock, and the Gulf of Maine stock, the latter appearing to contain at last two smaller groups exhibiting different migratory patterns. The western Scotian Shelf stock overwinters in the Browns Bank-LaHave Bank area, while in summertime individuals disperse over these banks and into inshore areas as far north as the Bay of Fundy (Figure 1). Seasonal movements also occur in the western Gulf of Maine. Some haddock there have been found to migrate between Jeffreys Ledge and the Bay of Fundy region (northeastward in spring and summer, and southwestward in fall and winter). A second Gulf of Maine group ranges between Jeffreys Ledge and Nantucket Shoals, and sometimes onto Georges (Figure 1). Georges Bank haddock do not wander to any great extent.

Though most evidence supports the idea of separate--or fairly separate--stocks among Gulf of Maine, Georges, and Nova Scotian fish, good year classes (annual crops of young) tend to coincide in all three areas. This is particularly so for Georges and Gulf of Maine haddock. Conceivably, larvae may drift in significant numbers from one stock's territory to another's, but that has yet to be proven. More likely, conditions favoring reproduction in one group in a given year tend simply to favor all groups.

Habits

Adult haddock, confirmed bottom dwellers, seldom rise toward the surface as both Atlantic cod and pollock do. They mainly inhabit depths of 25-80 fathoms, and are rarely found shoaler than 6 fathoms or deeper than 100 fathoms. Preferred waters are cool, between 35° and 52°F (2° and 11°C), and of quite high salinity: from 31.5 to 34.5 °/oo. Typical haddock ground is rather hard and smooth: sand, gravel, clay, or broken shell. They avoid weed, ledge, and oozy bottom.

After hatching, young haddock live in midwater, feeding on planktonic crustaceans and growing to a length of 3 inches (8 cm) or so by late summer. Thereafter, they descend to the sea floor where they browse upon nearly every kind of animal of suitable size. As shown in the table below, their diet is quite different from that of some of their near relatives, seen especially in their taste for marine worms and echinoderms (starfish, sea urchins, sand dollars, sea cucumbers).

	Predator				
Prey group	Atlantic cod	Pollock	Silver hake	Red hake	Haddock
Polychaetes	1.3	0.3	0.2	2.9	17.6
Crustaceans	20.7	50.8	25.0	54.1	16.2
Mollusks	7.6	0.4	2.2	6.3	3.1
Echinoderms	1.2	-	trace	0.6	29.9
Fishes	64.0	47.0	70.9	25.3	14.6
Others	5.2	1.5	1.7	10.8	18.6

Percentages of different kinds of prey in the diet of several cod-like fishes, based upon samples taken in the western North Atlantic between Nova Scotia and Chesapeake Bay during 1969-72.

Haddock stomachs often contain burrowing forms of worms and mollusks, indicating that they feed partly by rooting in the bottom. The percentage of fish in the diet appears to vary from place to place. The haddock's diet, compared with others analyzed in the table, is the least specialized among commercially important cod-like fishes off New England. Such analysis is one way of discovering the interactions and competition among species occupying the same grounds. Understanding the responses of groups of species to fishing and to environmental changes (such as shifts in prey abundance) is seen as a key to managing New England's mixed fishery resources.

Growth

Haddock growth is rapid at first, slowing considerably with advancing age. In its second seven years of life, a haddock adds only seven or eight percent to its length. By comparison, a cod between the ages of seven and fourteen years will grow almost 40 percent longer, thereafter showing only a moderate tendency to slow down. A 30-pound (13.6-kg) haddock caught off Nova Scotia in 1949 is said to have been the largest ever landed in Boston, but cod twice this size are not rare and still far below the maximum recorded weight for that species.

Growth rate among individual haddock, even those living on the same ground, varies, but in general it is governed both by temperature, which influences matabolism and feeding rate, and especially by the food supply. Haddock have time and again been observed to grow rapidly when their numbers were sparse and slowly when they crowd their feeding grounds (Figure 2). Whenever stock size increases after a good year class enters the fishery, and particularly when two good years come together, growth rates fall. All-time low abundance, which occurred in the early and middle 1970's, was mirrored by all-time high growth rates, rates up to 50 percent greater than they had been before massive international fleets depleted the stocks.

Growth of haddock on different grounds varies widely, with Georges Bank fish usually outgrowing the rest. At age five, Georges Bank haddock historically have averaged about 22 inches (55 cm) in length, fish from Browns Bank 19 inches (48 cm), and fish from Grand Banks only 15 inches (38 cm) or so. Gulf of Maine haddock are typically, though not always, a bit smaller than Georges Bank haddock at a given age. In recent years, because of their scarcity on Georges Bank, haddock there have grown exceptionally fast, outstripping growth in other areas by a greater than usual amount.

Reproduction

Many haddock recruited to the New England fishery are not yet sexually mature, but the age at which recruitment and maturity occur varies quite widely. ("Recruitment" is the process by which the fishery is resupplied by reproduction and growth of young fish. A recruited fish is one grown large enough to be commercially worth catching; that size differs with circumstances.) Very roughly, half a year's crop of haddock (termed a "year class" by fishery scientists) may be mature by age two, and nine-tenths of it by age three, Georges Bank fish growing faster and larger usually, and maturing earlier than fish from other localities.

Like cod, haddock spawn prolifically. A female haddock early in her sexually mature phase of life might produce 50 to 150 thousand eggs in a single season, and an old one approaching maximum size perhaps three million. Historically, New England's most intensive haddock spawning has been on eastern Georges Bank, though any part deeper than Georges Shoals might be used in one year or another. Haddock also spawn near Nantucket Shoals and in the vicinity of the Great South Channel (Figure 1). (Areas there and on eastern Georges are closed to bottom trawling during the spawning season.) Depth limits for spawning are 15 to 60 fathoms or so at the extremes, but most spawning takes place between 30 and 50 fathoms on broken ground where sand,

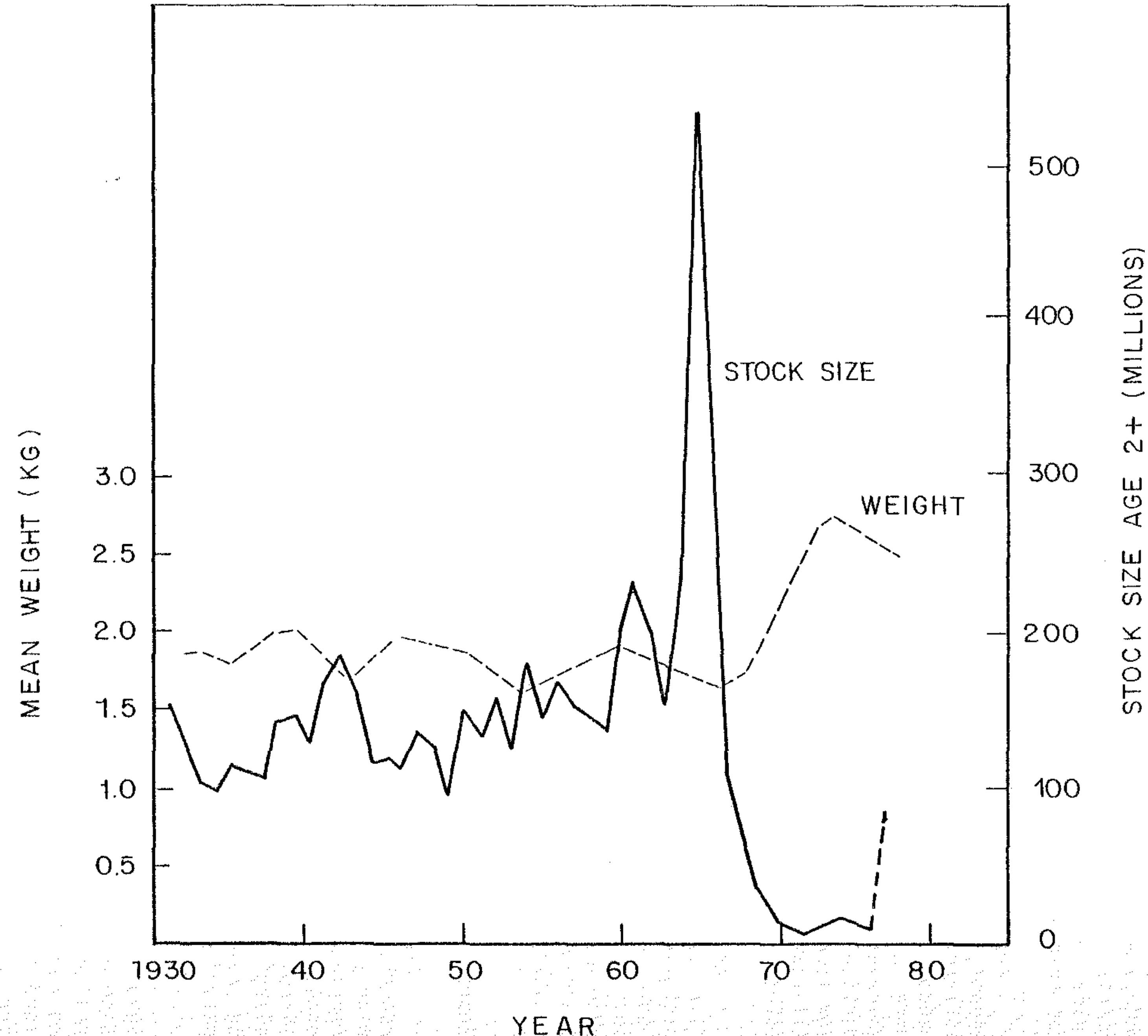

Figure 2. Trends in the average weight o -to-seven-year-old Georges Bank haddock, compared with stock size durin 78. Note increasing weight of individual fish when stock size decreases.

gravel, mud, and small rocks may be found. Some spawning also occurs along the coast of the Gulf of Maine and on the Scotian Shelf. Those Gulf of Maine and Scotian fish which mix in the summer in the Bay of Fundy appear to segregate for breeding, hence preserving the genetic distinctness of these stocks. Spawning occurs within a temperature range of 35°-44°F (2°-6°C). Spawning dates for a given year are strongly influenced by temperature, however, and a difference of 3° or 4°F can shift the time of peak egg production by a month or more. On Georges Bank, that peak may occur from late February and early March to late April. Hatching takes place in about two weeks at average spring temperatures.

Haddock eggs and larvae float near the surface and may drift long distances where currents are strong, as on Georges. Such drift can be critical in survival. On Georges, for example, there is often a strong clockwise flow of water around the Bank. If this should be well established during a spawning season, it will tend to keep passively drifting eggs and larvae within the plankton-rich environment there. Often, however, that current pattern is disrupted, for instance, by storms or by influence of the Gulf Stream. Then, eggs and larvae may be drawn or driven off into less favorable, even lethal, conditions.

Abundance of plankton that larval fishes feed upon is not constant even in biologically rich areas; for the larvae to benefit, adequate supplies must be available when they begin to feed. This does not always happen. Even when it does, an exceptionally large hatch of larvae may find competition for available food severe. In short, a successful crop depends on the right conjunction of several variable factors.

For haddock, a clear correspondence has yet to be shown between size of the parent stock and the number of their offspring surviving to resupply the fishery, except when the parent stock is extremely large or small. Large numbers of parents may produce so many young that these starve in competition with one another. Very small parent stocks tend to produce small numbers of young; though these may survive very well, they are simply insufficient to make the stock increase much. This was the case during the late 1960's and early 1970's. Rarely, a small spawning stock has disproportionate success; numbers recover abruptly from critically low levels. Circumstances favoring this are not yet fully understood, and certainly cannot be relied upon to restore a depleted fishery (Figure 3).

HISTORY OF THE FISHERY

Beginnings

Compared with the cod fishery, which is centuries old, a substantial commercial haddock fishery was late in developing in New England. Cod were considered best for salting (haddock were unsuitable for that purpose), but use of ice made trade in fresh fish possible and haddock came into their own, growing quickly in public esteem. Haddock fillets cut and frozen at dockside soon found acceptance far inland.

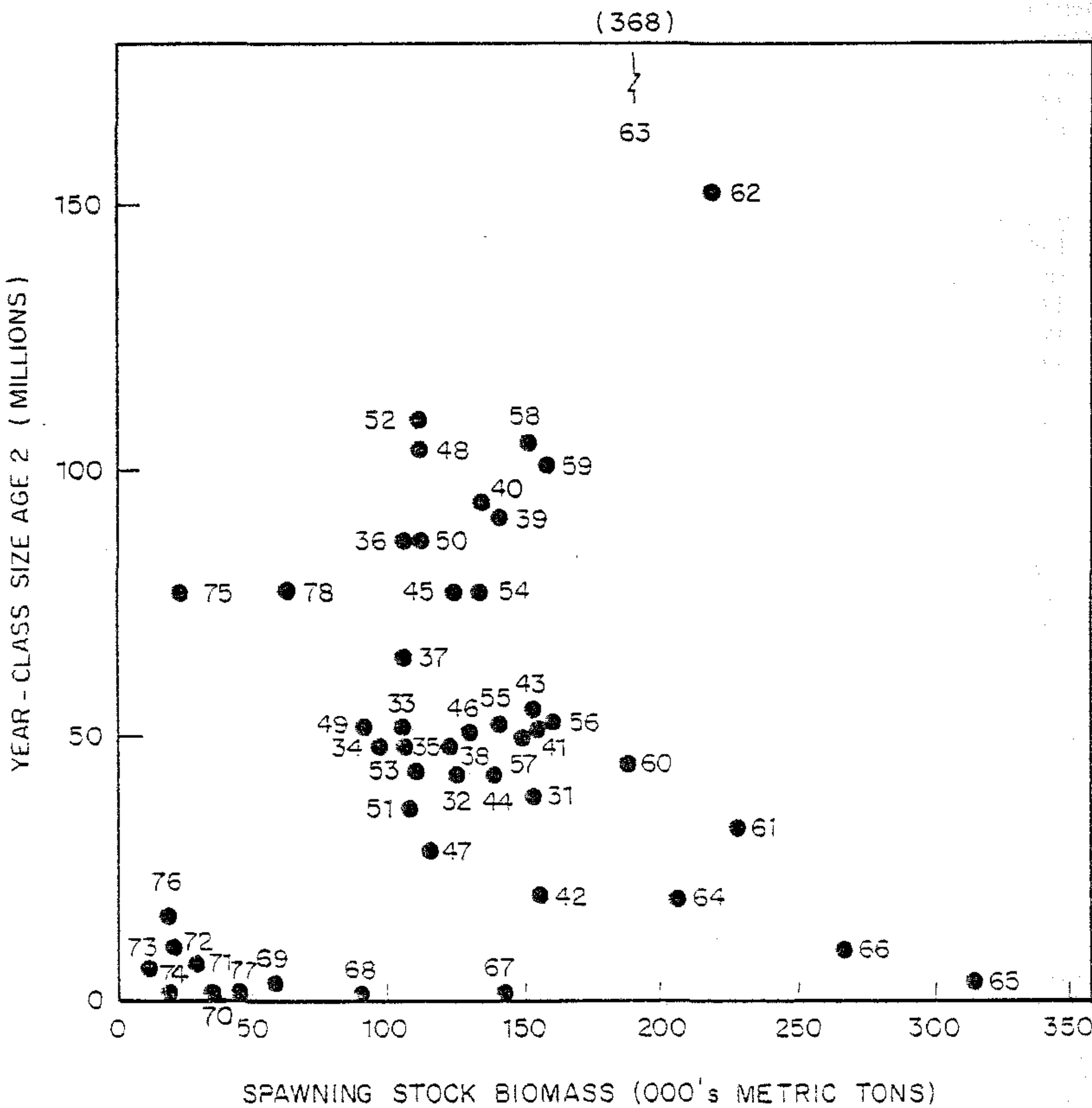

Figure 3. Relation between the numbers of two-year-old haddock recruited to the fishery, and the spawning stock size on Georges Bank between 1931 and 1978 (numerals designate the year). Except for extremely small stocks (late 1960's and early 1970's) or extremely large ones (mid-1960's), there is no consistent relationship evident between numbers of parents and number of recruits produced.

On haddock grounds, dory fishing with hook and line yielded slowly to trawling after the turn of the century. Beam trawls were supplanted by otter trawls, which in improved versions are now by far the main commercial gear, but hook-and-line fishermen persisted alongside trawlermen for a long time. In the late 1920's, roughly half the catch was still taken by longlines, and a small fraction still is.

Full Exploitation

In the decade between 1891 and 1901, U.S. haddock landings averaged nearly 25,000 metric tons annually, with a maximum of 30,000 tons being taken in a single year. Catches grew in size with increasing numbers of trawlers from these and other ports, markedly so through the 1920's until a peak of 132,000 tons was reached in 1929. From that point on, haddock resources showed signs of stress. Fishermen and fishery scientists worried as catches dropped sharply. Many fishermen were forced to switch to other species. In the 1930's, the U.S. Bureau of Fisheries initiated biological studies of haddock and a new system of statistical reporting.

As fishermen eased up on haddock somewhat, average U.S. catches settled to about 70,000 tons annually, 52,000 of these from Georges Bank and the Gulf of Maine. These levels, close to the estimated long-term sustainable catch, prevailed from the mid-1930's to 1960. In 1949 it was agreed by all countries concerned that scientific management of fish resources in this region be carried out cooperatively; a treaty that year founded ICNAF, the International Commission for the Northwest Atlantic Fisheries. Haddock off our coast were not a target of European fishermen in ICNAF's early years. Nevertheless, haddock stocks soon benefited from ICNAF research and regulation. Investigations of the effects of trawl mesh size upon catches showed that enlarged mesh openings would reduce wastage of undersized groundfish. New mesh regulations were issued in 1953. Harvesting became more efficient and discards of small haddock far fewer.

Overexploitation and Collapse

During the 1960's, unprecedented numbers of foreign vessels appeared on the principal haddock grounds of Georges; most came from the U.S.S.R. To start with, the Soviets had mainly sought Atlantic herring and silver hake, but in the mid-1960's, their attention was caught by large numbers of young haddock spawned in 1962 and 1963, which they fished intensively with hake and herring gear. At the same time, U.S. and Canadian fishermen intensified their own haddock effort. The result was an all-time peak catch in 1965 of 150,000 metric tons--three times the estimated annual sustainable yield for Georges Bank--followed by collapse of the resource. From the mid-1960's onward, recruitment of young haddock was consistently poor, poorer in fact than ever before recorded (Figure 3). New England's fishermen were devastated.

Then, ICNAF moved to reverse the disaster, making major spawning grounds off limits to trawlers in the spring and cutting the allowable catch for 1970 and 1971 to 12,000 tons from Georges Bank and Gulf of Maine. This number was halved during four of the five succeeding years; in 1974 it was set at zero, with a "by-catch" allowance of 6,000 tons. Recovery of haddock stocks began, but too slowly for New England fishermen. They joined in support of a new law providing more direct control over exploitation of traditional resources. In this way, collapse of the Georges Bank haddock resource played a significant part in enactment of the present "200-mile-limit law," the Magnuson Fishery Conservation and Management Act of 1976 (MFCMA).

Under MFCMA, the U.S. took unilateral control of most fish and shellfish within a 200-mile zone off the coast, and management was required to be based upon "optimum yield": maximum sustainable yield modified by certain economic, social, and ecological considerations. Eight Regional Fishery Management Councils came into being. Management of the battered haddock stock fell to New England's Council, which gave it top priority. Optimum yield, in the Council's judgement, would be the yield that most effectively speeded recovery of the stocks, so they set this at the earlier, conservative ICNAF level: 6,200 tons to be taken only incidentally when fishing for other species. Of this total, 6,000 tons were designated for commercial harvest, and 200 tons for recreational fishermen.

Brief Resurrection

There had been signs as the new Council took over that the 1975 year class would be good, the first good one in years. Assessments in 1977 showed it to be much stronger than the long-term average, and many times stronger than those produced during the years of collapse. The Council confronted a crisis. Haddock were so plentiful that fishermen on some grounds could avoid them only by keeping their nets out of the water. Catch limits had suddenly become quite impractical, but they were cumbersome to change under MFCMA. Massive discarding at sea was one result: misreporting of catches to circumvent the rules was another. The managers could not change limits until November 1977, and by that time much damage had been done. Thousands of tons of haddock had been wasted and masses of data vital for management planning lost.

Thereafter, constraints on the fishery were progressively eased, although discarding and misreporting continued. A "fishing year"--October of one year through September of the next--was made the basis for management, permitting more timely use of data from survey cruises. By the 1979/80 fishing year, optimum yield for Georges Bank and the Gulf of Maine had been raised to 32,500 tons on the strength of the 1975 year class, and 1979 survey results revealed that still another good year class, from 1978, would recruit to the Georges Bank fishery in 1980. With two such year classes in the water, there was reason to hope for recovery of New England's haddock. Unfortunately, recruitment did not continue to improve; subsequent year classes have been weak, adding little to the resource. Haddock from the 1975 and 1978 year classes were quickly depleted. All present evidence shows stocks sinking again toward levels seen a decade ago. Recovery may require the kind of circumstances for recruitment success which rarely occurs.

ASSESSMENT

Fish stocks increase by recruitment of young members and by growth of all members; stocks diminish through fishing and natural deaths. There is an optimum strategy for fishing each stock, to gain the most from growth before it slows and is offset significantly by natural death. This maximizing of "yield per recruit" is one objective of fishery management. Another, in the case of a depleted fishery, is control of fishing so that a stock can recover. Likely effects of different rates of fishing in each circumstance are weighed, and the best fishing mortality rate chosen for a given purpose. To translate this rate into actual catch though, there must be an estimate of stock size.

One approach to making such estimates is called virtual population analysis, VPA for short. The information needed for a VPA (numbers caught, average weights for fish of different ages, etc.) is derived from the commercial catch, which is sampled at the dock or at sea. Then, VPA's are made by combining the numbers of fish caught from a given year class over all years in which that year class has been present in a fishery. This sum amounts to a minimum estimate of original year-class size, because each fish represented in the estimate was in fact caught. Not all fish in a given year class are caught of course, and some die naturally each year. The initial estimate based on summing commercial catches is adjusted to reflect this. The adjusted estimates for all year classes present in a given year are then added to give total stock size.

The most trustworthy techniques for estimating stock size and the probable effects of fishing combine results of scientific surveys with data from the commercial fishery--when this is judged dependable. Commercial gear differs from survey gear in its efficiency and selectivity for size of fish caught. Moreover, commercial fishermen hunt their quarry, while survey tows are made at random following scientific sampling principles like those used by polltakers. Fish may be concentrated at one survey station and missing entirely at another. It is the averages which are sought.

Survey tows, made spring and fall each year with a standard net, supply several kinds of information. One is an abundance measure of young "prerecruit" fish, those too small to be caught in commercial trawl meshes. The number of prerecruits per tow can be used in forecasting recruitment and eventual commercial catch. Survey catches of recruited fish can be compared with commercial catch rates observed at the same time (these must be expressed in some standard unit of fishing effort); survey catch may also be compared with stock size estimated by VPA. Figure 4 shows how well, over time, the survey catch corresponded with stock size estimates from VPA for Georges Bank haddock. Estimates of present abundance and future recruitment, essential for management planning, depend upon this kind of close agreement.

Whenever an estimate is based on sampling, there is some question whether the sample (from a series of survey tows for instance) fairly represents the population sampled. The way in which stock and recruitment estimates are presented reflects this uncertainty. Instead of a single number, a range is given within which actual stock or year-class size most probably lies; these

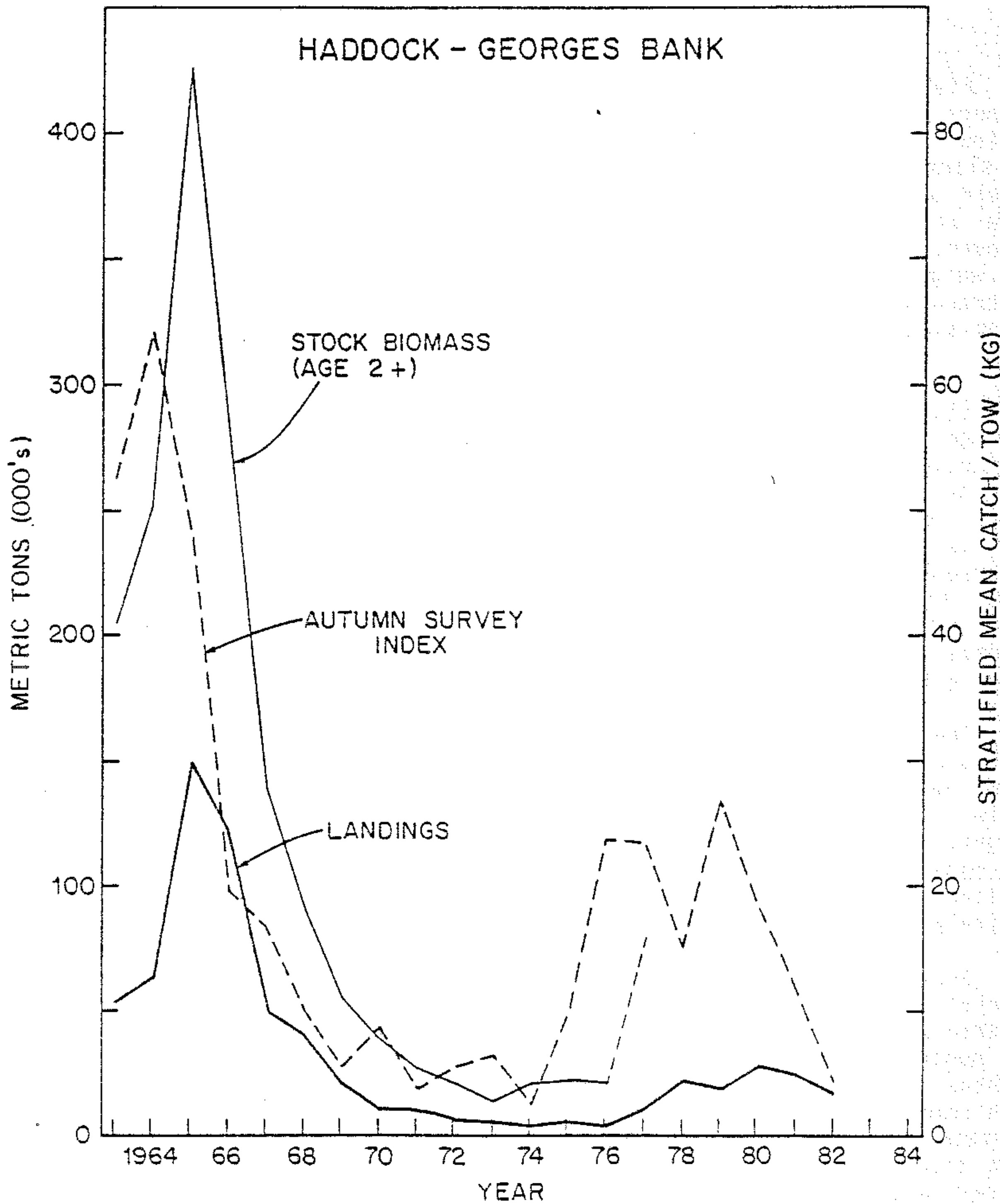

Figure 4. *Commercial landings and stock size estimates for Georges Bank haddock calculated from virtual population analysis (VPA), compared with fall bottom-trawl survey catch per tow during 1964-82. The apparent low level of landings during the 1976-80 period, when the survey index showed some stock recovery, may be due partly to under-reporting of catches then.*

are "confidence limits" for the estimate. When there are few reliable samples, the limits are wide; more data permit more precision.

To illustrate, Figure 5 relates year-class size of two-year-old haddock (calculated from VPA of commercial data) to NEFC fall bottom-trawl survey catch per tow at age one. Such relationships are commonly used in assessment work to predict recruitment levels. Here, for example, based on available information for 1963-76, a fall survey catch per tow of 40 one-year-old haddock indicates that there will be a year class of about 200 million haddock at age two. The wider confidence band (solid bold lines) is based on this information. We expect actual year class size corresponding to any given survey catch (those values ranging along the horizontal axis of the graph) to fall within this band. Had commercial data for 1977-81 been usable, narrower confidence limits (dashed thin lines) could have been calculated, a gain in precision of some 50 percent.

OUTLOOK

Recruitment

Before intensive fishing in the 1960's, the long-term (1935-60) average number of two-year-old haddock recruiting each year was 61 million. In nearly as long a period, since 1963, only two year classes have exceeded that average, those of 1975 and 1978. We may never know by what measure they exceeded it because many fish from these year classes were discarded, or misreported in commercial records.

Except for these two outstanding years, recruitment since the mid-1960's has been poor, far below average. Still, the close succession of good years held out hope for recovery. This was strengthened by survey results from the fall of 1980 which suggested that the 1980 year class, sampled then for the first time, would also be successful. Unfortunately, more recent surveys indicate that this year class is far smaller than the long-term average. This evaluation is supported by poor recuitment of these fish to the commercial fishery in the summer and fall of 1982; catches of small "scrod" haddock were very low. The weak 1980 year class will apparently be followed by another even weaker. Survey catches of the 1981 year class, made in the fall of that year and in the spring of 1982, were among the lowest of the entire survey series, comparable to survey catches made between 1967 and 1971. Year classes then averaged a mere three percent of the long-term (1935-60) average. Survey catches of 1982-year-class haddock in the fall 1982 survey were also very low.

Stock Size

Because of deficiencies mentioned in catch records from 1977 to 1981, haddock stock size for recent years cannot be directly estimated by virtual population analysis (VPA); indirect methods must be substituted. One of these applies the "average" historical relationship between survey catch and stock sizes calculated by VPA to the present survey catch, deriving 1982 stock size from that relationship. The average is based on reliable data taken over many years. An alternative method is based on relative efficiency of survey and

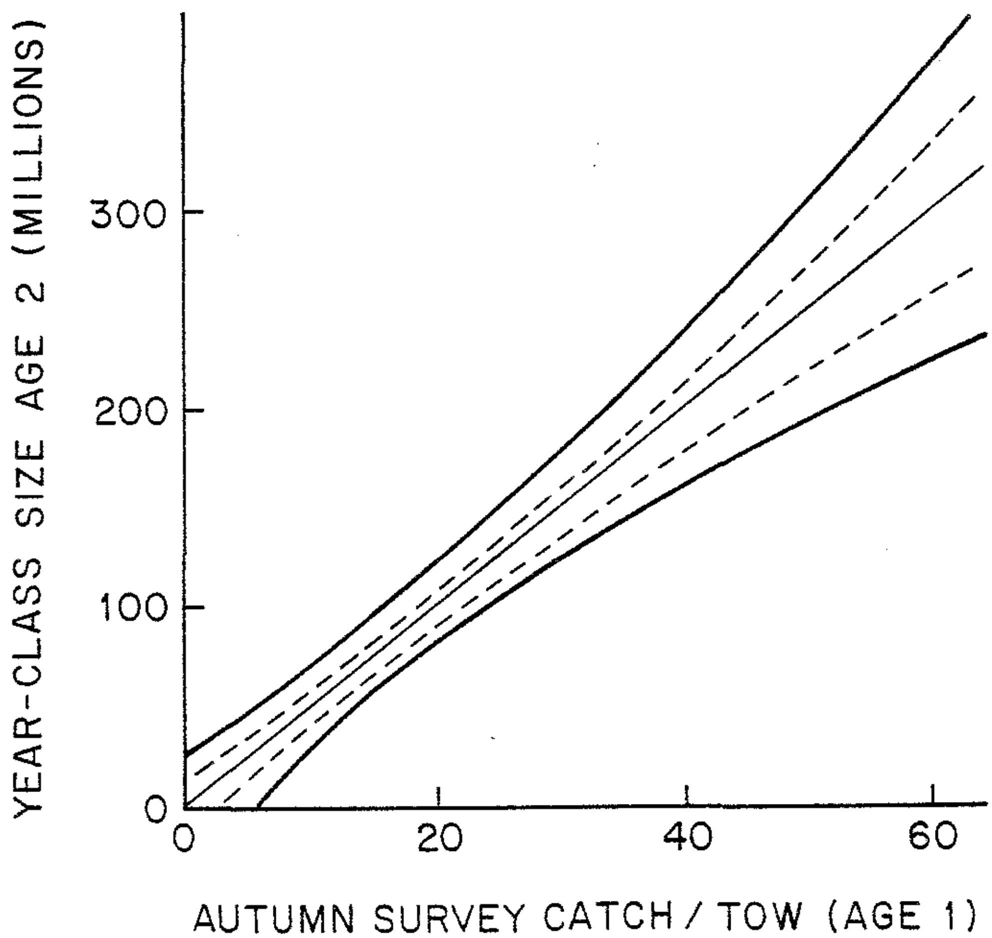

Figure 5. Relation between Northeast Fisheries Center fall bottom trawl survey catch per tow of one-year-old haddock and the number of two-year-olds recruiting to the Georges Bank fishery. Reliability of such predictions depends upon the number of data points available and their variability; "confidence limits" placed about the predicted values are a measure of this reliability. The confidence limits shown here as bold solid lines are calculated from information available for the 1963-76 period. Had commercial data for more recent years (1977-81) been more reliable, the confidence limits would be expected to narrow considerably as shown by the thin dashed lines.

commercial gear. Catches with each gear are used in calculating a "catchability" factor for the survey gear which in turn is used to estimate stock size. Estimates made in this way compare well with those made by VPA for years when commercial data are judged to have been reliable.

The first of these two indirect methods, applied to catches made in the 1981 fall survey and the 1982 spring survey, estimates stock size for 1982 at 46 to 54 million fish. The second method gives a comparable result. Such a stock size, let us say 50 million fish, is comparable to levels from the late 1960's, and is about one-third the average for the years 1935-60, before the foreign fleet arrived. In the past five years, the fishery has been almost entirely supported by the 1975 and 1978 year classes; these have been largely fished out. It is clear that haddock stocks and the fishery will not recover on the strength of recruits or prerecruits presently alive. The downward trend in fishable stock cannot reverse before 1985, if it should even then. The 1983 year class enters the fishery in that year, but its size is not yet known. Figure 6 shows ranges within which stock size and catch are expected to fall during the 1982-84 period. The ranges shown encompass all levels of fishing effort and recruitment which we can reasonably expect.

Haddock showed themselves capable, in the late 1970's, of recovering dramatically from very low population levels after a single spawning. Conditions evidently must be ideal for this to happen; there is no present way of forecasting such conditions. Before the 1960's, stocks were made up of several year classes and had a certain resilience in their ability to reproduce; a weak year class made less difference if there were a good number of survivors from stronger year classes still in the population. The history of the haddock fishery shows that for decades before 1960, when the stock was always well above levels of recent years, even the poorest yields were never as low as they are repeatedly now. Since the intense fishing of the 1960's, the fishery has relied heavily on one or two year classes and has quickly fished them down to a point where, under average environmental conditions, there may simply be too few spawners for adequate reproduction.

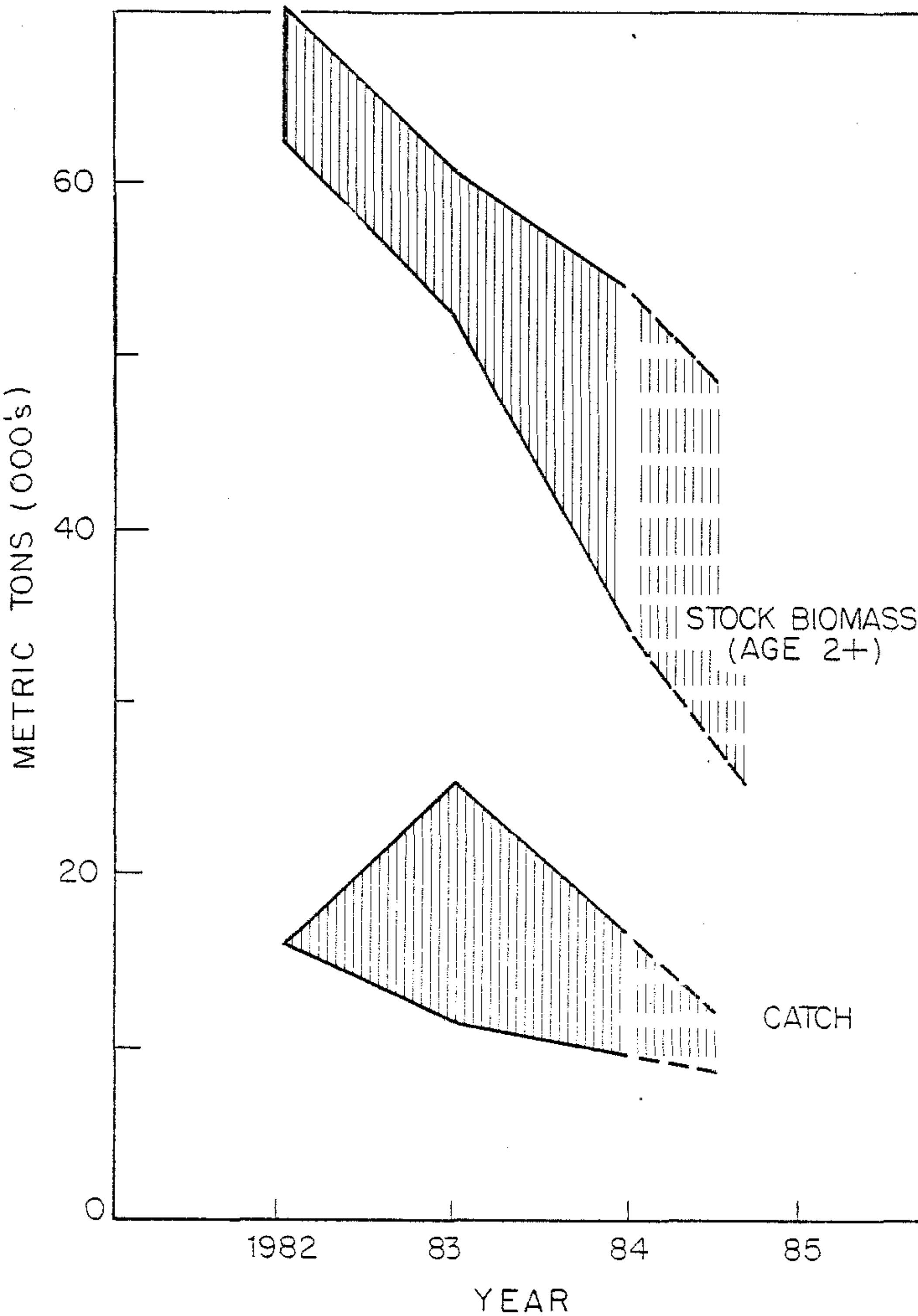

Figure 6. Ranges within which stock sizes and catches of Georges Bank haddock are expected to lie in 1983 and 1984, given available recruitment estimates and expected levels of fishing effort.