Northeast Fisheries Science Center Reference Document 03-17

37th Northeast Regional Stock Assessment Workshop (37th SAW)

Advisory Report

September 2003

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A Report of the 37th Northeast Regional Stock Assessment Workshop

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Advisory Report

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

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Northeast Fisheries Science Center Reference Documents

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ADVISORY REPORT ON STOCK STATUS

INTRODUCTION

The *Advisory Report on Stock Status* is one of two reports produced by the Northeast Regional Stock Assessment Workshop process. The *Advisory Report* summarizes the technical information contained in the *Stock Assessment Review Committee (SARC) Consensus Summary of Assessments* and is intended to serve as scientific advice for fishery managers on resource status.

An important aspect of scientific advice on fishery resources is the determination of current stock status. The status of the stock relates to both the rate of removal of fish from the population – the exploitation rate – and the current stock size. The exploitation rate is simply the proportion of the stock alive at the beginning of the year that is caught during the year. When that proportion exceeds the amount specified in an overfishing definition, overfishing is occurring. Fishery removal rates are usually expressed in terms of the instantaneous fishing mortality rate, F, and the maximum removal rate is denoted as $F_{THRESHOLD.}$

Another important factor for classifying the status of a resource is the current stock level, for example, spawning stock biomass (SSB) or total stock biomass (TSB). Overfishing definitions, therefore, characteristically include specification of a minimum biomass threshold as well as a maximum fishing threshold. If a stock's biomass falls below the biomass threshold ($B_{THRESHOLD}$) the stock is in an overfished condition. The Sustainable Fisheries Act mandates plans for rebuilding the stock should this situation arise.

Since there are two dimensions to the status of the stock– the rate of removal and the biomass level – it is possible that a stock not currently subject to overfishing in terms of exploitation rates is in an overfished condition, that is, has a biomass level less than the threshold level. This may be due to heavy exploitation in the past, or a result of other factors such as unfavorable environmental conditions. In this case, future recruitment to the stock is very important and the probability of improvement is increased greatly by increasing the stock size. Conversely, fishing down a stock that is at a high biomass level should generally increase the long-term sustainable yield. This philosophy is embodied in the Sustainable Fisheries Act — stocks should be managed on the basis of maximum sustainable yield (MSY). The biomass that produces this yield is called B_{MSY} and the fishing mortality rate that produces MSY is called F_{MSY}.

Given this, stocks under review are classified with respect to current overfishing definitions. A stock is overfished if its current biomass is below $B_{THRESHOLD}$ and overfishing is occurring if current F is greater than $F_{THRESHOLD.}$ The schematic below depicts how status criteria are interpreted in this context.

Overfishing guidelines are based on the precautionary approach to fisheries management and encourage the inclusion of a control rule in the overfishing definition. Control rules, when they exist, are discussed in the Advisory Report chapter for the stock under consideration. Generically, the control rules suggest actions at various levels of stock biomass and incorporate an assessment of risk, in that F targets are set so as to avoid exceeding F thresholds.

BIOMASS

		$B < B_{THRESHOLD}$	$B_{THRESHOLD} < B < B_{MSY}$	$B > B_{MSY}$
EXPLOITATION	$F > F_{THRESHOLD}$	Overfished, overfishing is occurring; reduce F, adopt and follow rebuilding plan	Not overfished, overfishing is occurring; reduce F, rebuild stock	$F = F_{TARGET} <= F_{MSY}$
RATE	$F < F_{THRESHOLD}$	Overfished, overfishing is not occurring; adopt and follow rebuilding plan	Not overfished, overfishing is not occurring; rebuild stock	$F = F_{TARGET} <= F_{MSY}$

GLOSSARY OF TERMS

ADAPT. A commonly used form of computer program used to optimally fit a Virtual Population Assessment (**VPA**) to abundance data.

ASPM. Age-structured production models, also known as statistical catch-at-age (SCAA) models, are a technique of stock assessment that integrate fishery catch and fishery-independent sampling information. The procedures are flexible, allowing for uncertainty in the absolute magnitudes of catches as part of the estimation. Unlike **virtual population analysis (VPA)** that tracks the cumulative catches of various year classes as they age, ASPM is a forward projection simulation of the exploited population.

Availability. Refers to the distribution of fish of different ages or sizes relative to that taken in the fishery.

Biological reference points. Specific values for the variables that describe the state of a fishery system which are used to evaluate its status. Reference points are most often specified in terms of fishing mortality rate and/or spawning stock biomass. The reference points may indicate 1) a desired state of the fishery, such as a fishing mortality rate that will achieve a high level of sustainable yield, or 2) a state of the fishery that should be avoided, such as a high fishing mortality rate which risks a stock collapse and long-term loss of potential yield. The former type of reference points are referred to as "target reference points" and the latter are referred to as "limit reference points" or "thresholds". Some common examples of reference points are $\mathbf{F_{0.1}}$, $\mathbf{F_{MAX}}$, and $\mathbf{F_{MSY}}$, which are defined later in this glossary.

$\mathbf{B_0}$**.** Virgin stock biomass, i.e., the long-term average biomass value expected in the absence of fishing mortality.

$\mathbf{B_{MSY}}$**.** Long-term average biomass that would be achieved if fishing at a constant fishing mortality rate equal to $\mathbf{F_{MSY}}$.

Biomass Dynamics Model. A simple stock assessment model that tracks changes in stock biomass rather than numbers. Biomass dynamics models employ assumptions about growth (in weight) and can be tuned to abundance data such as commercial catch rates, research survey trends or biomass estimates.

Catchability. Proportion of the stock removed by one unit of effective fishing effort (typically age-specific due to differences in selectivity and availability by age).

Control Rule. Describes a plan for pre-agreed management actions as a function of variables related to the status of the stock. For example, a control rule can specify how F or yield should vary with biomass. In the National Standard Guidelines (NSG), the "MSY control rule" is used to determine the limit fishing mortality, or **Maximum Fishing Mortality Threshold (MFMT)**. Control rules are also known as "decision rules" or "harvest control laws."

Catch per Unit of Effort (CPUE). Measures the relative success of fishing operations, but also can be used as a proxy for relative abundance based on the assumption that CPUE is linearly related to stock size. The use of CPUE that has not been properly standardized for temporal-spatial changes in catchability should be avoided.

Exploitation pattern. The fishing mortality on each age (or group of adjacent ages) of a stock relative to the highest mortality on any age. The exploitation pattern is expressed as a series of values ranging from 0.0 to 1.0. The pattern is referred to as "flat-topped" when the values for all the oldest ages are about 1.0, and “dome-shaped” when the values for some intermediate ages are about 1.0 and those for the oldest ages are significantly lower. This pattern often varies by type of fishing gear, area, and seasonal distribution of fishing, and the growth and migration of the fish. The pattern can be changed by modifications to fishing gear, for example, increasing mesh or hook size, or by changing the proportion of harvest by gear type.

Mortality rates. Populations of animals decline exponentially. This means that the number of animals that die in an "instant" is at all times proportional to the number present. The decline is defined by survival curves such as:

$$N_{t+1} = N_t e^{-z}$$

where N_t is the number of animals in the population at time t and N_{t+1} is the number present in the next time period; Z is the total instantaneous mortality rate which can be separated into deaths due to fishing (fishing mortality or F) and deaths due to all other causes (natural mortality or M) and e is the base of the natural logarithm (2.71828).

To better understand the concept of an instantaneous mortality rate, consider the following example. Suppose the instantaneous total mortality rate is 2 (i.e., Z = 2) and we want to know how many animals out of an initial population of 1 million fish will be alive at the end of one year. If the year is apportioned into 365 days (that is, the 'instant' of time is one day), then 2/365 or 0.548% of the population will die each day. On the first day of the year, 5,480 fish will die (1,000,000 x 0.00548), leaving 994,520 alive. On day 2, another 5,450 fish die (994,520 x 0.00548) leaving 989,070 alive. At the end of the year, 134,593 fish [$1,000,000 \times (1 - 0.00548)^{365}$] remain alive. If, we had instead selected a smaller 'instant' of time, say an hour, 0.0228% of the population would have died by the end of the first time interval (an hour), leaving 135,304 fish alive at the end of the year [$1,000,000 \times (1 - 0.00228)^{8760}$]. As the instant of time becomes shorter and shorter, the exact answer to the number of animals surviving is given by the survival curve mentioned above, or, in this example:

$$N_{t+1} = 1,000,000e^{-2} = 135,335 \text{ fish}$$

Exploitation rate. The proportion of a population alive at the beginning of the year that is caught during the year. That is, if 1 million fish were alive on January 1 and 200,000 were caught during the year, the exploitation rate is 0.20 (200,000 / 1,000,000) or 20%.

F_{MAX}. The rate of fishing mortality that produces the maximum level of yield per recruit. This is the point beyond which **growth overfishing** begins.

$F_{0.1}$. The fishing mortality rate where the increase in yield per recruit for an increase in a unit of effort is only 10% of the yield per recruit produced by the first unit of effort on the unexploited stock (i.e., the slope of the **yield-per-recruit** curve for the $F_{0.1}$ rate is only one-tenth the slope of the curve at its origin).

$F_{10\%}$. The fishing mortality rate which reduces the spawning stock biomass per recruit (**SSB/R**) to 10% of the amount present in the absence of fishing. More generally, Fx%, is the fishing mortality rate that reduces the SSB/R to x% of the level that would exist in the absence of fishing.

F_{MSY}. The fishing mortality rate that produces the maximum sustainable yield.

Fishery Management Plan (FMP). Plan containing conservation and management measures for fishery resources, and other provisions required by the **MSFCMA**, developed by Fishery Management Councils or the Secretary of Commerce.

Generation Time. In the context of the National Standard Guidelines, generation time is a measure of the time required for a female to produce a reproductively-active female offspring for use in setting maximum allowable rebuilding time periods.

Growth overfishing. The situation existing when the rate of fishing mortality is above $\mathbf{F_{MAX}}$ and when the loss in fish weight due to mortality exceeds the gain in fish weight due to growth.

Limit Reference Points. Benchmarks used to indicate when harvests should be constrained substantially so that the stock remains within safe biological limits. The probability of exceeding limits should be low. In the National Standard Guidelines, limits are referred to as thresholds. In much of the international literature (e.g., FAO documents), "thresholds" are used as buffer points that signal when a limit is being approached.

Landings per Unit of Effort (LPUE). Analogous to **CPUE** and measures the relative success of fishing operations, but is also sometimes used a proxy for relative abundance based on the assumption that CPUE is linearly related to stock size.

MSFCMA. (Magnuson-Stevens Fishery Conservation and Management Act). U.S. Public Law 94-265, as amended through October 11, 1996. Available as NOAA Technical Memorandum NMFS-F/SPO-23, 1996.

Maximum Fishing Mortality Threshold (MFMT, $\mathbf{F_{THRESHOLD}}$). One of the **Status Determination Criteria (SDC)** for determining if overfishing is occurring. It will usually be equivalent to the F corresponding to the **MSY** Control Rule. If current fishing mortality rates are above $\mathbf{F_{threshold}}$, overfishing is occurring.

Minimum Stock Size Threshold (MSST, $\mathbf{B_{threshold}}$). Another of the **Status Determination Criteria**. The greater of (a) ½B_{MSY}, or (b) the minimum stock size at which rebuilding to $\mathbf{B_{MSY}}$ will occur within 10 years of fishing at the **MFMT**. MSST should be measured in terms of spawning biomass or other appropriate measures of productive capacity. If current stock size is below $\mathbf{B_{THRESHOLD}}$, the stock is overfished.

Maximum Spawning Potential (MSP). This type of reference point is used in some fishery management plans to define overfishing. The MSP is the spawning stock biomass per recruit (**SSB/ R**) when fishing mortality is zero. The degree to which fishing reduces the SSB/R is expressed as a percentage of the MSP (i.e., %MSP). A stock is considered overfished when the fishery reduces the %MSP below the level specified in the overfishing definition. The values of %MSP used to define overfishing can be derived from stock-recruitment data or chosen by analogy using available information on the level required to sustain the stock.

Maximum Sustainable Yield (MSY). The largest average catch that can be taken from a stock under existing environmental conditions.

Overfishing. According to the National Standard Guidelines, "overfishing occurs whenever a stock or stock complex is subjected to a rate or level of fishing mortality that jeopardizes the capacity of a stock or stock complex to produce MSY on a continuing basis." Overfishing is occurring if the **MFMT** is exceeded for 1 year or more.

Optimum Yield (OY). The amount of fish that will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities and taking into account the protection of marine ecosystems. **MSY** constitutes a "ceiling" for OY. OY may be lower than MSY, depending on relevant economic, social, or ecological factors. In the case of an overfished fishery, OY should provide for rebuilding to $\mathbf{B_{MSY}}$.

Partial Recruitment. Patterns of relative vulnerability of fish of different sizes or ages due to the combined effects of selectivity and availability.

Rebuilding Plan. A plan that must be designed to recover stocks to the $\mathbf{B_{MSY}}$ level within 10 years when they are overfished (i.e. when B < **MSST**). Normally, the 10 years would refer to an expected time to rebuilding in a probabilistic sense.

Recruitment. This is the number of young fish that survive (from birth) to a specific age or grow to a specific size. The specific age or size at which recruitment is measured may correspond to when the young fish become vulnerable to capture in a fishery or when the number of fish in a cohort can be reliably estimated by a stock assessment.

Recruitment overfishing. The situation existing when the fishing mortality rate reaches a level that causes a significant reduction in recruitment to the spawning stock. This is caused by a greatly reduced spawning stock and is characterized by a decreasing proportion of older fish in the catch and generally very low recruitment year after year.

Recruitment per spawning stock biomass (R/SSB). The number of fishery recruits (usually age 1 or 2) produced from a given weight of spawners, usually expressed as numbers of recruits per kilogram of mature fish in the stock. This ratio can be computed for each year class and is often used as an index of pre-recruit survival, since a high R/SSB ratio in one year indicates above-average numbers resulting from a given spawning biomass for a particular year class, and vice versa.

Reference Points. Values of parameters (e.g. $\mathbf{B_{MSY}}$, $\mathbf{F_{MSY}}$, $\mathbf{F_{0.1}}$) that are useful benchmarks for guiding management decisions. Biological reference points are typically limits that should not be exceeded with significant probability (e.g., **MSST**) or targets for management (e.g., **OY**).

Risk. The probability of an event times the cost associated with the event (loss function). Sometimes "risk" is simply used to denote the probability of an undesirable result (e.g. the risk of biomass falling below **MSST**).

Status Determination Criteria (SDC). Objective and measurable criteria used to determine if a stock is being overfished or is in an overfished state according to the National Standard Guidelines.

Selectivity. Measures the relative vulnerability of different age (size) classes to the fishing gears(s).

Spawning stock biomass. The total weight of all sexually mature fish in a stock.

Spawning stock biomass per recruit (SSB/R or SBR). The expected lifetime contribution to the spawning stock biomass for each recruit. SSB/R is calculated assuming that F is constant over the life span of a year class. The calculated value is also dependent on the exploitation pattern and rates of growth and natural mortality, all of which are also assumed to be constant.

Survival Ratios. Ratios of recruits to spawners (or spawning biomass) in a stock-recruitment analysis.

TAC. Total allowable catch is the total regulated catch from a stock in a given time period, usually a year.

Target Reference Points. Benchmarks used to guide management objectives for achieving a desirable outcome (e.g., **OY**). Target reference points should not be exceeded on average.

Uncertainty. Uncertainty results from a lack of perfect knowledge of many factors that affect stock assessments, estimation of reference points, and management. Rosenberg and Restrepo (1994) identify 5 types: measurement error (in observed quantities), process error (or natural population variability), model error (mis-specification of assumed values or model structure), estimation error (in population parameters or reference points, due to any of the preceding types of errors), and implementation error (or the inability to achieve targets exactly for whatever reason).

Virtual population analysis (VPA) (or cohort analysis). A retrospective analysis of the catches from a given year class which provides estimates of fishing mortality and stock size at each age over its life in the fishery. This technique is used extensively in fishery assessments.

Year class (or cohort). Fish born in a given year. For example, the 1987 year class of cod includes all cod born in 1987. This year class would be age 1 in 1988, age 2 in 1989, and so on.

Yield per recruit (Y/R or YPR). The average expected yield in weight from a single recruit. Y/R is calculated assuming that F is constant over the life span of a year class. The calculated value is also dependent on the exploitation pattern, rate of growth, and natural mortality rate, all of which are assumed to be constant.

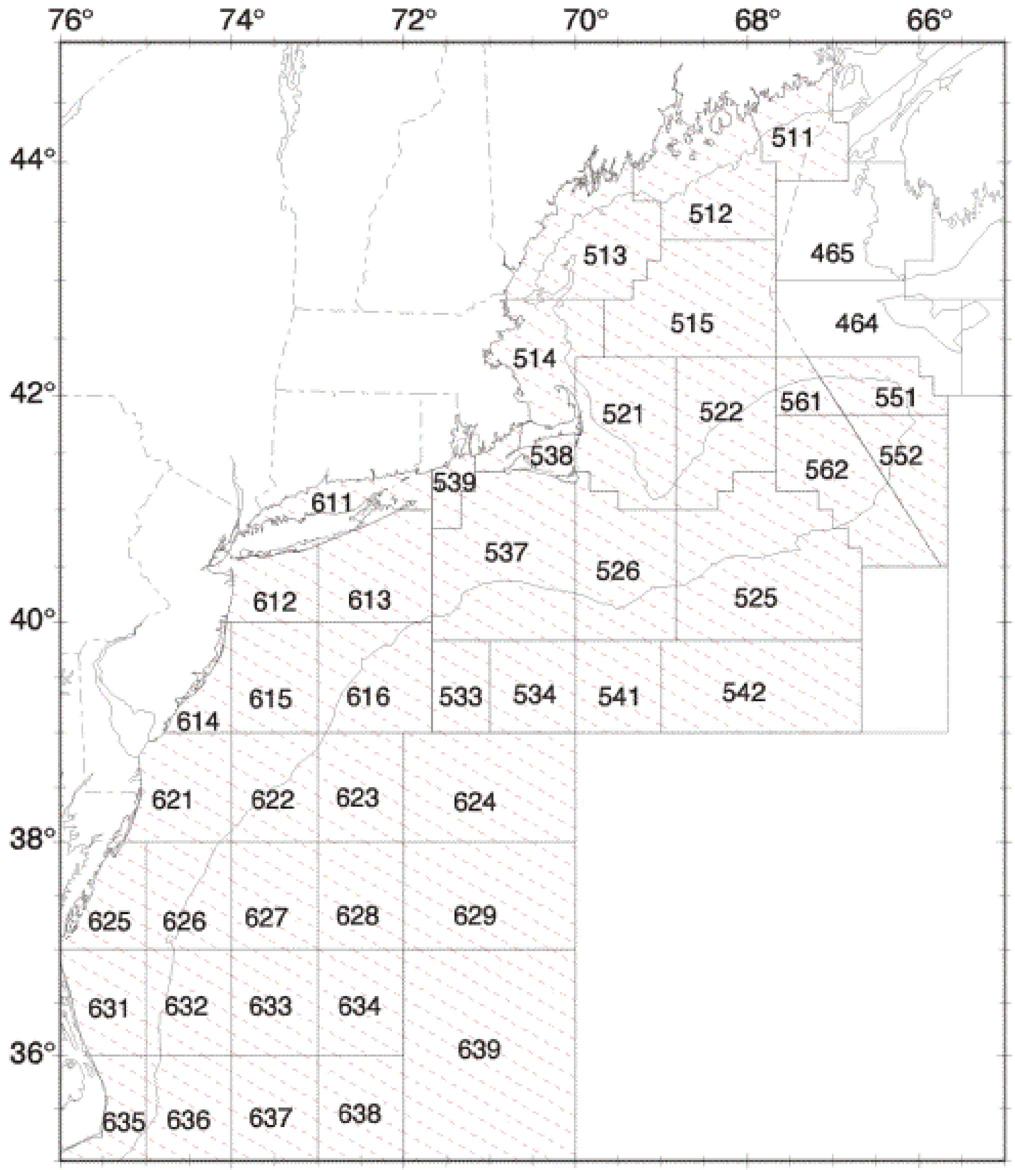


Figure 1. Statistical areas used for catch reporting

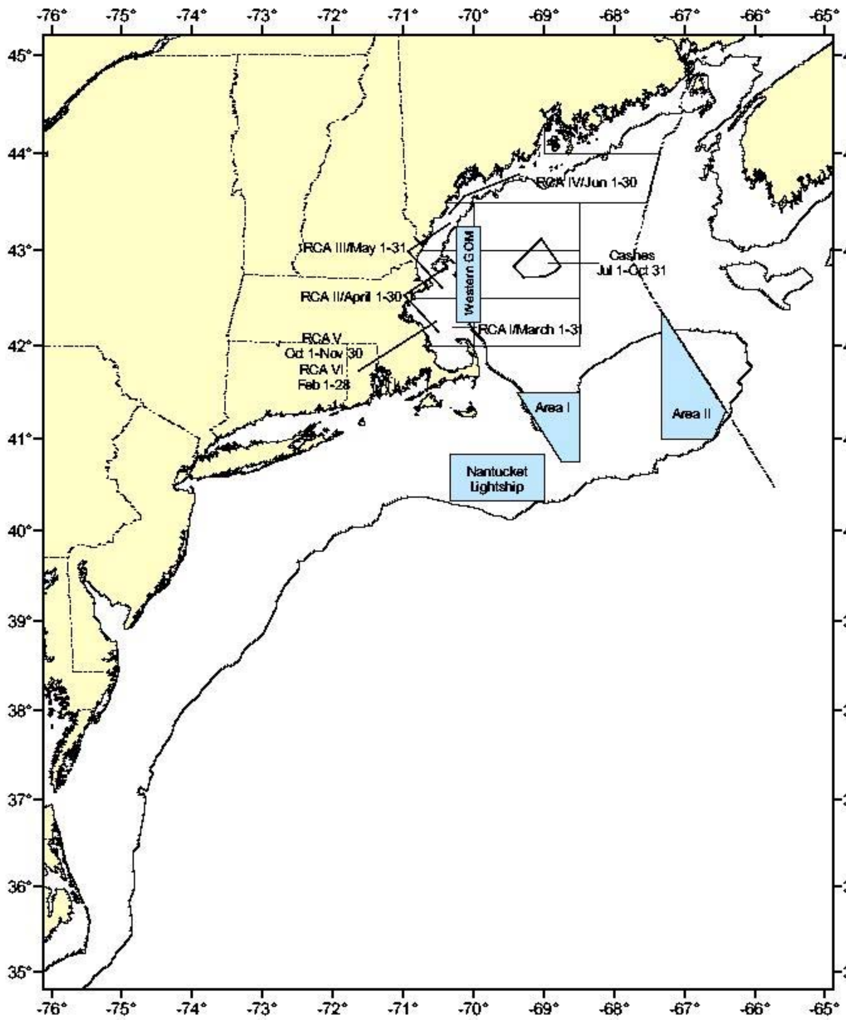


Figure 2. Year-around area closures (shaded polygons) and seasonal rolling closures (open polygons).

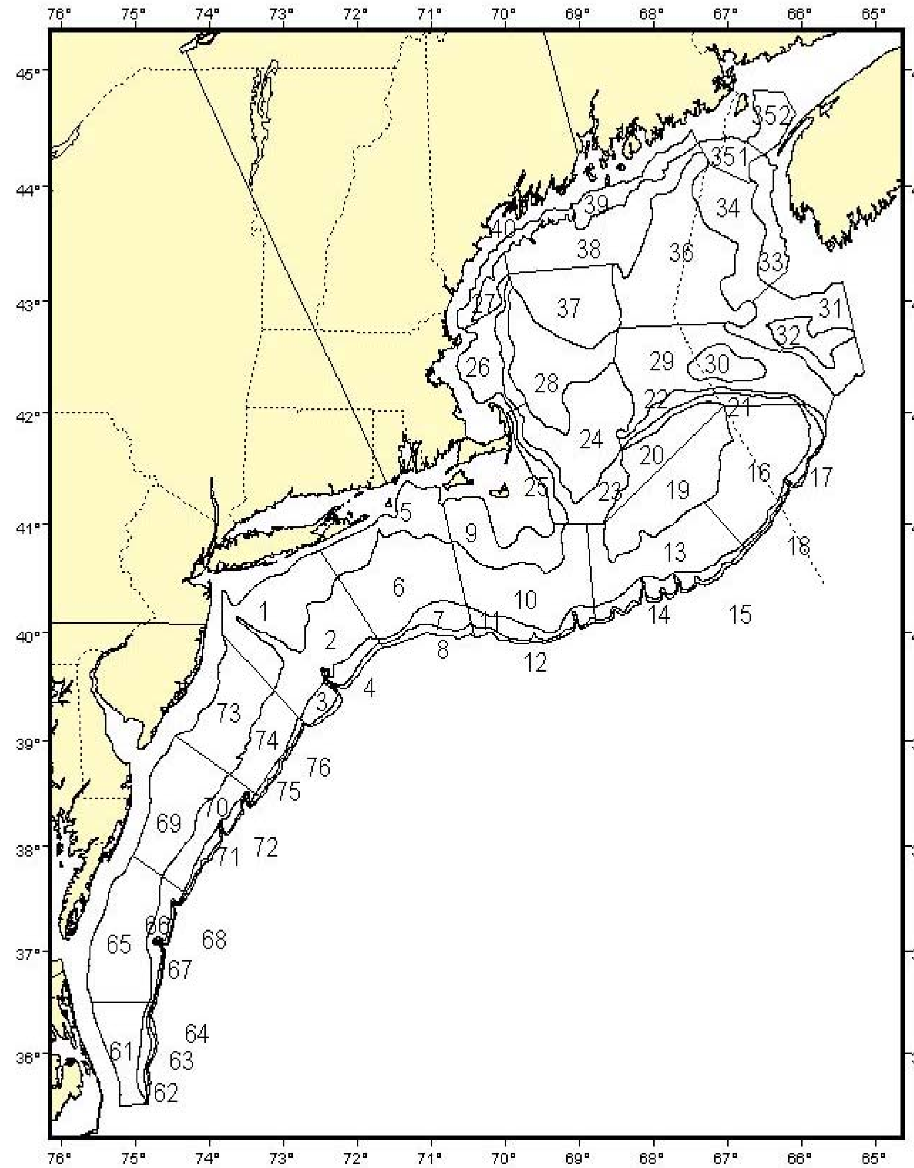


Figure 3. NEFSC bottom trawl survey sampling strata.

A. WITCH FLOUNDER ADVISORY REPORT

State of stock: The witch flounder stock was not overfished, but overfishing was occurring in 2002 (Figure A5). Fully recruited fishing mortality in 2002 was 0.41 (exploitation rate = 31%) nearly double F_{MSY} = 0.23 (Figure A1). The fishing mortality rate declined 63% between 1996 and 2002 and 46% relative to the 1995-2002 average. Spawning stock biomass was estimated to be 18,300 mt in 2002, 72% of SSB_{MSY} (25,200 mt; Figures A2 and A5). Spawning stock biomass has increased by a factor of 4 from a record low level of 3,800 mt in 1995 and is the highest in the VPA time series. However, the current spawning stock biomass is dominated by the youngest mature age classes 5 to 7 (Figure A9), which are also the main component in the recent years' landings (Figure A10).

Management Advice: Fishing mortality should be reduced to F_{MSY} or below. The stock is expected to exceed the biomass target, even if status quo fishing mortality continues. Reducing fishing mortality will rebuild age structure of spawners and maintain biomass near the target.

Forecast for 2003-2005: Fishing at the status quo F (0.41) or at the target F(0.23) in 2003-2005 is expected to allow biomass to increase above SSB_{MSY} and initiate rebuilding of the age structure. However, based on retrospective analysis, the projections of SSB may be optimistic.

Forecast Table: SSB estimated to be 18,300 mt in 2002. Initial 2003 stock sizes for ages 3-11+ are from the calibrated VPA. Average 1999-2002 partial recruitment, average 1999-2002 mean weights at age, and a maturation ogive representing 1999-2003 maturities were used in projections. Forecast medians (50% probability level); weights reported in '000 mt.

2003				2004			2005		
Landings	Disc.	SSB	F	Landings	Disc.	SSB	Landings	Disc.	SSB
$F_{2003} = F_{2002} = 0.41$									
6.254	0.251	26.677	$F_{SQ} = 0.41$	8.652	0.191	32.121	10.474	0.132	33.733
			$F_{MSY} = 0.23$	5.174	0.109	32.705	6.992	0.076	37.600
			$75\%F_{MSY} = 0.17$	3.908	0.081	32.902	5.480	0.057	39.080
$landings_{2003} = landings_{2002}$ (F = 0.199)									
3.186	0.121	27.241	$F_{MSY} = 0.23$	5.781	0.111	35.389	7.519	0.077	40.160
			$75\% F_{MSY}=0.17$	4.366	0.083	35.613	5.899	0.058	41.753

Catch and Status Table (weights in '000 mt, recruitment in millions): Witch flounder

Year	1995	1996	1997	1998	1999	2000	2001	2002	1982-2002 Max	Min	Mean
USA Comm Landings	2.21	2.09	1.77	1.85	2.12	2.44	3.02	3.19	6.66	1.47	3.17
Total Discards	0.19	0.25	0.30	0.28	0.21	0.12	0.22	0.28	0.42	0.02	0.18
Shrimp Fishery Discards	0.03	0.01	0.02	0.01	<0.01	<0.01	<0.01	<0.01	0.33	>.01	0.16
Large Mesh OT Fishery Discards	0.16	0.24	0.28	0.27	0.20	0.11	0.22	0.28	1.63	0.01	0.16
Catch used in Assessment	2.40	2.34	2.07	2.13	2.33	2.55	3.24	3.47	6.67	1.65	3.34
Spawning stock biomass[1]	3.92	3.83	4.05	5.16	6.59	8.87	12.31	18.30	18.30	3.83	8.58
Recruitment (Age 3)	12.67	15.88	20.23	29.66	42.90	67.65	58.70	29.60	67.65	3.00	19.6
Fully recruited F (ages 8-9,u)	0.63	1.13	1.09	0.65	0.51	0.55	0.76	0.41	1.13	0.23	0.56
Exploitation Rate	44%	64%	62%	45%	37%	40%	50%	31%	64%	19%	40%

[1] At beginning of spawning season, March 1.

Stock Identification and Distribution: A single stock of witch flounder is considered to inhabit the region from the northern Gulf of Maine to southwestern Georges Bank. The stock may extend to the south and into deeper slope waters. Distribution in Gulf of Maine is contiguous with the Scotian Shelf; however, for this assessment, only witch flounder in U.S. waters were assessed.

Catches: U.S. landings increased during the 1960s from 1,200 mt to about 3,000 mt, then fluctuated between 2,000 and 3,000 mt until the early 1980s. In the mid 1980s landings abruptly increased, peaking at nearly 7,000 mt in 1984. Landings declined to 1,467 mt in 1990 and have since fluctuated between 2,000 and 3,186 mt (Figure A1). Landings in 2002 were 3,200 mt. Discards have ranged from 25 mt in 1986 to over 400 mt in 1994. Over the 1982-2002 time period, estimated discards have represented between 0.5% and 14.5% by weight (2% and 45% by number) of the total U.S. commercial catch. Recreational catches are negligible.

Data and Assessment: An analytical assessment (VPA) of U.S. commercial catch (landings plus discards from the shrimp and large mesh otter trawl fisheries) at age data was conducted, and an alternative assessment using a statistical catch at age model was evaluated (Figure A8). Information on recruitment and abundance was taken from standardized NEFSC spring and autumn survey catch-per-tow at age data. The uncertainty associated with the estimates of fishing mortality and spawning stock biomass in 2002 was evaluated (Figures A6 and A7).

Biological Reference Points: NEFSC (2002) re-estimated the biological reference points for witch flounder based on results from the 1999 assessment using yield and SSB per recruit analyses and the arithmetic mean VPA age 3 recruitment. These reference points were updated in the current assessment using updated mean weights, maturity, fishery selectivity at age, and average recruitment consistent with those recommended by the Biological Reference Point Review workshop. The yield and SSB per recruit analyses indicate $F_{40\%}$ = 0.23 (Figure A4), MSY = 4,375 mt, and SSB_{MSY} = 25,240 mt (Figure A5) with an assumed M = 0.15.

Fishing Mortality: Fishing mortality (ages 8-9, unweighted) increased from 0.26 (21% exploitation) in 1982 to 0.68 (46% exploitation) in 1985, declined to 0.23 (19% exploitation) in 1992, increased to 1.13 (64% exploitation) in 1996, then declined to 0.41 (31% exploitation) in 2002 (Figure A1). The 80% confidence interval for 2002 F is 0.31- 0.56 (Figure A6).

Discards of witch flounder are a relatively minor component of total catch (8% by weight in 2002) but account for 60% of fishing mortality on ages 1 through 5, which was less than F=0.03. The shrimp fishery accounts for 2% of the fishing mortality on these age groups, while the large-mesh otter trawl fishery accounts for 58% of the fishing mortality.

Recruitment: Long-term arithmetic mean recruitment (age 3 fish) is 19.6 million fish. The 1995-1999 year classes appear to be above average, and the 1997 year class is the largest in the VPA time series (Figure A3).

Spawning Stock Biomass: SSB declined from 16,900 mt in 1982 to about 3,800 mt in 1996 (Figures A2 and A3) but has increased to 18,300 mt in 2002 primarily due to recent above average recruitment. The 80% confidence interval for the 2002 SSB is 15,600 – 23,000 mt (Figure A7).

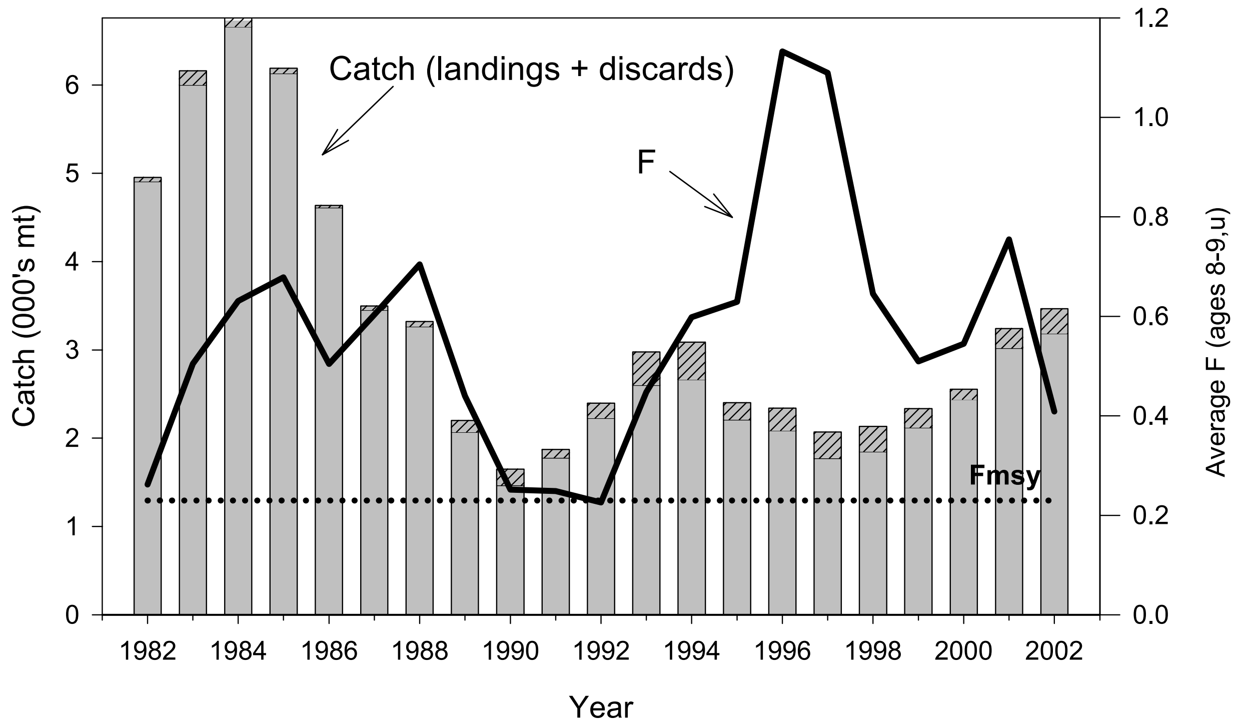
Special Comments: The SARC used new data to update fishing mortality and spawning biomass reference point values. The value of the F_{MSY} proxy ($F_{40\%MSP}$) increased from 0.17 to 0.23. The higher value is due to the combined effects of increases in the number of explicit ages in the SSB-per-recruit analyses, and updated mean weights, maturity at age, and partial recruitment values. Of these factors, changes in fishery selectivity (partial recruitment), likely due to increases in the minimum mesh size, had the greatest overall impact on the F reference point. Increases in the estimated SSB_{MSY} from 19,900 mt to 25,200 mt are primarily due to the inclusion of the 1997 and 1998 year classes. The recent above average year classes may be poorly determined, and based on the retrospective pattern for recruitment, may be overestimated.

An alternative statistical catch-at-age analysis was conducted. As a comparison to the accepted VPA model, F_{2002} = 0.48 (VPA F_{2002} = 0.41), SSB_{2002} = 10,500 mt (VPA SSB_{2002} = 18,300 mt) (Figure A8).

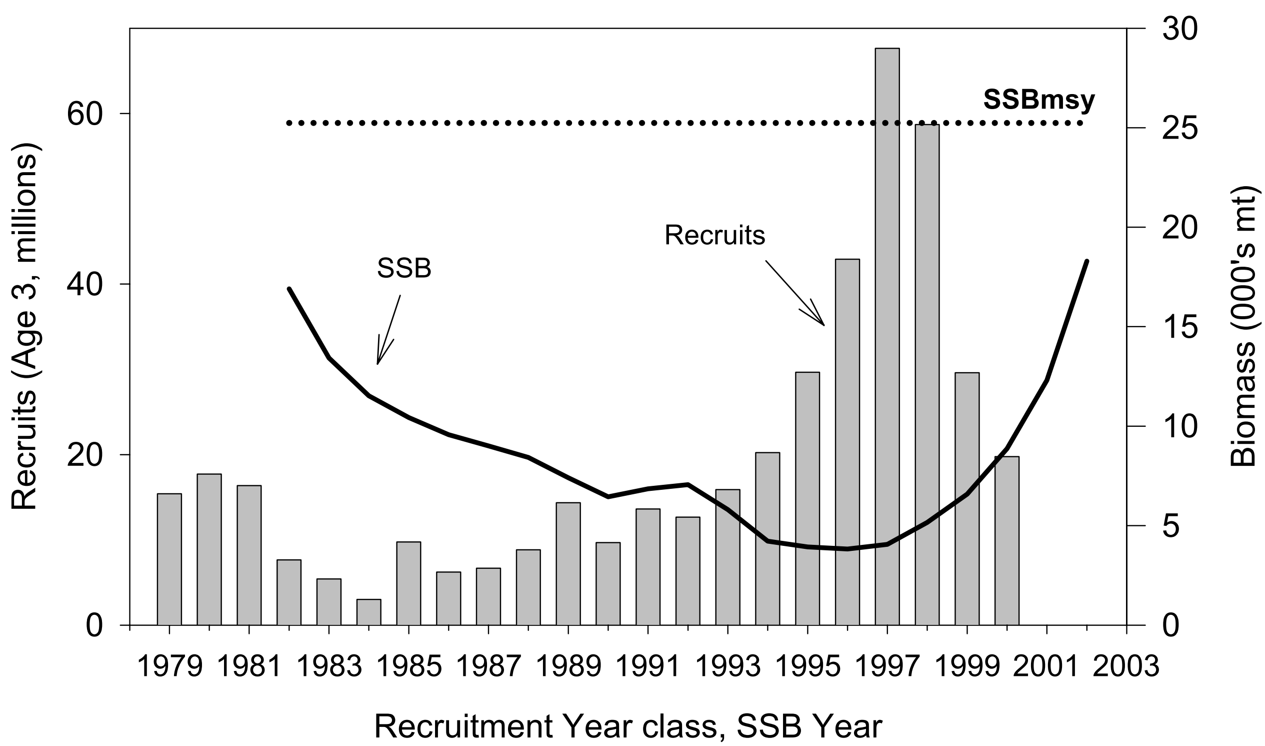
In 2002, 71% of the spawning stock biomass was comprised of young witch flounder (ages 5 to 7); at equilibrium, fishing at F_{MSY}, these age groups would comprise 29% of the spawning stock biomass (Figure A9).

Source of Information: Report of the 37th Stock Assessment Workshop/Consensus Summary of Assessments, NEFSC CRD 03-16, and Assessment of the Gulf of Maine and Georges Bank Witch flounder stock for 2003; Northeast Fisheries Science Center, NEFSC CRD 03-14. 2002. Final Report of the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish. NEFSC Ref. Doc. 02-04 123 p.

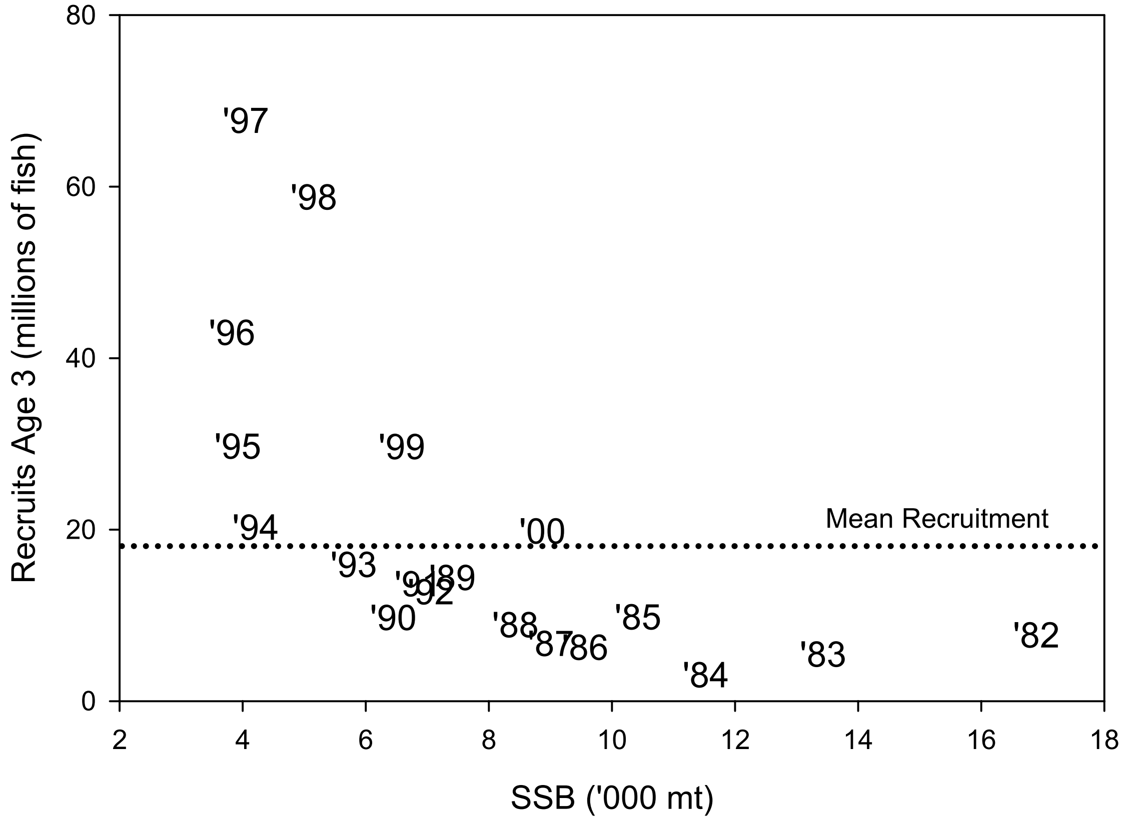
A.1. Trends in total catch and fishing mortality for witch flounder



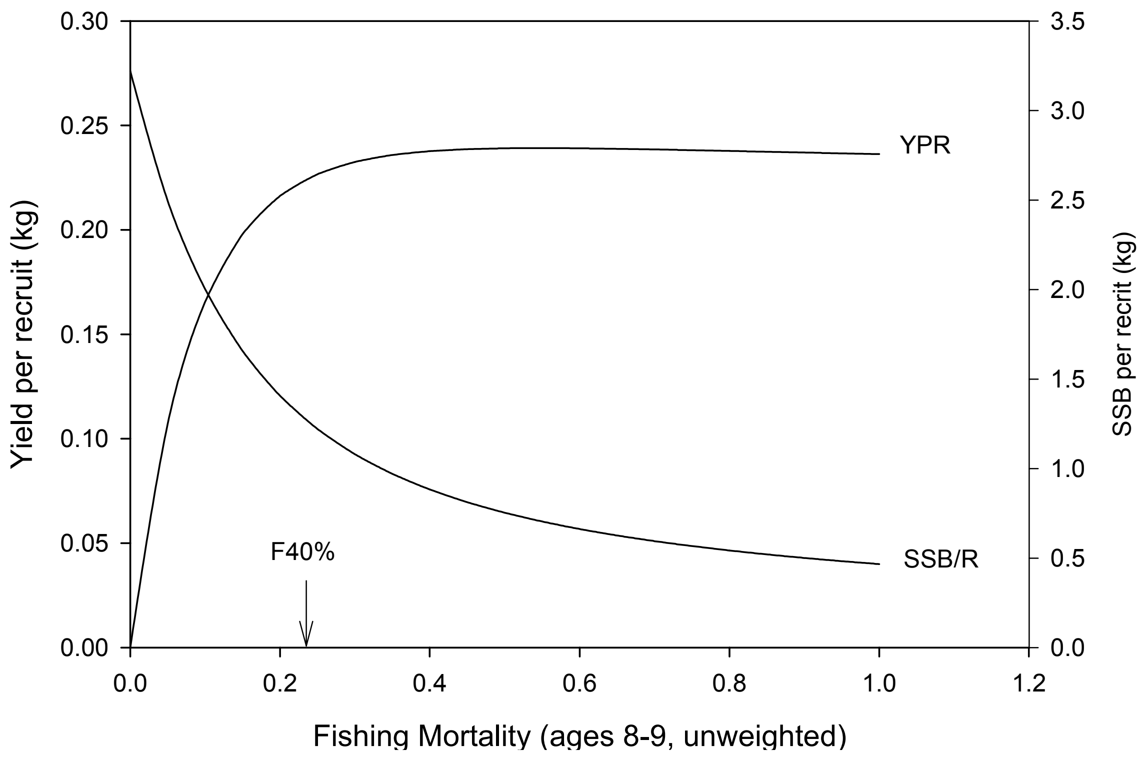
A.2. Trends in SSB and recruitment (Age 3) for witch flounder



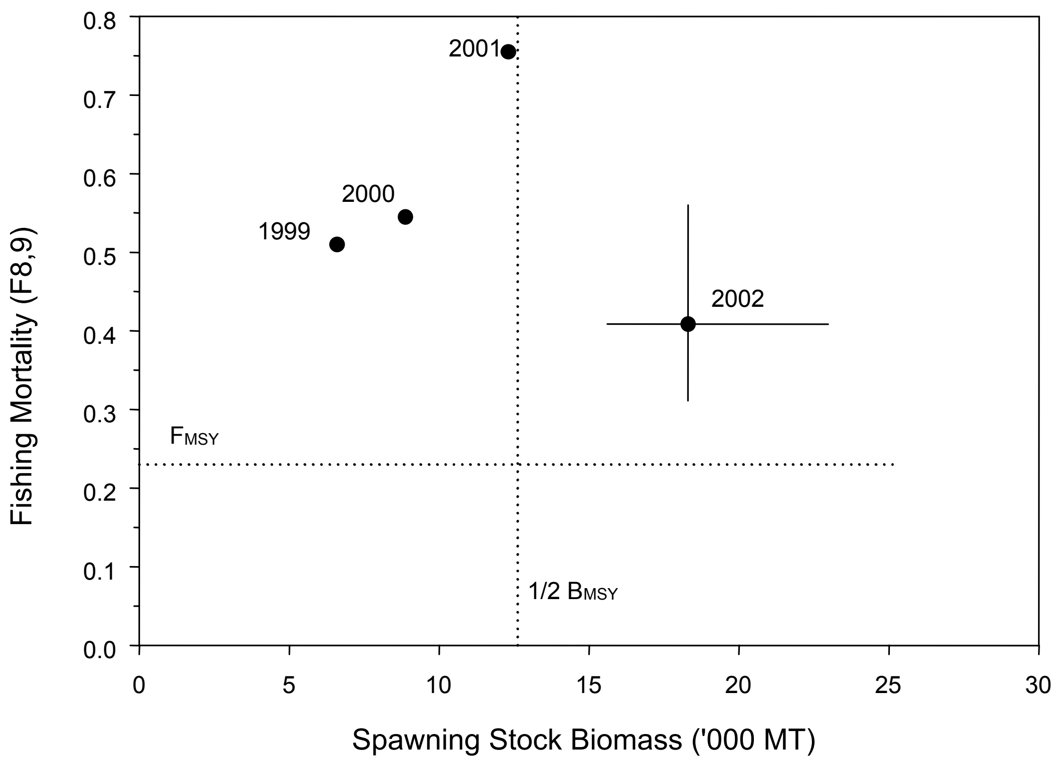
A.3. Spawning stock biomass and recruits (Age 3) for witch flounder



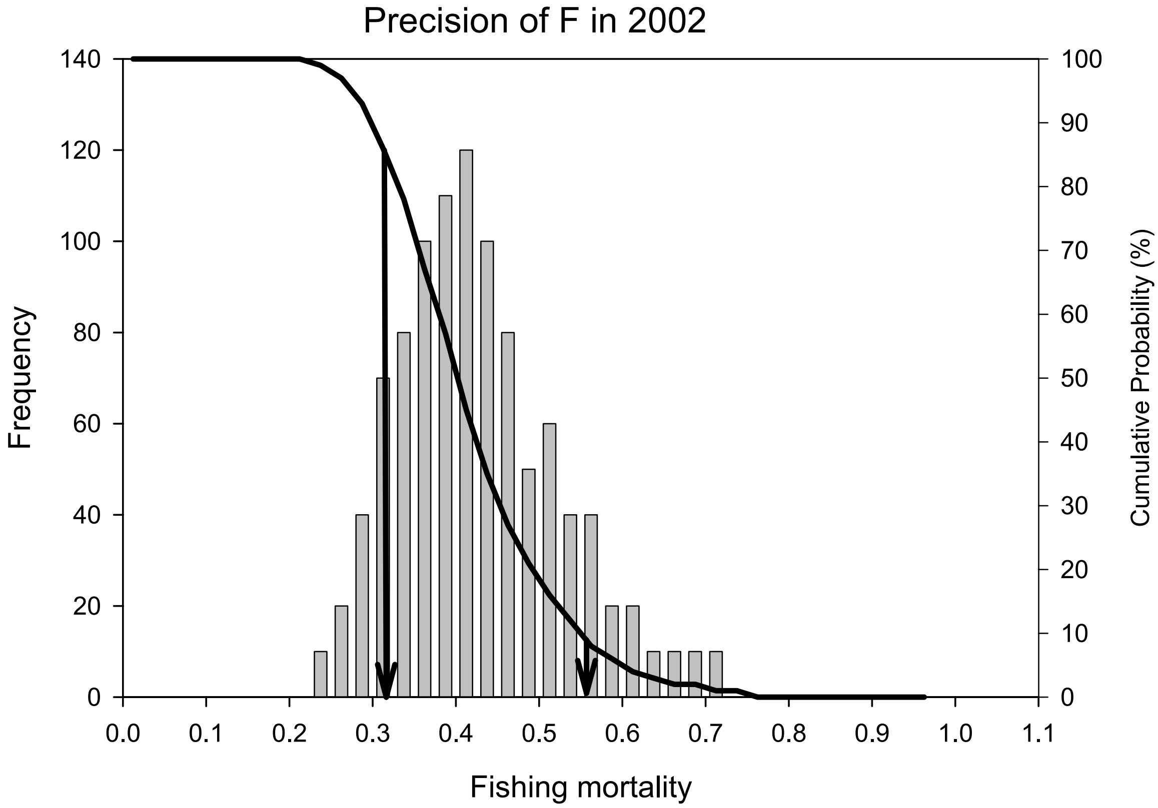
A.4. Yield and SSB per Recruit for witch flounder



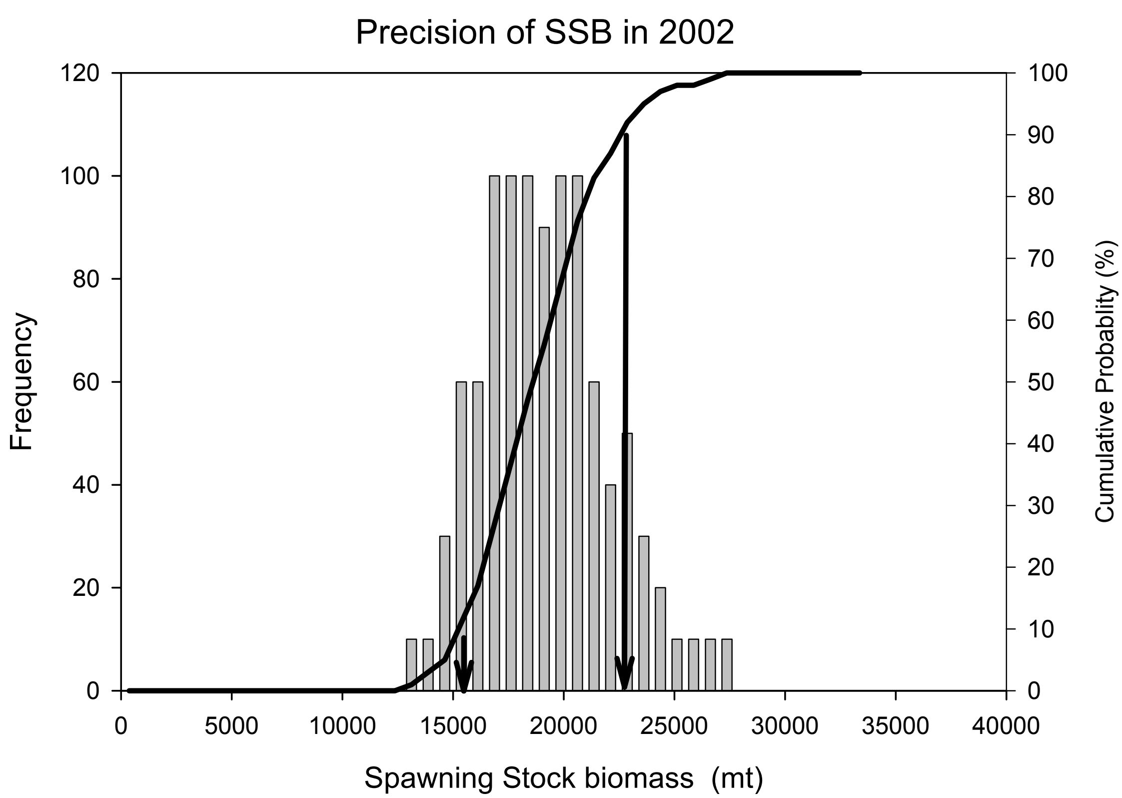
A.5. SFA Reference Points, and recent status determinations (with 80% CI indicated for 2002) for witch flounder



A.6. Precision of 2002 estimate of F for witch flounder

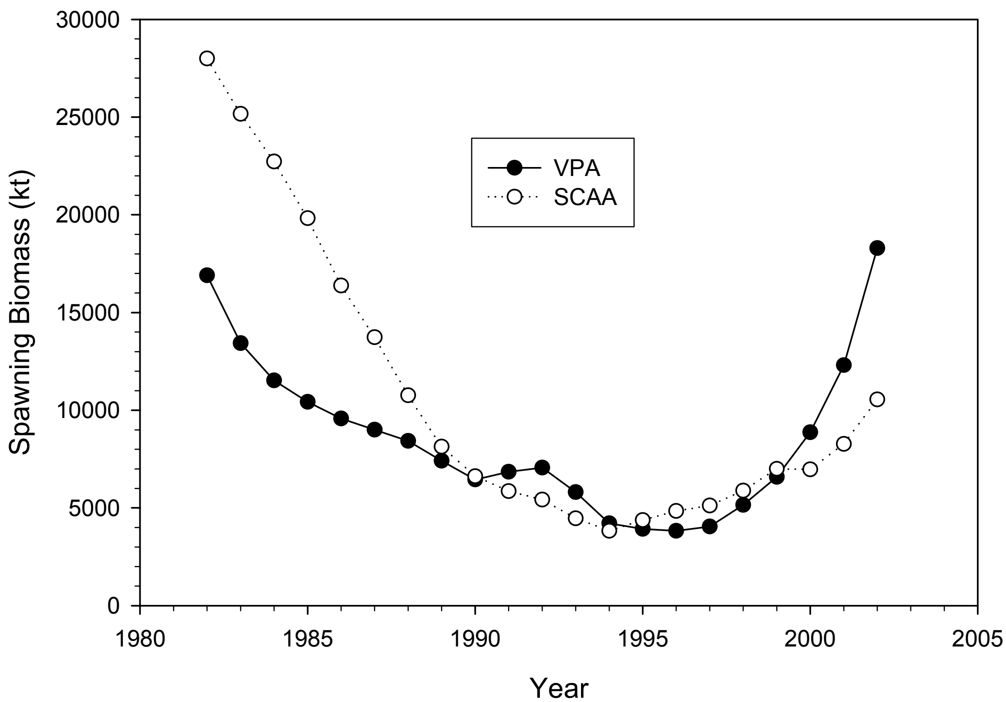


A.7. Precision of 2002 estimate of SSB for witch flounder

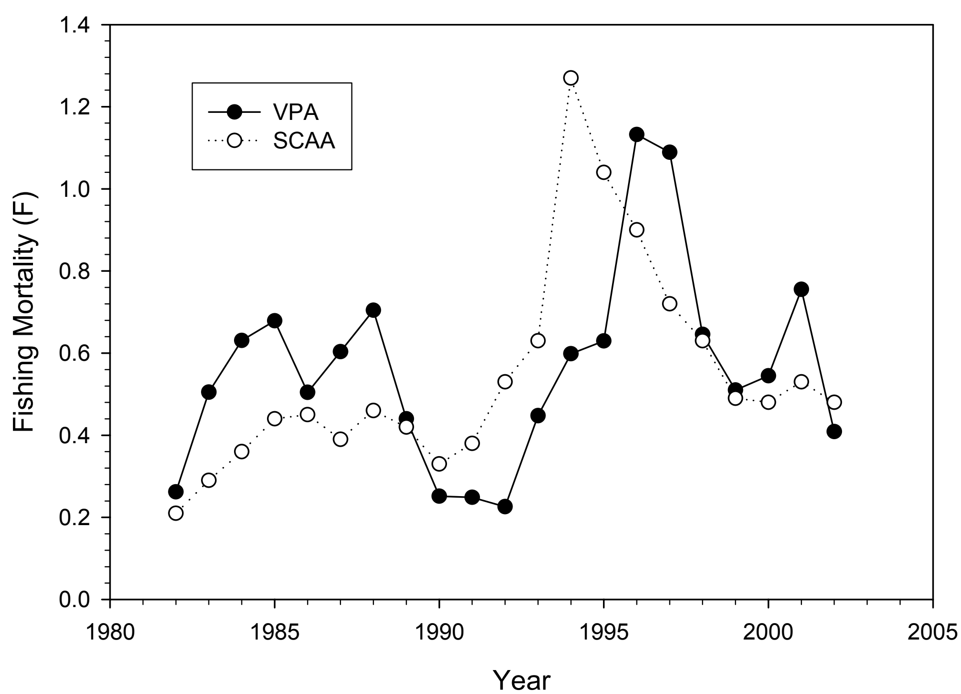


A.8. Comparison of VPA and SCAA estimates of spawning stock biomass for witch flounder

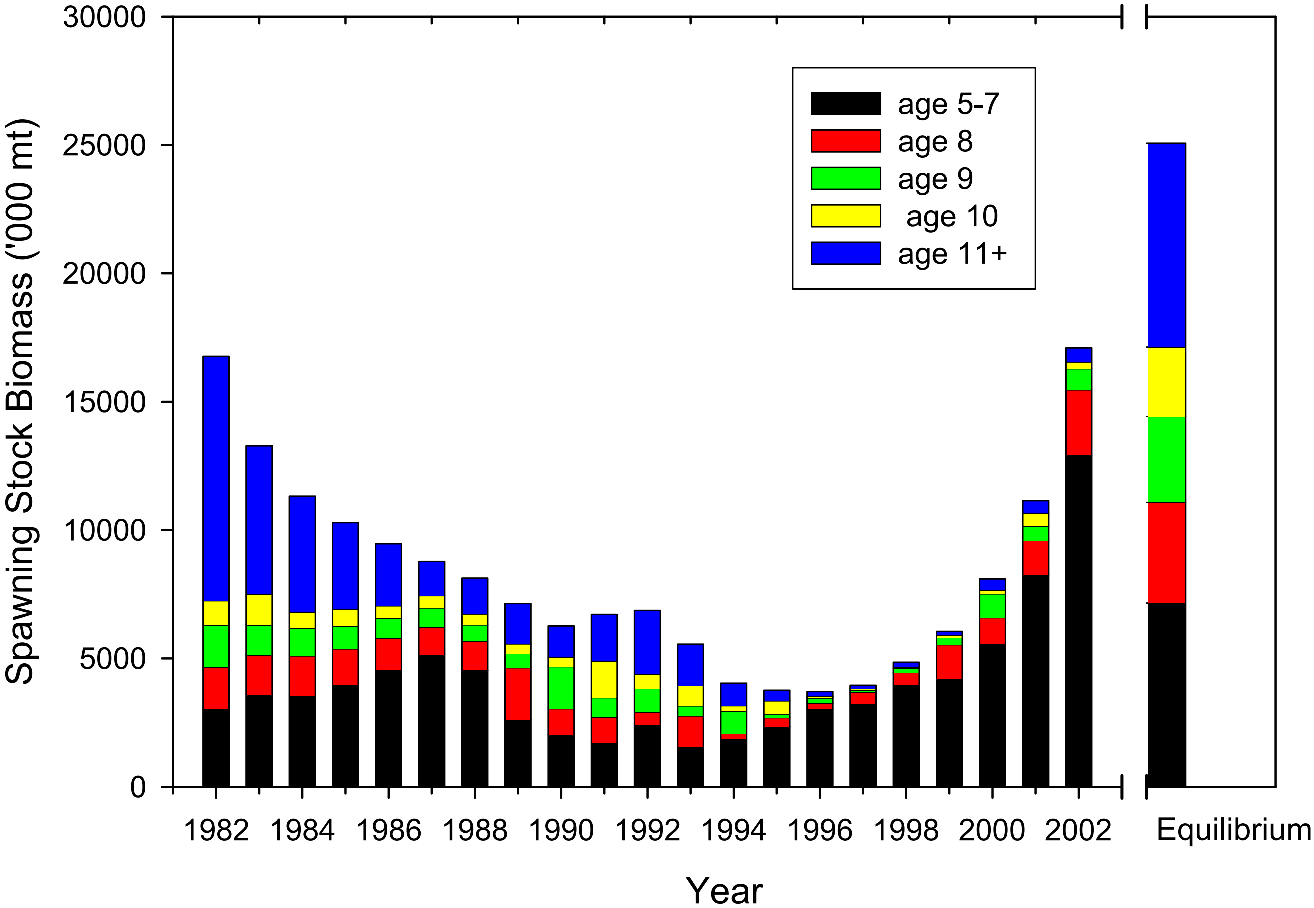
Comparison of ADAPT virtual population analysis (VPA) and statistical catch-at-age analysis (SCAA) estimates of witch flounder spawning biomass, 1982-2002



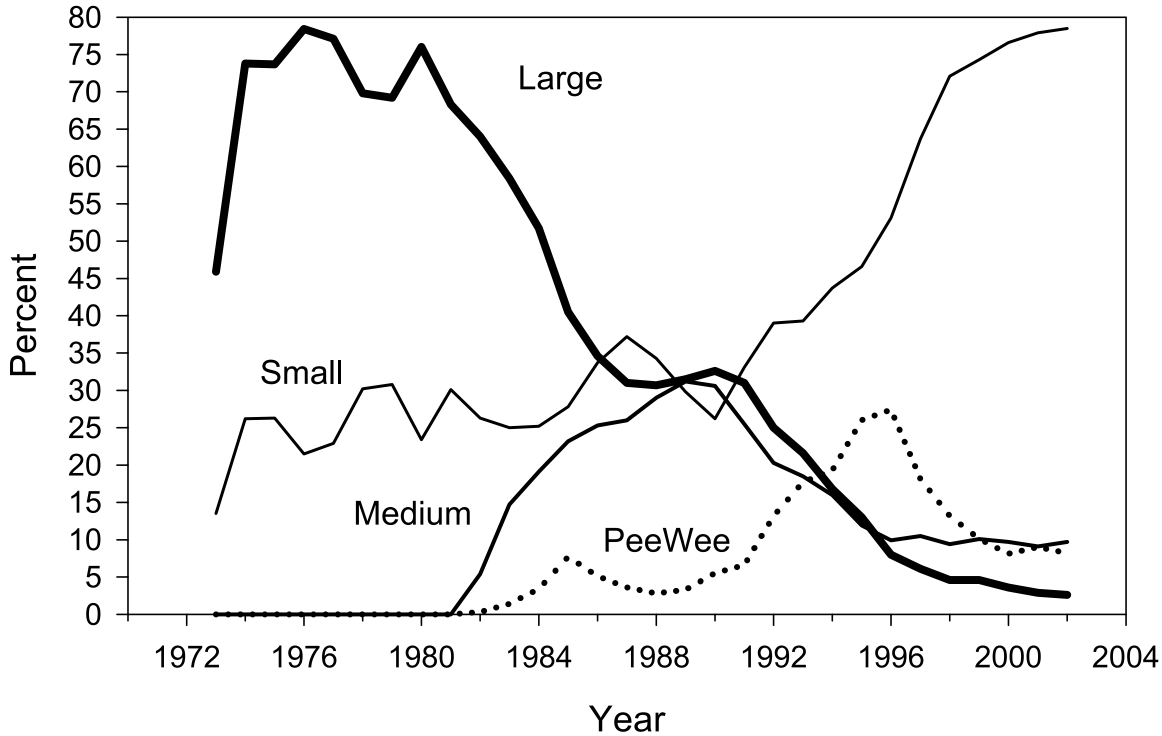
Comparison of ADAPT virtual population analysis (VPA) and statistical catch-at-age analysis (SCAA) estimates of witch flounder fishing mortality, 1982-2002



A.9. Trends in age composition of spawning stock biomass for witch flounder



A.10. Landings trends by market category for witch flounder



B. SPINY DOGFISH ADVISORY REPORT

State of Stock: The spiny dogfish stock is overfished and overfishing is not occurring. Estimated fishing mortality in 2002 (F = 0.09) exceeds the rebuilding target (F = 0.03) by a factor of 3, and is near the overfishing threshold (F = 0.11). The female spawning portion of the biomass has declined by about 75% since 1988 and is at 29% of the biomass target. Estimates of the exploitable and total biomass in 2002 are about 140,000 mt and 371,000 mt, respectively, about half of the peak level observed in 1985 (Figure B5). Recent reductions in spawning stock biomass cannot be replaced quickly due to the reproductive biology of spiny dogfish, and the current low level of SSB is expected to result in low recruitment for the next several years. Recruitment estimates from 1997 to 2003 represent the seven lowest values in the entire series (Figure B3).

Management Advice: Given low current spawning biomass, poor recruitment and reduced pup survivorship, the SARC recommends total removals (landings, discards, Canadian catch) below those derived from the estimated rebuilding F (0.03). Targeting females should be avoided.

Forecast: Rebuilding of spiny dogfish populations will take at least 15 years under the most optimistic scenario (Figure B7). The low biomass of spawning females, high abundance of males, and the near absence of dogfish less than 50 cm will induce large oscillations in the stock regardless of management strategies. Biomass of males and immature females in the 36-70 cm range should decrease over the next decade as the small cohorts produced in the 1990s grow. Replacement of the spawning stock, i.e., accumulation of large females in the 100 cm range, could take another two decades. Forecasts of rebuilding which take into account the apparent lower survival of pups from smaller females indicate that rebuilding will not occur.

Projection Table for Scenarios, Spiny Dogfish

Scenario	Constant F 2004-2032	Year	SSB (mt)	Yield (mt)	Discard (mt)
RMP F	0.08	2003	57,608	2,290	8,692
		2004	91,077	7,790	8,597
		2012	81,105	7,727	6,539
		2022	120,140	9,086	6,230
		2032	128,266	9,528	6,781
Current F	0.09	2003	57,608	7,070	8,692
		2004	86,948	8,812	8,472
		2012	71,971	8,212	6,191
		2022	103,262	9,207	5,552
		2032	104,320	9,106	5,701
Rebuild F	0.03	2003	57,608	2,290	8,692
		2004	91,077	2,960	8,597
		2012	113,641	3,892	7,512
		2022	189,434	5,365	8,790
		2032	250,959	7,038	11,829
Zero F	0.00	2003	57,608	-	8,692
		2004	93,083	-	8,658
		2012	141,174	-	8,316
		2022	256,575	-	11,164
		2032	392,134	-	17,252
Constant Harvest		2003	57,608	7,252	8,692
8.8 million lbs.		2004	86,842	7,252	8,467
		2012	90,693	7,253	6,746
		2022	135,518	7,253	6,764
		2032	161,989	7,254	8,091
Reduced Survival	0.09	2003	57,608	7,070	8,692
		2004	86,948	8,812	8,452
		2012	71,971	7,848	4,119
		2022	12,953	1,655	1,049
		2032	1,696	302	262

Landings and Status Table (weights in '000 mt, recruitment in millions): Spiny Dogfish

Year	1996	1997	1998	1999	2000	2001	2002	2003	1968-2002 Max	Min	Mean
USA commercial landings	27.2	18.4	20.6	14.9	9.3	2.3	2.2	-	27.2	<0.1	7.2
Foreign commercial landings	0.7	0.7	1.7	3.0	3.2	4.1	3.4	-	24.5	0.4	5.2
Discards, commercial[1]	14.1	6.3	4.3	3.7	3.7	7.0	5.0	-	47.3	3.7	16.7
USA recreational catch[2]	0.4	0.8	0.6	0.6	0.6	2.1	1.9	-	2.1	0.4	1.1
Total landings	28.3	19.8	23.0	18.5	13.0	8.5	7.5	-	28.3	1.5	13.1
Spring survey females[3]	60.5	44.9	15.5	32.5	29.2	19.8	32.2	29.7	89.2	1.6	46.4
F on female exploitable stock[4]	0.24	0.17	0.32	.24	.19	.08	.09		0.32	0.08	0.19
Swept Area Biomass Estimates[5]											
Total Stock (male+female)	521	489	406	358	343	337	371		665	337	473
Exploitable stock (male+female)	234	216	144	135	132	144	140		234	92	148
Female SSB[6]	114	91	52	53	62	65	58		270	52	128
Recruitment index[7]	33.9	1.8	2.9	1.0	3.1	1.3	1.9	5.3	128.4	1.0	29.5

[1] Total discard mortality in trawl, gill net and hook fisheries, 1989-2002, assuming 75% gillnet, 50% trawl and 25% hook discard mortality.
[2] Includes all landed and released recreational catch assuming 100% discard mortality, 1981-2002.
[3] Raw spring survey average weight (kg) per tow, 1981-2003
[4] Stochastic estimator of F on female exploitable stock, 1990-2002, minimum footprint assumption.
[5] Stochastic estimates of biomass, 1990-2002, for total, exploitable and female spawning stock, minimum footprint assumption.
[6] Individuals >=80 cm.
[7] NEFSC spring survey, expanded number of individuals <35 cm (millions).

Species Distribution and Stock Identification: Spiny dogfish are distributed in the Northwest Atlantic between Labrador and Florida, are most abundant between Nova Scotia and Cape Hatteras, and are considered to be a unit stock in NAFO Subareas 2-6. Seasonal migrations occur northward in spring/summer and southward in autumn/winter. Analysis of spatial and temporal abundance patterns from NEFSC spring and autumn and Canadian summer research vessel survey catches suggests that the spring survey provides a valid abundance measure for the entire stock.

Tagging studies and research surveys conducted in North Carolina waters by East Carolina University (ECU) suggest that spiny dogfish found south of Cape Hatteras during the winter comprise a minor component of the stock north of Cape Hatteras, as defined above. Tag returns from the ECU studies were mainly from North Carolina waters in winter and Massachusetts waters in summer. Few ECU tags were recovered in Canadian waters. Further study of dogfish stock structure is needed.

Catches: Dogfish landings were dominated by foreign catches from 1966 to 1977, peaking in 1974 at about 25,000 mt (Figure B2). US commercial landings dominated the catch from 1979 to 2000, peaking in 1996 at about 28,000 mt. Total landings have declined steadily since 1998 and were sharply lower in 2001 and 2002. In the last two years, the Canadian catches are the largest proportion of estimated landings and recreational catches are, for the first time, a significant proportion of total landings (Figure B2).

Quantitative estimates of discards are available for 1990-2002, and have ranged from 3,700 to 47,000 mt. Estimated discard mortalities during 1990-1991 of about 47,000 mt indicate total catch mortality in those years of about 60,000 mt, and suggest that total catch mortality in previous years may have been much higher than reported landings. However, discard mortality is applied to all size classes and both sexes whereas the landings are concentrated on mature females. Discards have declined significantly in recent years, most likely due to effort restrictions on other species.

Data and Assessment: Spiny dogfish were last assessed in March 1998 (SAW 26). The current assessment updates the findings of the SAW 18 (June 1994) and SAW 26, and incorporates new estimates of stock biomass and fishing mortality. Estimates of means and variances of discarded catch have been included in assessment models for the first time. Since age compositions of the landings and discards are not available, the analytical models are length-based. Indices of abundance were derived from research vessel survey catch per tow. New biological data on the relationship between maternal size, and numbers and size of pups were incorporated. Natural mortality (M) was estimated to be 0.092 based on an assumed longevity of 50 years. Estimates of biomass and fishing mortality were derived from a stochastic length-based, survey swept-area method using data from the commercial fishery and NEFSC trawl surveys. Fishing mortality estimates based on the Beverton-Holt model and NEFSC spring survey data were also computed over an assumed range of sizes at entry and natural mortality rates. A size- and sex-structured equilibrium life history model incorporating known biological parameters was used to estimate yield per recruit and female pups per female recruit corresponding to varying levels of F and minimum size at entry to the fishery. A stochastic, length-based projection model was developed to predict yield, population sizes and rebuilding times under alternative management scenarios. Selectivity patterns for exploited female and male dogfish were developed.

Biological Reference Points: Reference points established in the MAFMC/NEFMC Spiny Dogfish Fishery Management Plan (1999) include a B_{TARGET} of 180,000 mt, a $B_{THRESHOLD}$ of 100,000 mt, an $F_{THRESHOLD}$ of F=0.11 and an F_{TARGET} of F=0.08, all in terms of adult (>= 80 cm) female biomass. The B_{TARGET} reference point was subsequently disapproved. The biomass target in the ASMFC FMP is determined from the trawl survey results and is currently 167,000 mt. These reference points were neither updated nor re-estimated by the current assessment.

Fishing Mortality: F on the female exploitable stock varied between 0.1 and 0.3 between 1990 and 2000 (Figure B1). Despite the much lower level of landings, fishing mortality rates in 2001-2002 remain high (F_{2001} = 0.08; F_{2002} = 0.09), relative to the rebuilding target (0.03).

Recruitment: Annual pup production is low (4-9 pups per litter) and directly related to the number and size structure of spawning females. Recruitment estimates from 1997 to 2003 represent the seven lowest values in the entire series (Figure B3).

Stock Biomass: Research vessel abundance and biomass survey indices increased from the early 1970s through 1992 (Figure B5), and then declined by 33% during 1992-2002 (600,000 mt to 400,000 mt). Most of this change in overall abundance has been driven by the removal of dogfish greater than 80 cm (Figure B5). Swept-area estimates of the spawning (female) biomass (defined as >=80 cm fish) increased six-fold from about 50,000 mt in 1968 to 295,000 mt in 1989 and have declined to about 50,000 mt in 1998 and remained relatively constant since (Figure B1). Owing to the high proportion of females in the landings, estimated minimum biomass of females >=80 cm has declined more sharply than the combined male-female >=80-cm biomass. Length-frequency data from both the US commercial landings and six separate research vessel survey catches indicate a pronounced and consistent decrease in average length of mature females in recent years (Figure B6). Changes in the overall size composition of the stock since the onset of the intensive fishery (Figure B6) suggest marked changes in present and future reproductive potential.

Special Comments: The low abundance of pups in the spring survey, first noted in the SARC 26 assessment, has continued for seven consecutive years through the spring 2003 NMFS trawl survey. Declines in the abundance of dogfish less than 60 cm suggest that the estimates of low pup production are not artifacts of reduced availability to the gear. Average size of pups in the survey has declined, consistent with newly developed data on the reduced average size of pups produced by smaller females. Spawning potential will decline as these weak year classes reach maturity. In the long term projection, which accounts for the apparent lower survival of pups from smaller females, the lower spawning potential leads to stock collapse under current fishing mortality rates (Figure B7).

The current Federal FMP fails to specify either a biomass rebuilding goal or a relevant time frame for rebuilding, as required by the SFA. The SARC recommends SSB_{MAX} as a biomass target, currently estimated as 190,000 mt (swept area biomass assuming nominal footprint of 0.012 nm^2) of mature female biomass (Figure B4).

Coordinated assessment and management of this resource by the US and Canada is strongly recommended. Recent increases in Canadian landings may compromise the pace of rebuilding that would otherwise be achieved via catch reductions in the US. Continued harvesting at rates in excess of the $F_{REBUILD}$ (0.03) of large spiny dogfish in the US and Canadian fisheries, given recent poor recruitment, poses a substantial risk to the spawning stock of spiny dogfish.

Sources of Information: Bowman, R., R. Eppi, and M. Grosslein. 1984. Diet and consumption of spiny dogfish in the northwest Atlantic. ICES CM 1984/G:27; Link, J.S., L. P. Garrison, and F.P. Almeida. 2002. Ecological interactions between elasmobranchs and groundfish species of the Northeastern U.S. continental shelf. N. Am. J. Fish. Mgmt. 22: 500-562; MAFMC, NEFMC. 1999. Spiny Dogfish Fishery Management Plan. MAFMC, Dover DE, March, 292 pp., apps; NEFSC 1994. Report of the 18th Stock Assessment Workshop/Stock Assessment Review Committee, NEFSC CRD 94-22; NEFSC 1998. Report of the 26th Northeast Regional Stock Assessment Workshop (26th SAW). Stock Assessment Review Committee (SARC) Consensus Review of Assessments. CRD 98-03; Rago, P. J., Sosebee, K.A., Brodziak, J.K.T., Murawski, S.A. and Anderson, E.D.. 1998. Implications of recent increases in catches on the dynamics of Northwest Atlantic spiny dogfish (*Squalus acanthias*). Fisheries Research 39:165-181.

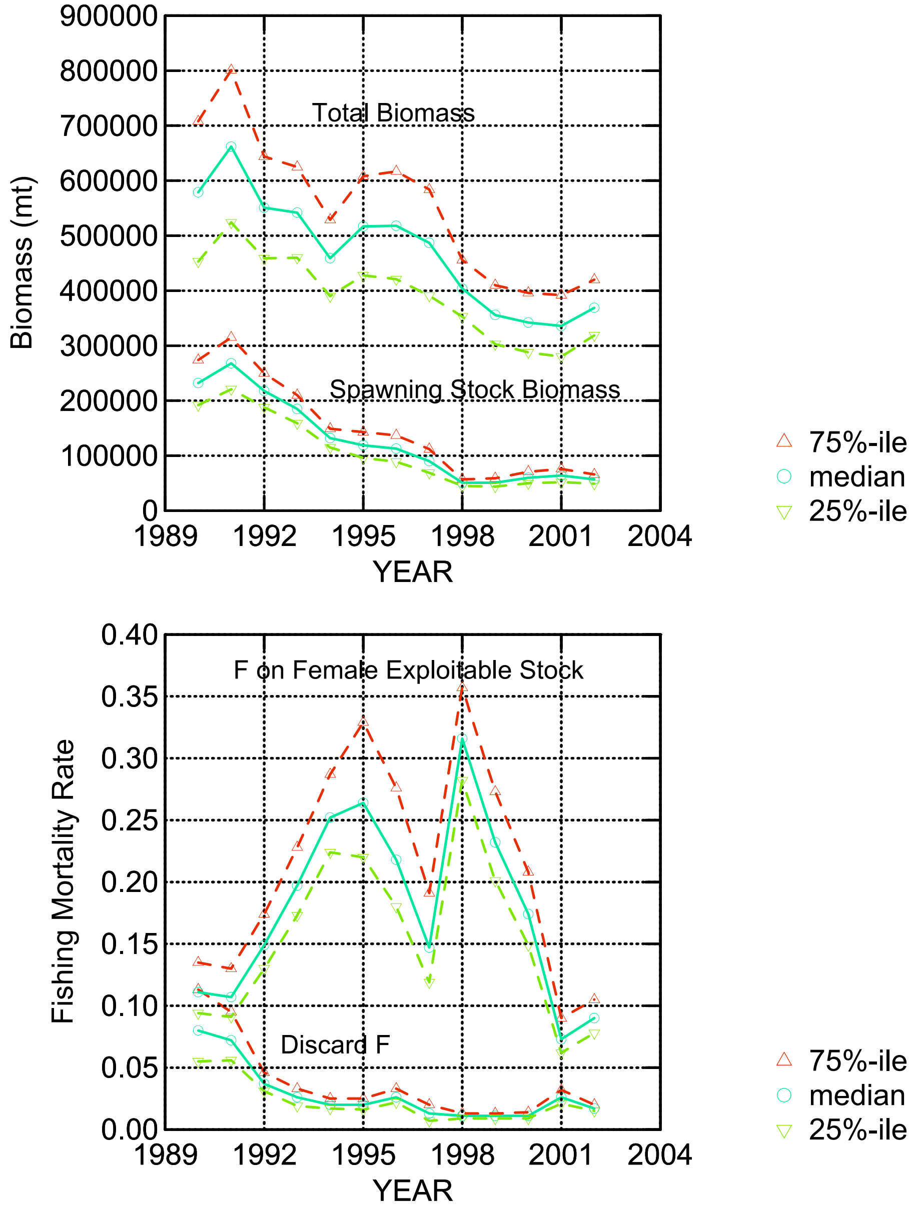


Fig. B.1 Summary of stochastic estimates of biomass and F with interquartile range, 1990-2002

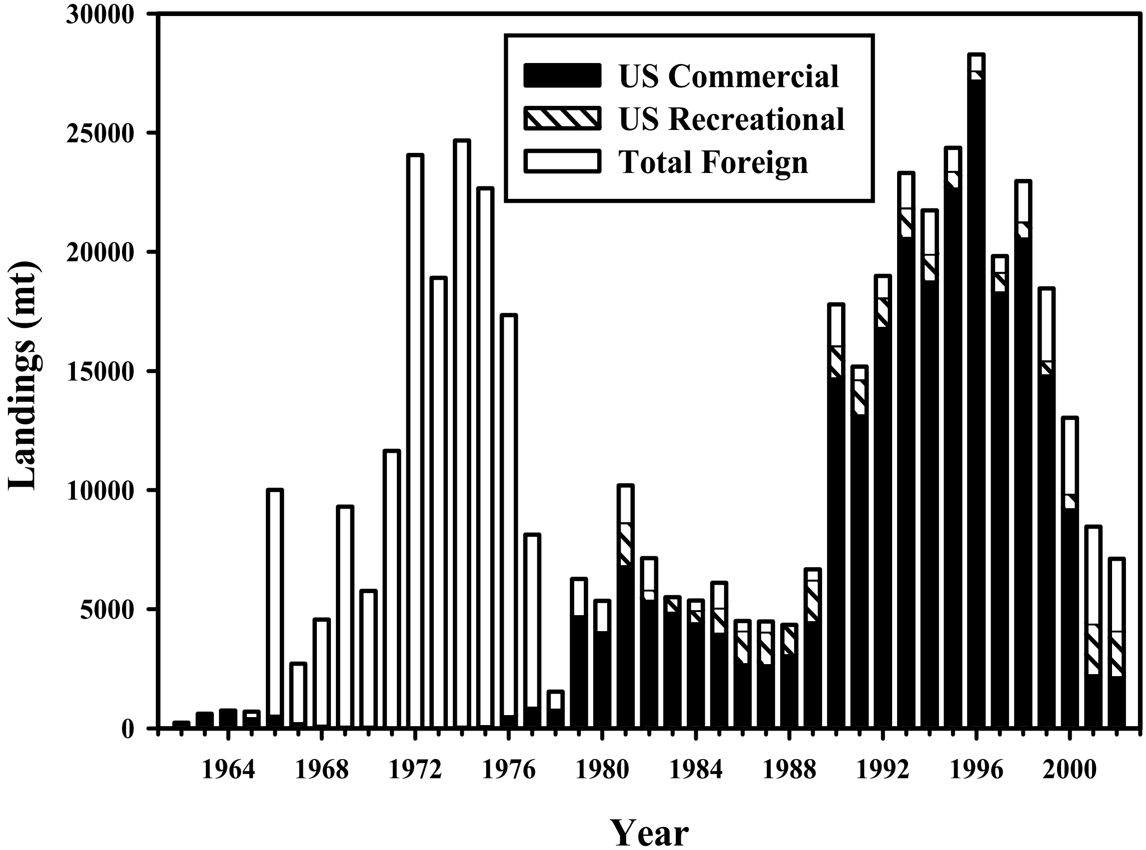


Figure B.2. Commercial landings (metric tons) and recreational catch of spiny dogfish from NAFO subareas 2-6, 1962-2002.

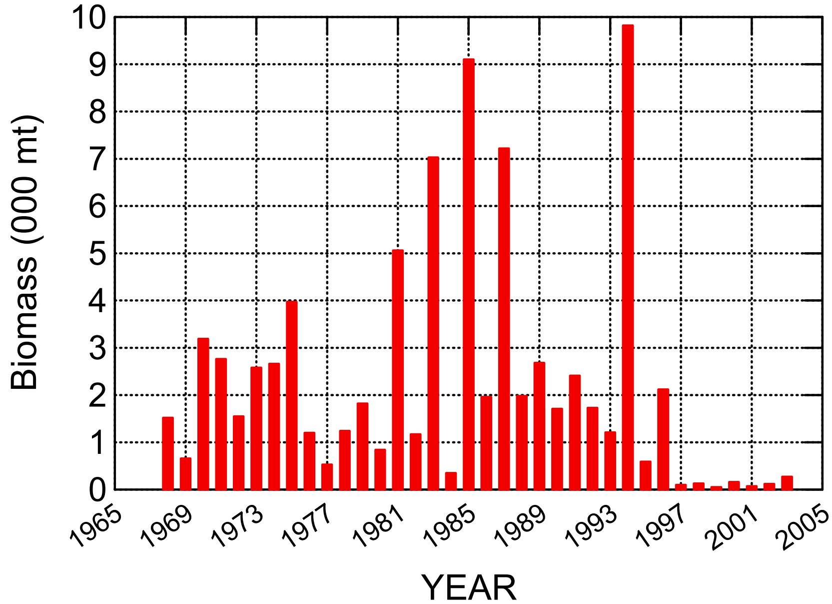


Fig. B.3 Swept area estimate of dogfish biomass (000 mt) recruits in spring R/V trawl survey, 1968-2003. Recruits defined as individuals less than 36 cm.

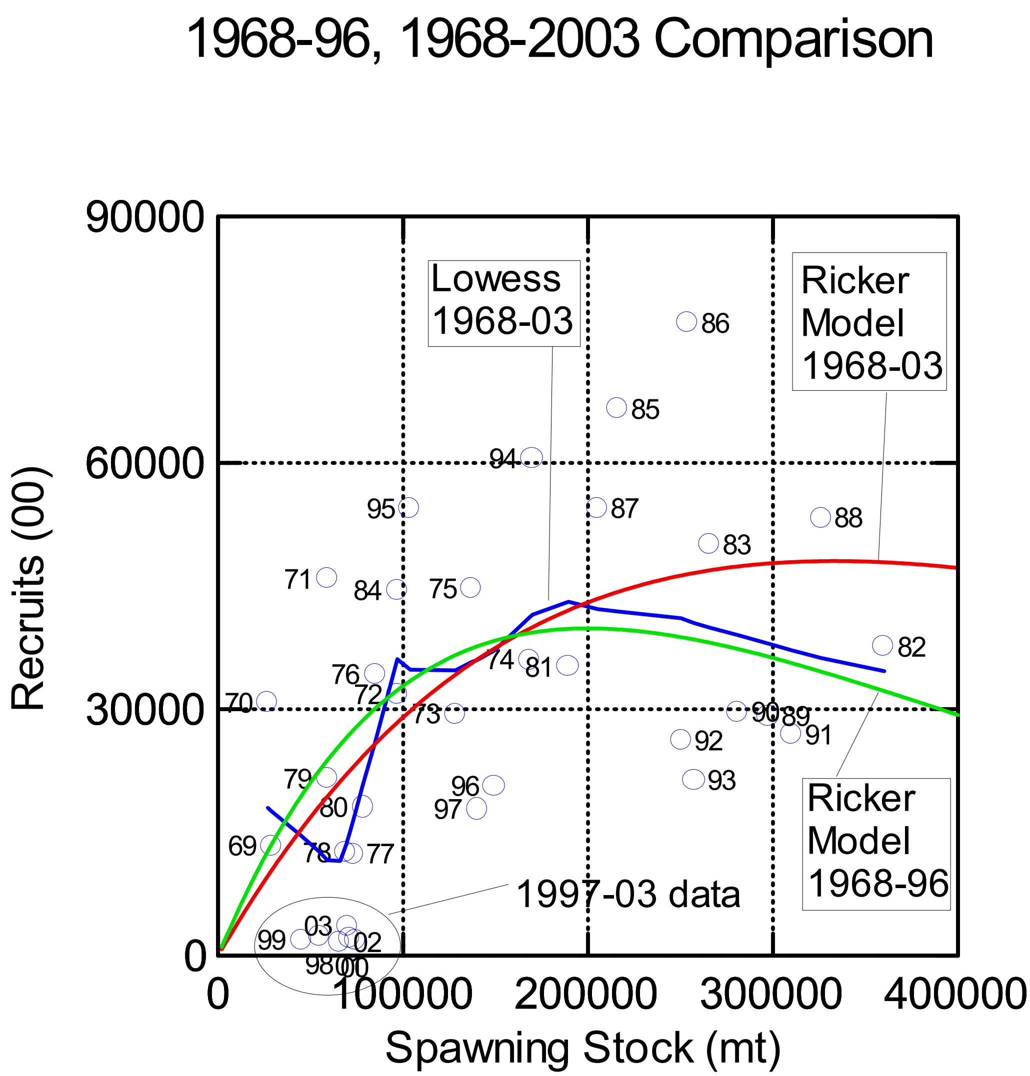


Figure B.4 Comparison of parametric and nonparametric S-R curves for spiny dogfish for 1968-1996 and 1968-2003. Point estimates of SSB_{max} based on nominal footprint of 0.01 nm^2 and unscaled NEFSC spring trawl survey catch rates. Nonparametric models based on Lowess smooths with tension = 0.6.

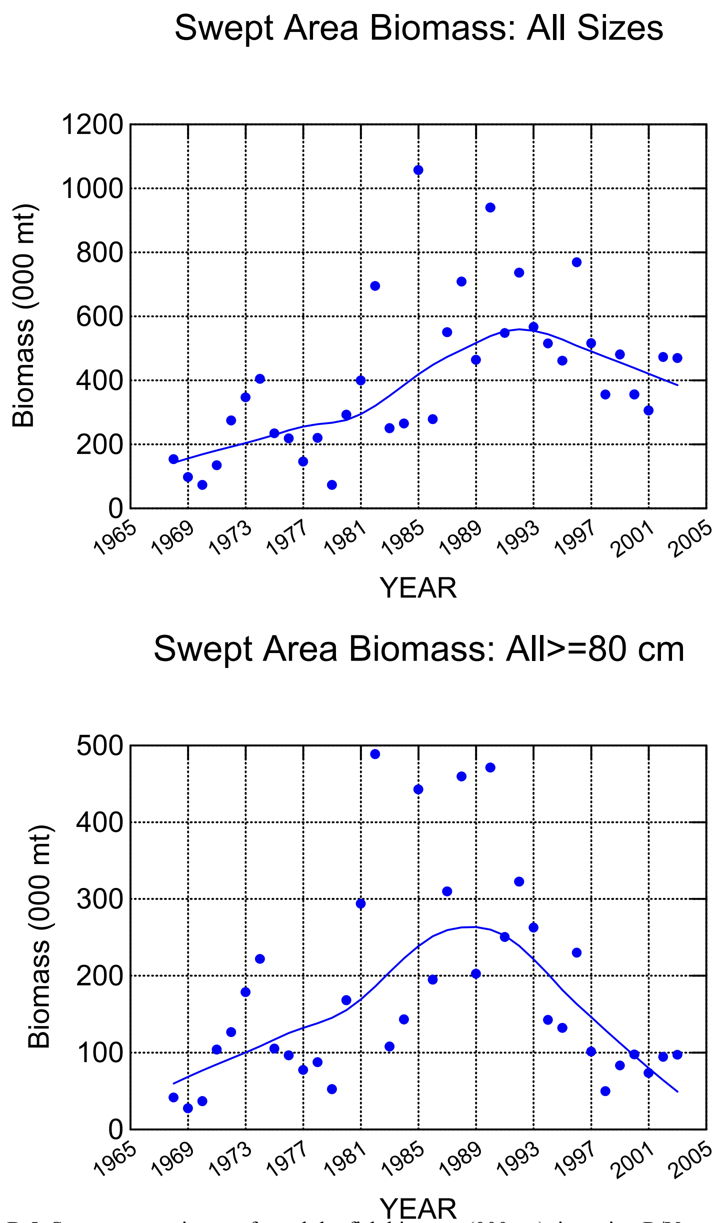


Fig. B.5 Swept area estimate of total dogfish biomass (000 mt) in spring R/V trawl survey, 1968-2003. Line represents Lowess smooth with tension factor = 0.5.

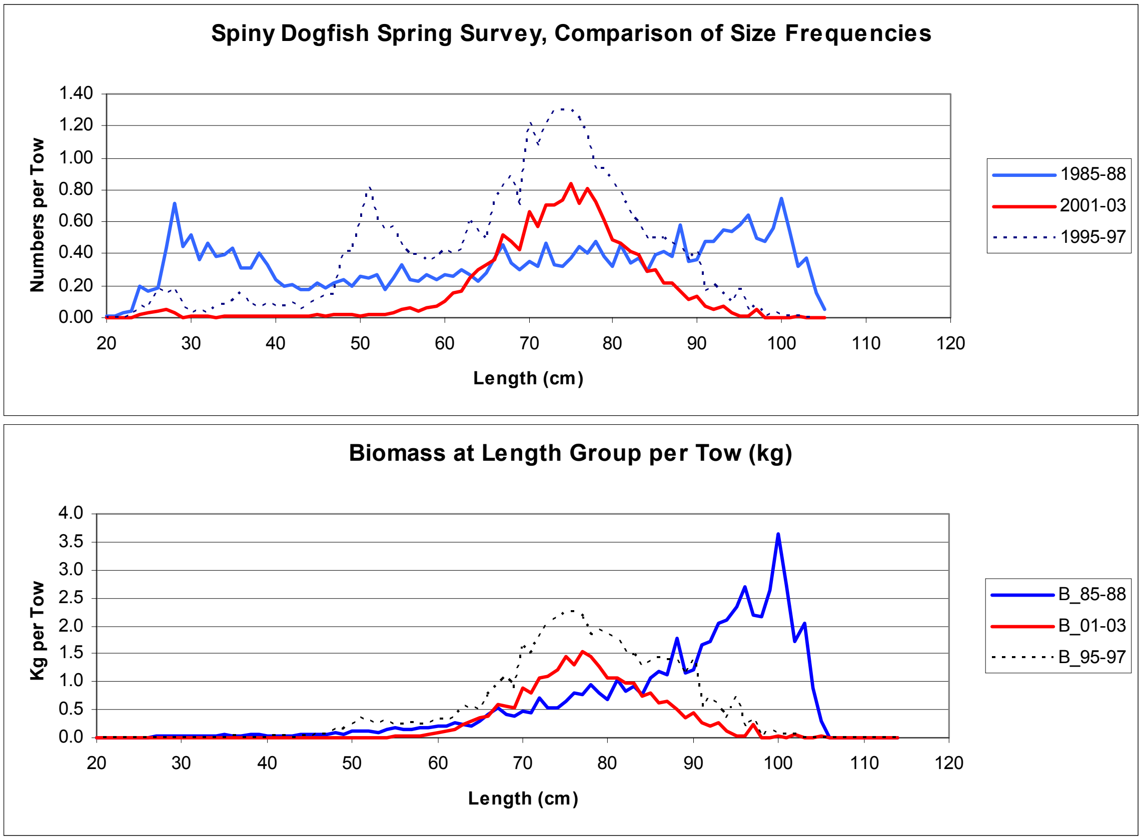


Fig. B.6. Comparison of length frequency distributions and biomass at length in the NEFSC R/V spring trawl survey for three time periods.

Figure B7. Yield and biomass, long-term projections, spiny dogfish. Scenarios include F = 0.08, as called for in the current FMP; F_{SQ}, a continuation of current F (0.09); a constant harvest strategy of 8.8 million pounds annually; application of $F_{REBUILD}$ (F=0.03); and 'Reduced So', a scenario formally accounting for lower survival of smaller pups under status quo F (0.09).

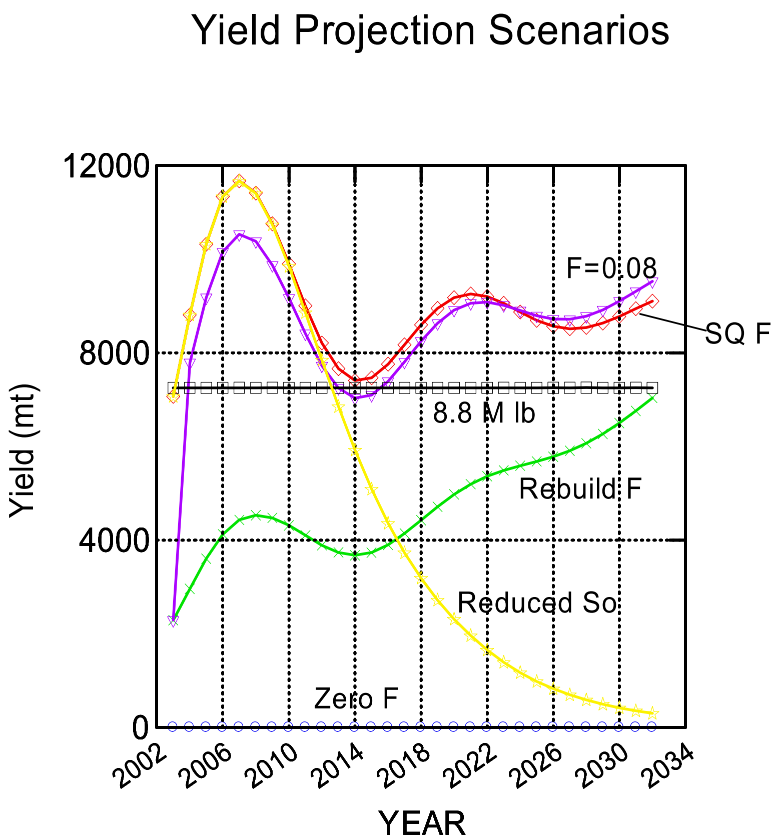
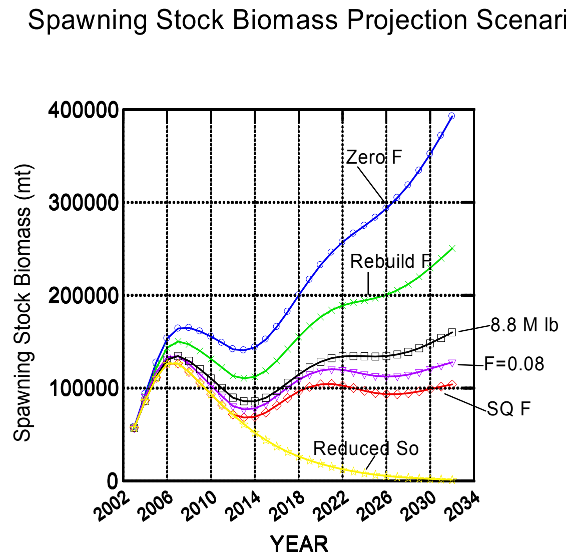
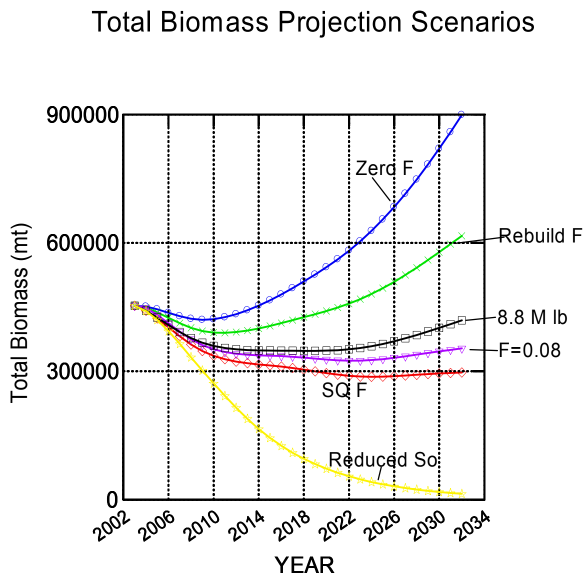


Figure B7 (continued). Yield and biomass, long-term projections, spiny dogfish. Scenarios include F = 0.08, as called for in the current FMP; F_{SQ}, a continuation of current F (0.09); a constant harvest strategy of 8.8 million pounds annually; application of $F_{REBUILD}$ (F=0.03); and 'Reduced So', a scenario formally accounting for lower survival of smaller pups under status quo F (0.09).





C. ATLANTIC SURFCLAM ADVISORY REPORT

State of Stock: The surfclam stock in the EEZ is not overfished and overfishing is not occurring (Figure C6). Total biomass was estimated at 1.1 million mt in 1997, and 1.5 million mt in 1999 but declined in 2002 to 0.8 million mt (B_{MSY} = 0.7 mmt). Clam catch was not great enough to account for the apparent decline in biomass between 1999 and 2002. The majority of the catch is from Northern New Jersey (NNJ), which contains about 39% of the stock biomass. Annual fishing mortality rates (F) in 1999 and 2002 were 0.02 and 0.03 for the whole resource; 0.02 and 0.05 for the whole resource excluding Georges Bank; 0.03 and 0.05 for the NNJ region; and 0.04 and 0.08 for the southern New Jersey (SNJ) region (F_{MSY} = 0.15).

Management Advice: Although the stock is above B_{MSY}, uncertainty in the current level and future trend in biomass suggest that substantial increases in catch levels are not advised. In addition, because surfclams are sedentary and fishing is concentrated in relatively small areas, it may be advantageous to avoid localized depletion.

Forecasts: Projections assume a constant negative instantaneous rate of surplus production (0.051 y^{-1}) during 2002-2005, use reported catch in 2002 and predicted catch during 2003-2005 equal to the quota for 2003, all increased by + 12% (the maximum adjustment for incidental mortality), and prorated by region. Total biomass for 2002 is from a regression model used to smooth original efficiency-corrected swept area biomass (ESB) estimates. For the total stock, projections through 2006 suggest there will be a small increase in fishing mortality rate accompanied by a moderate decrease in biomass (approximately -8% per year).

Short term projections:

Year	2003	2004	2005
Biomass[1]	849	780	714
Catch[2]	28.07	28.07	28.07
Fishing Mortality	0.034	0.038	0.041

1. on 1 January, in 1,000s of mt
2. Catch = landings + 12% discard, in 1000s of mt

Catch and Status Table (weights in '000 mt): Surfclams

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	[1]Min	[1]Avg	[1]Max
Quota:												
EEZ	22.0	19.8	19.8	19.8	19.8	19.8	19.8	22.0	24.2	-	-	-
Landings:												
EEZ	21.9	19.6	19.8	18.6	18.2	19.6	19.8	22.0	23.8	18.2	20.4	23.8
NNJ	17.8	15.7	16.1	14.1	13.1	14.4	13.7	16.1	14.9	13.1	15.1	17.8
SNJ	0.7	0.7	1.3	2.9	3.6	4.3	3.6	1.2	2.8	0.7	2.3	4.3
DMV	3.5	2.8	2.2	1.5	0.4	0.7	2.0	3.2	4.5	0.4	12.5	25.2
Other (EEZ)	0.1	0.4	0.1	0.1	1.1	0.2	0.5	1.5	1.6	0.1	3.4	11.6
State	9.1	9.4	9.0	7.7	6.3	7.1	11.3	9.2	-	1.4	7.4	11.7

Year	1997	1999	2002
[2]Biomass:			
EEZ	1,146	1,460	803
NNJ	485	487	315
SNJ	37	116	42
DMV	292	317	143
Other (EEZ)	332	540	303
[2]Recruitment:			
EEZ	163	174	60
NNJ	51	29	15
SNJ	4	40	3
DMV	46	53	10
Other (EEZ)	62	52	32
[3]Fishing Mortality Rate (F):			
EEZ	0.018	0.015	0.033
NNJ	0.032	0.033	0.053
SNJ	0.089	0.041	0.076
DMV	0.006	0.002	0.035
Other (EEZ)	0.000	0.000	0.006

[1]Reported landings from the period 1978-2002. [2]Biomass (of fully recruited clams) and recruitment for the last 3 surveys are based on efficiency-corrected swept-area survey data. "Recruitment" includes 120-129 mm in NNJ and SNJ and 100-112 mm in other areas. [3]F is based on reported landings plus a 12% maximum adjustment for indirect mortality. Discards were near zero since 1992.

Stock Distribution and Identification: The Atlantic surfclam occurs from the subtidal zone to 50 m depth. Its range includes state waters and the US EEZ along the Atlantic seaboard from Maine through North Carolina. Surfclam larvae are planktonic for 2-3 weeks and may disperse sufficiently to cause gene flow throughout their geographical range.

Catches: Since 1978, total EEZ annual landings of surfclams have varied between 13,200 mt and 24,500 mt (meat weight) (Figure C1). The fishery is managed with an annual catch quota, which has constrained catches in most years. Since 1983, 90% -100% of the EEZ landings have been taken from the Mid-Atlantic region. During 1986-2002, 64% -91% of the Mid-Atlantic landings came from the Northern New Jersey region, 1%-19% came from the Delmarva region, and 0% -22% came from the Southern New Jersey region (SNJ). Catches in SNJ have increased since 1995. Catches in DMV increased after 1999. Discarding reached substantial levels (e.g., 33% by weight of the total catch in the NJ region) in the early 1980s because of minimum size limits, declined through the mid- to late-

1980s, and has been low in the 1990s when minimum size limits were absent. The most recent (2002) pattern of landings is shown in Figure C2.

Data and Assessment: Surfclams were last assessed in 1999 (SAW30). The present assessment used efficiency corrected swept area biomass estimates based on clam survey data from the EEZ in 1997, 1999 and 2002. Fishing mortality rates were computed by dividing annual catches by annual efficiency-adjusted swept area biomass estimates. A biomass dynamics model (KLAMZ) used discard, landings per unit effort (LPUE), region specific growth curves and shell length-meat weight relationships, and research survey data to estimate surfclam biomass, recruitment biomass and fishing mortality rates during 1978-2002. A maximum adjustment for indirect mortality was assumed equal to 12% of landings (by weight) in all analyses.

Biological Reference Points: Based on age and growth studies, SARC 30 adopted M = 0.15. The current best proxy for F_{MSY} is F = M = 0.15 y^{-1} (Figure C5). SARC 30, which reviewed data through 1999, stated "the current total biomass can be used as a lower bound estimate for the carrying capacity, and half the total current biomass can serve as a proxy for B_{MSY}." The estimate of B_{1999} was 1,268,500 mt based on the KLAMZ model (SARC 30). The value of B_{1999} was re-estimated for the present assessment (SARC 37) as 1,460,500 mt, based on efficiency-corrected swept area biomass from the 1999 NMFS survey. Although these two point estimates of B_{1999} differ by about 15%, the difference is not statistically significant.

SFA Control Rule: Overfishing occurs whenever the fishing mortality rate on the entire stock is larger than $F_{THRESHOLD}$ (0.15). The stock will be declared overfished if total biomass falls below $B_{THRESHOLD}$ (estimated as $B_{MSY}/2$). The proxy for B_{MSY} is $B_{1999}/2$. When stock biomass is less than the biomass threshold, the fishing mortality rate threshold is reduced from F_{MSY} in a linear fashion to zero (Figure C6).

Fishing Mortality: Based on the catch-swept area model for the entire EEZ stock, F_{2002} = 0.03, with an 80% confidence interval of 0.02 - 0.05. For the entire EEZ stock excluding Georges Bank, F_{2002} = 0.05 (80% confidence interval 0.03 - 0.07). For the Northern New Jersey region, F_{2002} = 0.05; for Southern New Jersey F_{2002} = 0.08; for Delmarva, F_{2002} = 0.04. Other regions, which are largely unfished, had lower estimated recent Fs.

Recruitment: Survey data from 1978 – 2002 were used to track trends in abundance of recruits. In the NNJ and DMV regions, and in the stock as a whole, survey recruitment indices were low in 1999 and 2002 (Figure C4).

Stock Biomass: Biomass and 80% confidence intervals (CI) for 2002 were 315,000 mt (163,000-607,000) in the Northern New Jersey region, 143,000 mt (74,000-275,000) in the Delmarva region, 236,000 mt (107,000-521,000) on Georges Bank, 36,000 mt (18,000-72,000) in Southern New England, 42,000 mt (19,000-93,000) in Southern New Jersey, 12,000 mt (5,000-29,000) off Long Island, and 18,000 mt (8,000-43,000) off Southern Virginia - North Carolina. Clams included in the biomass estimates were 120 mm+ shell length for NNJ and SNJ, and 100 mm+ elsewhere. For the Delmarva region in 2002, the KLAMZ model biomass estimate was higher (272,000 mt) than that from the catch-swept area model.

Special Comments: Biomass is estimated using efficiency-adjusted swept area calculations from dredge surveys. Estimates of dredge efficiency were obtained using a variety of co-operative sampling studies and state-of-the-art dredge efficiency sensor equipment during a joint NMFS-industry research program conducted in 1997, 1999 and 2002. There appear to be differences in the dredge efficiency in these three years. However, the experimental data allow the uncertainty in the efficiency estimates to be properly incorporated into the uncertainty of the biomass estimates.

There is evidence of increased surfclam mortality recently in the inshore, southern regions of the research survey. This might be due to elevated sea temperature. The future impact on the population cannot be predicted.

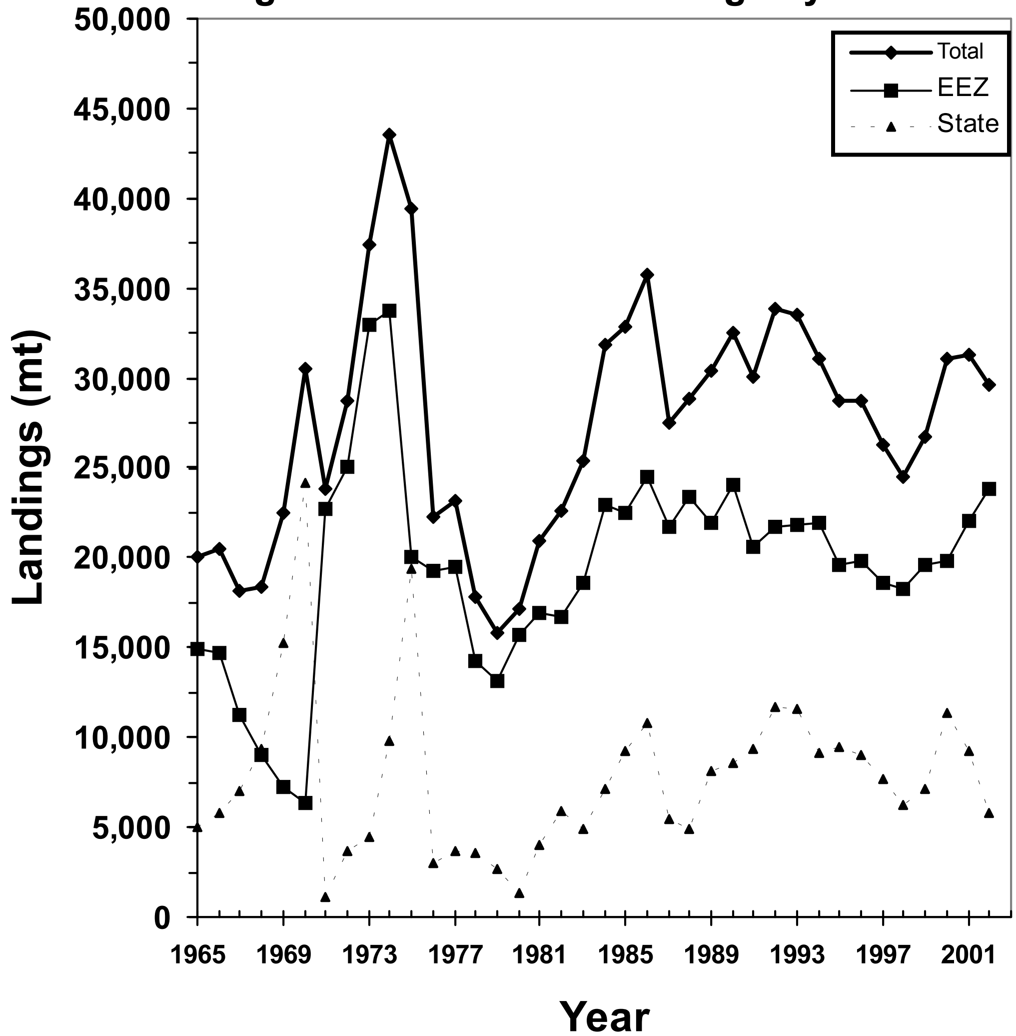
Commercial catch rates (LPUE) have declined in most of the harvested regions during the last 10 years. This is likely due to the "fishing down" of dense patches of clams (Figure C3).

Although the stock consists of at least 20 year classes, recruitment to the fishery is expected to be below average in the next 2 years.

The projection results do not incorporate information about age structure and thus should be considered only in general terms.

Sources of Information: 26th Northeast Regional Stock Assessment Workshop (26th SAW), Stock Assessment Review Committee (SARC) Consensus Summary of Assessments, NEFSC Ref. Doc. 98-03; 30th Northeast Regional Stock Assessment Workshop (30th SAW), Stock Assessment Review Committee (SARC) Consensus Summary of Assessments, NEFSC Ref. Doc. 00-03; 30th Northeast Regional Stock Assessment Workshop (30th SAW), Public Review Workshop, NEFSC Ref. Doc. 00-04; Weinberg, J.R. 1998. Density-dependent growth in the Atlantic Surfclam, *Spisula solidissima*, off the coast of the Delmarva Peninsula, USA. Mar. Biol. 130:621-630; Weinberg, J.R. 1999. Age-structure, recruitment, and adult mortality in populations of the Atlantic Surfclam, *Spisula solidissima*, from 1978 to 1997. Mar. Biol. 134:113-125; Weinberg, J. R., T.G. Dahlgren, and K. M. Halanych. 2002. Influence of rising sea temperature on commercial bivalve species of the U.S. Atlantic coast. Amer. Fish. Soc. Symp. 32:131-140; MAFMC, Amendment 13 to the Atlantic surfclam and ocean quahog fishery management plan. April 2003.

Figure C1. Surfclam Landings by Year



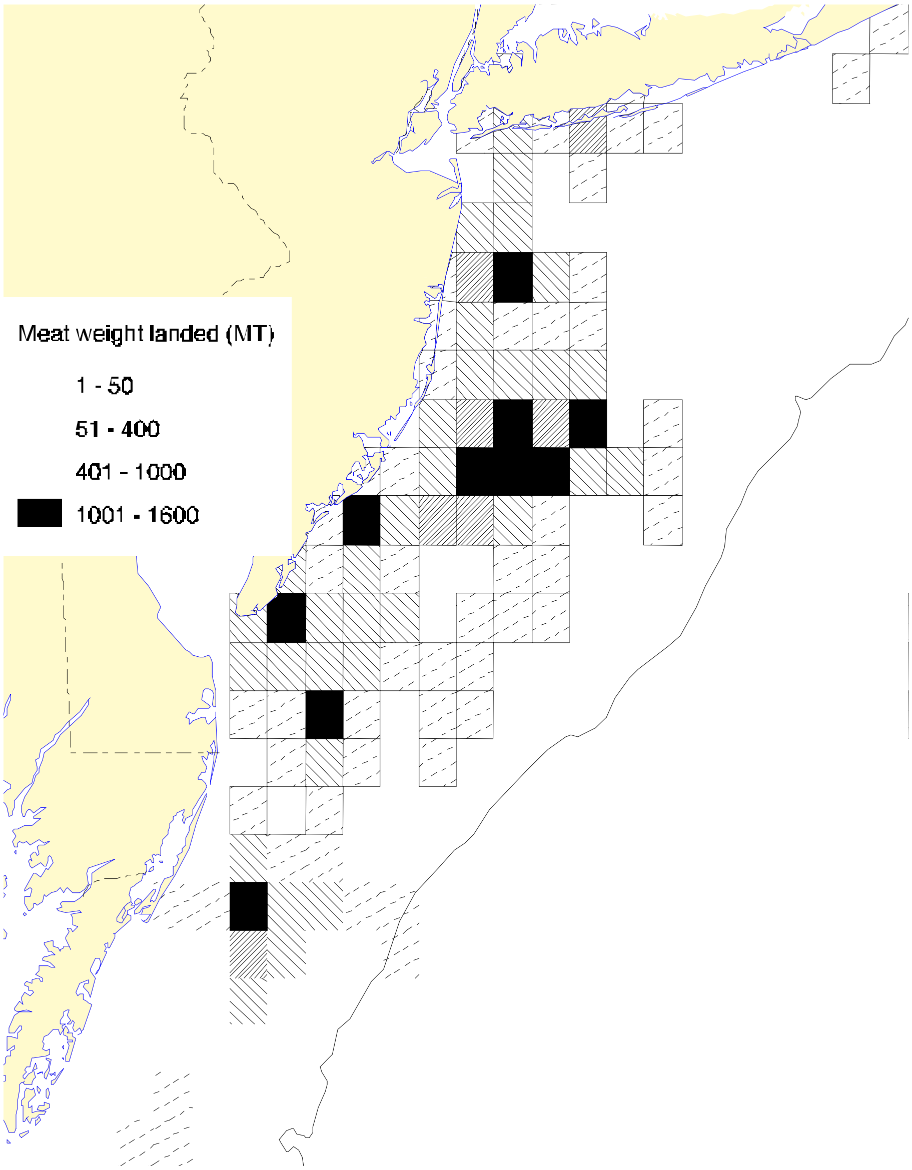


Figure C2. Distribution of surfclam landings during 2002 by ten-minute square

Figure C3. Surfclam Catch Rates for Medium and Large Vessels, by Region

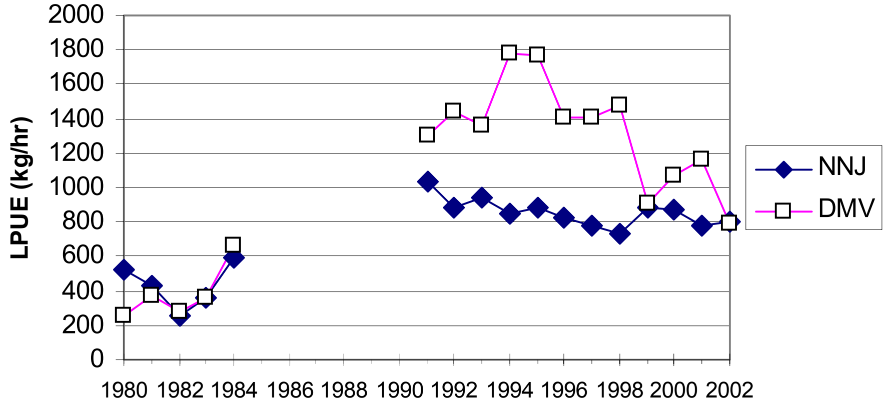


Figure C4. Surfclam Survey Recruit indices (88-119mm) by Region

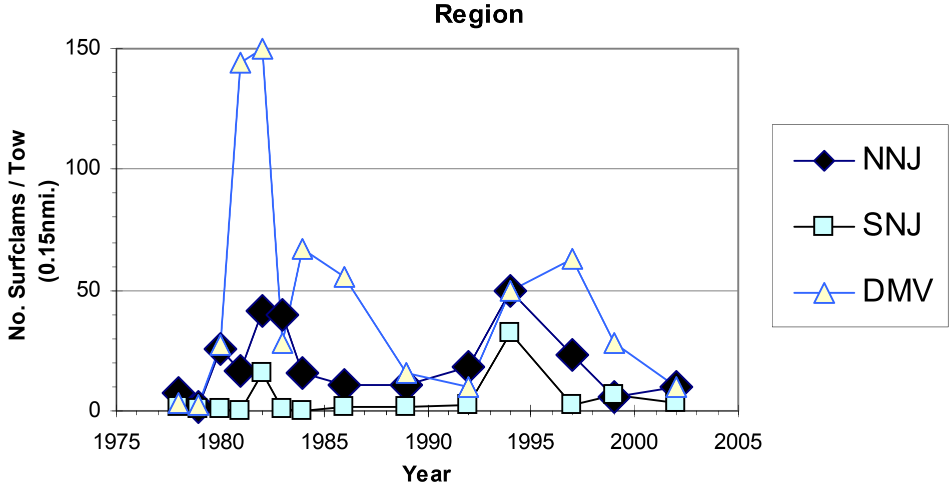


Figure C5. Yield per Recruit, NNJ (M=0.15, Recruit at 120 mm)

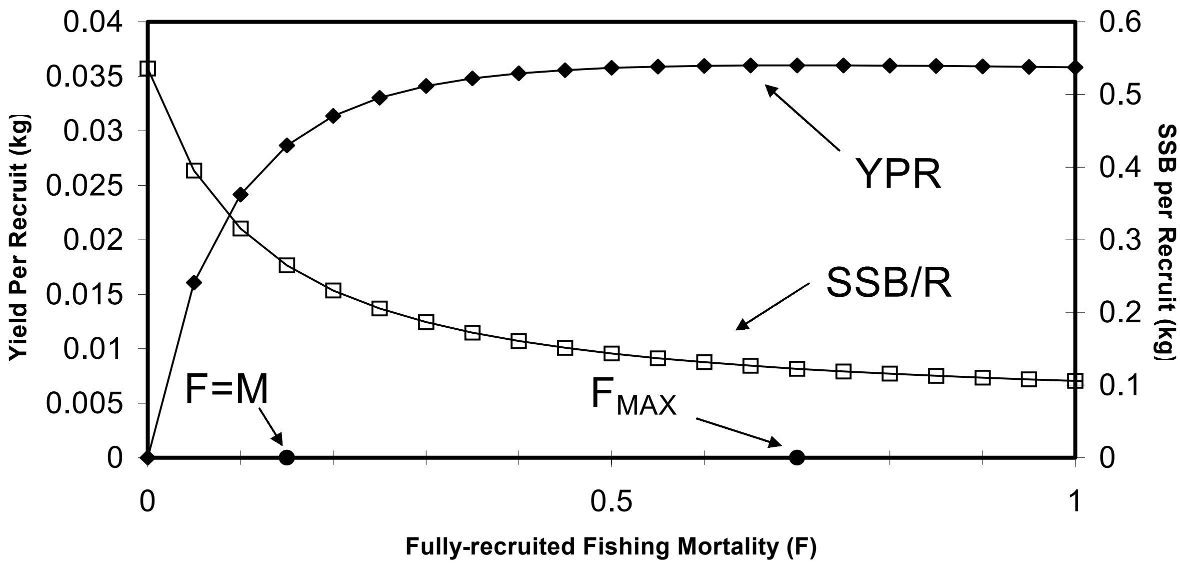
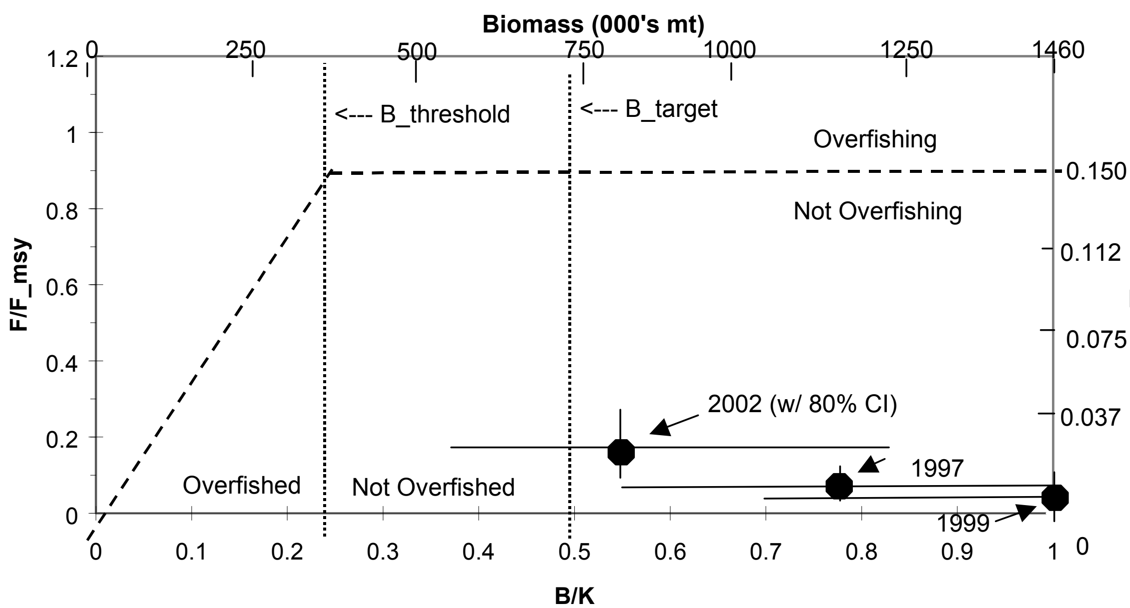


Figure C6. Surfclam Control Rule and Stock Status



D. NORTHERN SHORTFIN SQUID (*Illex*) ADVISORY REPORT

State of Stock: It is not possible to evaluate current stock status as there are no reliable current estimates of absolute stock biomass or fishing mortality rate. However, based on a number of qualitative analyses, overfishing was not likely to have occurred during 1999-2002. Stock status with respect to biomass is unknown. Relative exploitation indices for the domestic U.S. fishery have declined since reaching a peak in 1999 and were below the 1982-2002 mean during 2000-2002 (Figure D2). The recent declines in mean body weights, as well as recently declining biomass indices from U.S. and Canadian surveys, suggest that the stock is currently in a low productivity regime (Figure D3).

Management Advice: Under current stock conditions the nominal TAC of 24,000 mt, which assumes a stock at B_{MSY}, may not be sufficient to prevent overfishing. Given uncertainties in stock distribution and population biology the fishery should be managed in relation to the proportion of the stock on the shelf and available to US fisheries.

Forecast for 2004: No forecasts were made.

Landings and Status Table (landings in '000 mt): Northern Shortfin (Illex) Squid

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Max	Min	Mean
US EEZ Domestic Landings[1]	18.0	18.3	14.1	17.0	13.6	23.6	7.4	9.0	4.0	2.7	23.6	2.0	11.8
US EEZ Foreign Landings[2]	0	0	0	0	0	0	0	0	0	0	24.7	0	6.2
Total US EEZ Landings[2]	18.0	18.3	14.1	17.0	13.6	23.6	7.4	9.0	4.0	2.7	24.7	0	12.8
Subareas 3+4 Landings[2]	2.7	6.0	1.0	8.7	15.6	1.9	0.3	0.4	0.1	0.2	162.1	0.1	17.1
Total Landings (All areas)[2]	20.7	24.3	15.1	25.7	29.2	25.5	7.7	9.4	4.1	2.9	179.3	1.6	29.9
Escapement Index in Numbers, US Fall Survey[3] (number/tow)	10.4	6.8	8.0	10.8	5.8	14.6	1.4	7.4	4.5	6.4	27.1	0.6	8.8
Escapement Index in Biomass, US Fall Survey[3] (kg/tow)	1.6	0.9	0.7	0.9	0.5	1.4	0.2	0.7	0.3	0.4	9.3	0.1	1.6
Average body weight (g), US Fall Survey[2]	159	128	84	87	89	94	136	94	72	70	327	70	153

[1]Min, max, mean for 1987-2002.
[2]Min, max, mean for 1968-2002.
[3]Min, max, mean for 1967-2002.

Stock Distribution and Identification: The *Illex illecebrosus* population is assumed to constitute a unit stock throughout its range of exploitation from Cape Hatteras to Newfoundland. Stock structure is complicated by the overlap of seasonal cohorts. This highly migratory, oceanic species tends to school by size and sex and, based on age validation studies, is an annual species. A recent statolith-based aging study of squid caught in a survey conducted in U.S. waters indicated that the oldest individual was about seven months of age (215 days). Spawning for this species was observed for the first time in a survey on the U.S. shelf, in the Mid-Atlantic Bight fishing area, in late May 2000.

Catches: During 1973-1982, total stock landings (NAFO Subareas 3-6) averaged 71,900 mt and were predominately taken from Subareas 3+4. Total landings during this time peaked at 179,300 mt. Since 1982, total landings have been dominated by the domestic fishery, with the exception of 1997. Prior to 1967, U.S. landings of squid (*Illex* and *Loligo*) averaged about 2,000 mt per year. A directed foreign fishery for *Illex* developed in 1968 in U.S. waters, continued through 1982, and ended in 1987 (Figure D1). Domestic landings increased during 1988-1994, to 18,350 mt, and then averaged 14,900 mt during 1995-1997. In 1997, Subarea 3+4 landings were nearly equal to US EEZ landings and were at their highest levels since 1981. In 1998, US EEZ landings (23,600 mt) reached the highest level observed since 1977, resulting in a fishery closure because the TAC (19,000 mt) was exceeded. US landings dropped by 69% between 1998 and 1999. During 2000-2002, US landings declined from 9,011 mt to 2,723 mt; the lowest level since 1988.

Observer data for 1995-2002 indicate that discarding of *Illex* occurs primarily in the *Illex* and offshore *Loligo* fisheries and is higher in the latter. During this time period, annual discards from both fisheries combined ranged between 53 and 453 mt, 0.5% -4.4% of the *Illex* landings, by weight.

Data and Assessment: *Illex illecebrosus* was last assessed in 1999 at SAW 29. Assessment of the U.S. population is hampered by the lack of information on abundance and distribution before and during the fishery. However, new information about the age, growth and maturity of squid caught by a special *Illex* survey conducted in U.S. waters was incorporated into a maturation-natural mortality model. The model estimated the natural mortality rate of mature females, which die after spawning, at 0.80 per week when the natural mortality rate of immature squid was fixed at 0.01 per week. Aging error was also incorporated in the model. These natural mortality estimates were incorporated in yield-per-recruit and egg-per-recruit models to estimate biological reference points.

Trends in research survey indices of relative abundance and biomass and average body weights of *Illex* were examined, in addition to trends in LPUE indices. Relative exploitation rates for the U.S. fishery were computed based on the annual ratios of U.S. landings to autumn survey biomass indices.

An in-season assessment model that estimates weekly fishing mortality rates and stock size was run using 1999 landings, effort and squid length composition data from the landings. Unlike the SARC 29 assessment model, the new model incorporated recruitment and spawning and non-spawning estimates of natural mortality estimates from the maturation-natural mortality model. The results were considered preliminary however, as the model requires more rigorous testing.

Biological Reference Points: The current FMP specifies B_{MSY} as 39,300 mt and F_{MSY} as 1.22 per year. Ensuring adequate spawning stock escapement is of primary importance in the management of *Illex*; an annual species with highly variable interannual recruitment. A %MSP-based reference point that would ensure adequate spawning stock escapement should be evaluated for management use.

SFA Control Rule: The Amendment 8 control rule states that when the stock biomass exceeds B_{MSY}, the overfishing threshold is F_{MSY}, and target F is 75% F_{MSY}. Below B_{MSY}, target F decreases linearly and is set to zero when stock size is at the biomass threshold of $½B_{MSY}$.

Fishing Mortality: Relative exploitation rates (U.S.landings/NEFSC autumn survey biomass indices) for the U.S. fishery generally increased between 1988, the inception of the domestic fishery, and 1999. After the 1999 peak, relative exploitation rates declined and were below the 1982-2002 average during 2000-2002 (Figure D2). Fishing effort (days fished) and area fished declined during 1999-2002 due to a decline in fleet size and the number of trips. Weekly fishing mortality rates were estimated for 1999 using an in-season assessment model but the results are considered preliminary and are not included in this assessment.

Recruitment: Oceanographic conditions influence levels of recruitment and the distribution of recruits to fishery areas and have been shown to affect *Illex* squid recruitment in the Newfoundland jig fishery. During 1999-2002, surface and bottom temperatures in the autumn and spring bottom trawl surveys were warmer than average. The average size of squid in the landings, during 1999-2002, was smaller than during most years since 1994. This trend is likely indicative of environmental effects on stock productivity. Autumn bottom temperature anomalies were correlated with autumn survey biomass and abundance indices and spring survey mean body weights.

Statolith-based age analysis indicates that *Illex* spawns throughout most of the year and that in U.S. waters, recruitment occurs throughout the fishing season with several peaks.

Stock Biomass: The current level of stock biomass is unknown. The Canadian research bottom trawl survey occurs on the Scotian Shelf in July, near the start of the U.S. fishing season, and can be considered to represent a pre-fishery, relative biomass index. The U.S. autumn bottom trawl survey occurs primarily after the U.S. fishery and can be considered a relative index of spawner escapement. Both surveys indicate that the stock has remained in a low productivity state since the 1976-1981 high productivity period (Figure D3). Another indication that the stock is at a low level of productivity is the extended period of low mean body weights which has occurred since 1982, in both the U.S. (autumn) and Canadian (July) surveys (Figure D3). Mean body weights of squid from the U.S. autumn survey were below the 1982-2002 average during 2000-2002.

Special Comments: *Illex illecebrosus* is a highly migratory, transboundary species with a maximum observed age of 215 days for squid from U.S. waters. The overfishing definition currently in place for this stock, F_{MSY}, is not only difficult to estimate given the available information, but may also perform poorly given the stock's production dynamics.

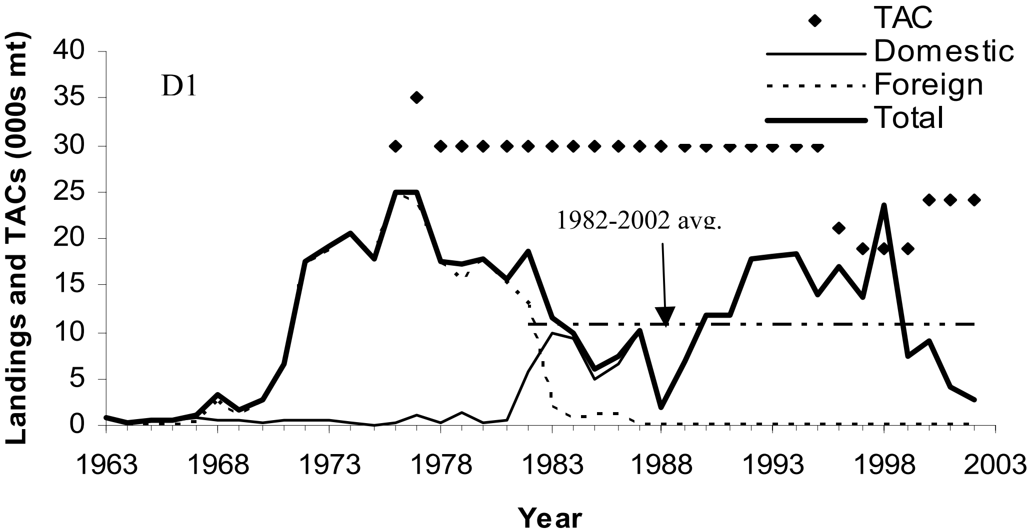
Cooperative research projects with the *Illex* fishing industry have been conducted since SARC 29 and have resulted in improvements in the data available for the current assessment. These projects included a pre-fishery bottom trawl survey of *Illex*, the collection of tow-based fisheries and biological data, and electronic logbook reporting, and should continue.

The new in-season models for fishing mortality and stock size estimation and reference points appear promising and should be further developed.

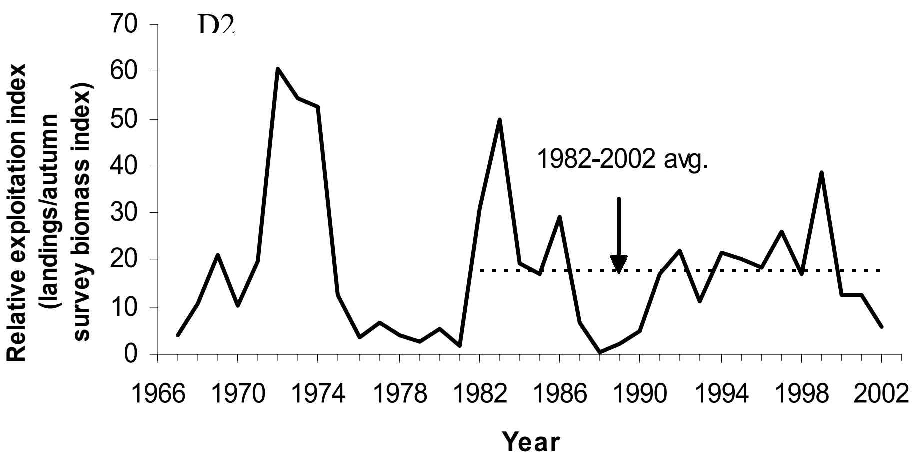
The merits of alternative approaches to managing the illex fishery, including constant quota, constant effort, real-time management, and constant escapement should be investigated, recognizing the available biological information models and uncertainty.

Current reference points may not ensure adequate spawning escapement for the stock as a whole. Management should consider the implication of increased exploitation relative to the necessity of adequate escapement of spawners and the role of the species as an important forage item in the ecosystem. Adequate spawner escapement from all fishery areas (NAFO Subareas 3-6) is required to ensure sufficient recruitment during the subsequent year.

Sources of Information: Report of the 37th Northeast Regional Stock Assessment Workshop, Stock Assessment Review Committee (SARC) Consensus Summary of Assessments (NEFSC Ref. Doc. 03-xx); Report of the 29th Northeast Regional Stock Assessment Workshop, Stock Assessment Review Committee (SARC) Consensus Summary of Assessments (NEFSC Ref. Doc. 99-14); Report of the 21st Northeast Regional Stock Assessment Workshop, Stock Assessment Review Committee (SARC) Consensus Summary of Assessments (NEFSC Ref. Doc. 96-05d); Hendrickson, L.C. In Review. Population biology of northern shortfin squid (*Illex illecebrosus*) in the northwest Atlantic Ocean and initial documentation of a spawning site in the Mid-Atlantic Bight (USA). ICES J. Mar. Sci.; Hendrickson, L.C., D.A. Hiltz, H.M. McBride, B.M. Northand J.E. Palmer. 2003. Implementation of electronic logbook reporting ina squid bottom trawl study fleet during 2002. Northeast Fish. Sci. Cent.Ref. Doc. 03-07. 30 p.; Hendrickson, L.C., E.G. Dawe and M.A. Showell. 2003. Interim monitoring report for the assessment of northern shortfinsquid (*Illex illecebrosus*) in Subareas 3+4 during 2002. NAFO SCR Doc.03/48. Ser. No. N4866. 13 p.; Dawe E. G. and L. C. Hendrickson. 1998. A review of the biology, population dynamics, and exploitation of short-finned squid in the Northwest Atlantic Ocean in relation to the assessment and management of the resource. NAFO SCR Doc. 98-59.

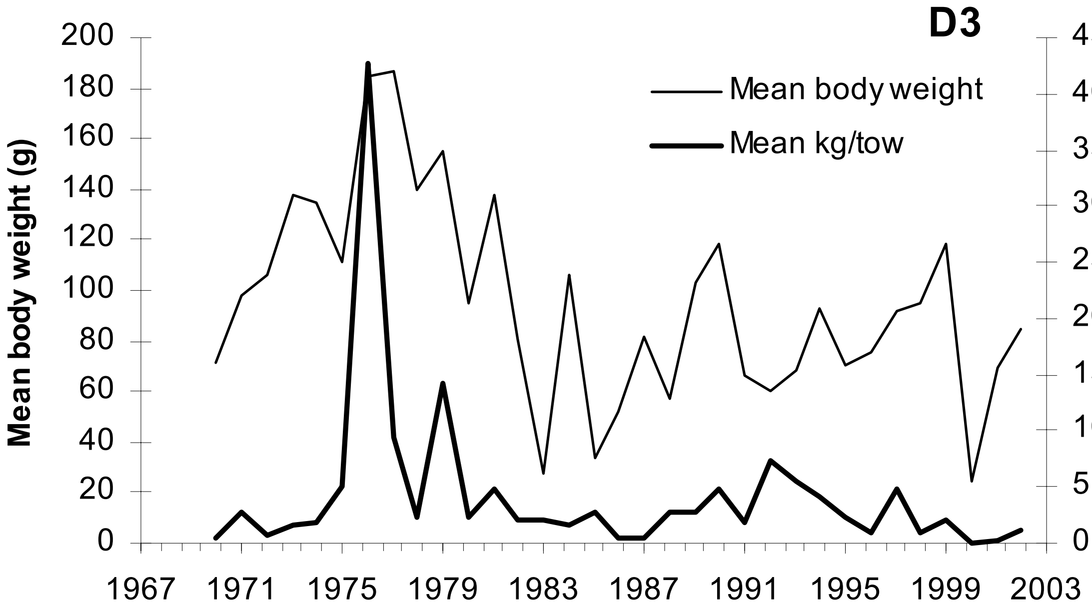


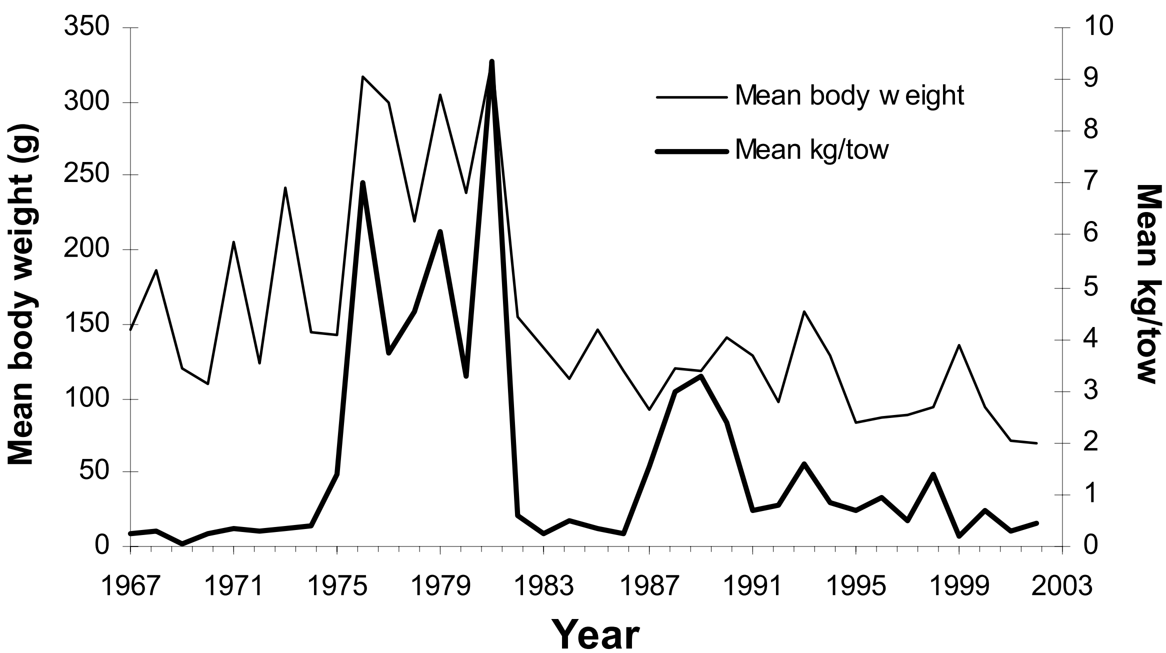
Trends in Commercial Landings and TACs, Illex



Relative exploitation indices in the US fishery, 1967-2002, Illex

Relative biomass indices and Illex mean body weights in the Canadian July bottom trawl survey (top), during 1970-2002, and in the U.S. autumn bottom trawl surveys (bottom) during 1967-2002.





E. ATLANTIC HAGFISH ADVISORY REPORT

In New England, a growing fishery for Atlantic hagfish (*Myxine glutinosa*) has initiated science and policy discussions about the development of the fishery, its potential for future expansion, and its effect on the resource. The hagfish fishery in New England was developed in the early 1990s, with the first reported landings of around 1 million pounds in 1993. Korean buyers quickly recognized that a fishery in the New England area could provide the high quality hagfish skins used in making leather as well as hagfish meat for human consumption.

<u>The Fishery</u>

Reported hagfish landings in New England quadrupled during the first four years of the fishery (1993-1996), exceeding the highest reported landings in other North American hagfish fisheries (including British Columbia, Oregon, Washington, California and Nova Scotia) by 1994. Landings increased six-fold from 1993 to 2000, with a reported 6.8 million pounds of hagfish landed in 2000 yielding over $1.8 million in revenues. Landings in 2001 and 2002 are estimated to be 3-6 million pounds in each year (Figure E1). There is no management program for this fishery, and consequently no permitting or reporting requirements. Thus, there is considerable uncertainty regarding the actual level of hagfish landings, as the data provided by fishers and processors may be incomplete. Moreover, the level of discards and discard mortality of hagfish culled at sea or rejected by the dealer in port is unknown. Landings are highest during the summer and fall months.

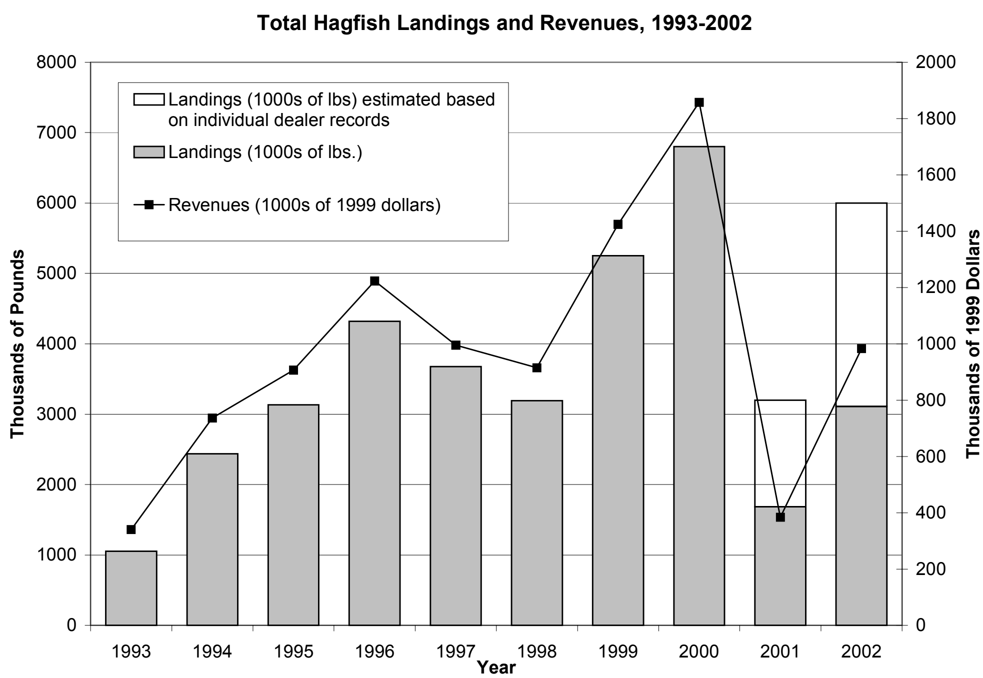


Figure E1 - Total hagfish landings and revenues, 1993-2002

Data Source: NMFS Dealer Database (WODETS/CFDETS)

Note: 2001 and 2002 landings adjusted based on individual dealer reports

The number of active vessels in the fishery has fluctuated between 1993 and the present, ranging from 5 to more than 30 vessels reporting landings per year (Figure E2). These vessels use specialized hagfish traps and land their catch primarily in Gloucester, Massachusetts. Hagfish are no longer landed in Maine (Figure E3). The average size of active vessels in the fishery has increased since 1993 (Figure E4), with new entrants as large as 165 feet. The fishing capabilities and efficiency of these larger vessels has increased even over the past year, as fishermen have developed more effective means of sorting and storage of hagfish at sea, an enhanced awareness of localized aggregations of hagfish, and improved product quality control.

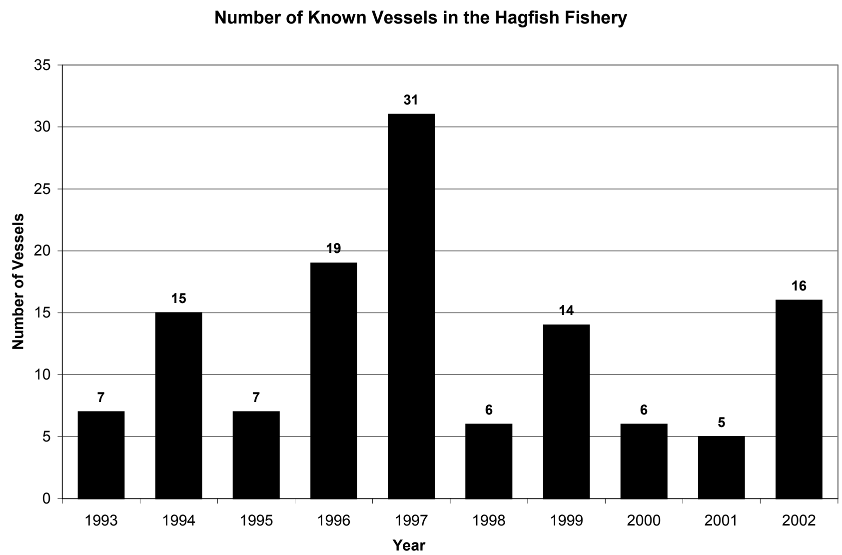


Figure E2 – Active hagfish vessels reported by dealer records, 1993-2002
Data Source: NMFS Dealer Database (WODETS/CFDETS)

Note: 2002 data may be incomplete

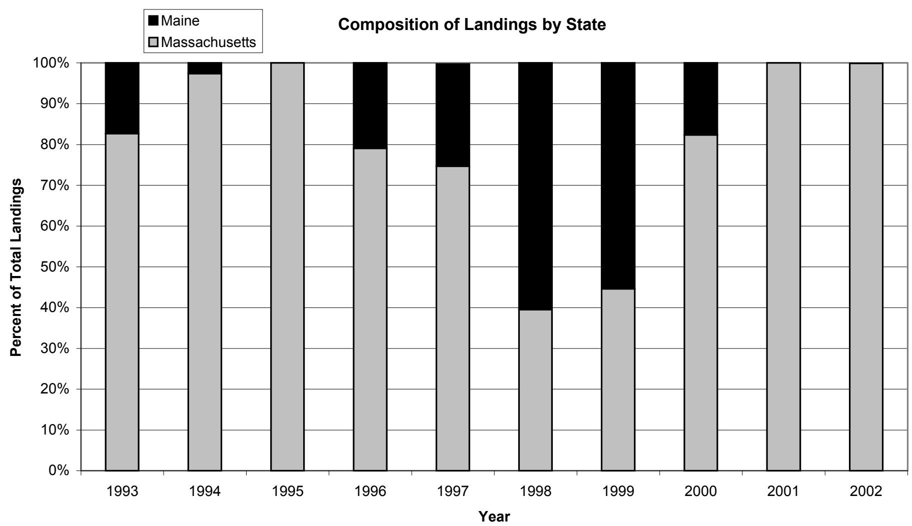


Figure E3 - Composition of hagfish landings by state
Data Source: NMFS Dealer Database (WODETS/CFDETS)
Note: 2002 data may be incomplete
States with less than 0.1% of total landings are not included.

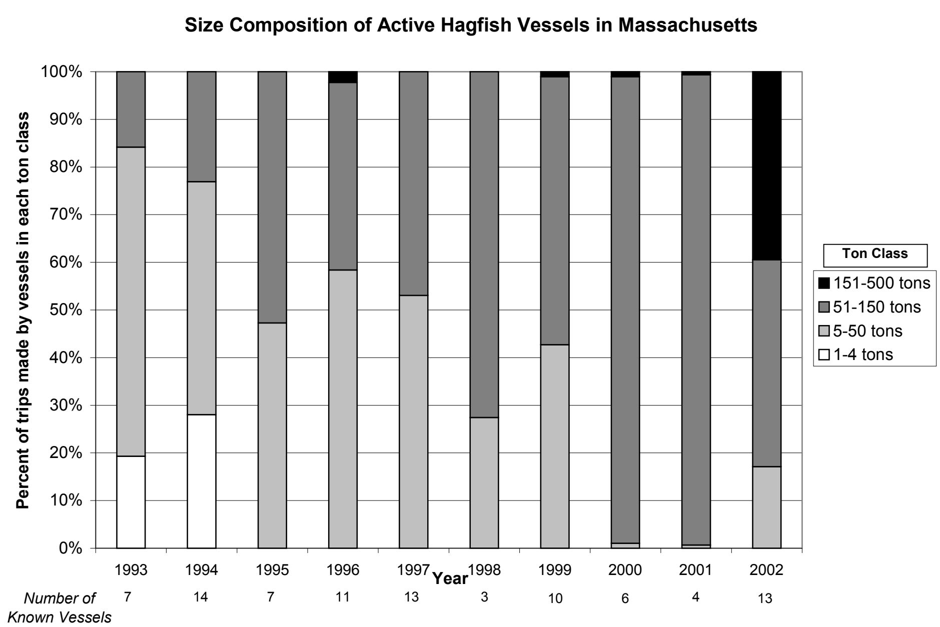


Figure E4 - Size composition of active hagfish vessels in Massachusetts, 1993-2002
Data Source: NMFS Dealer Database (WODETS/CFDETS)
Note: 2002 data may be incomplete

The fishery is prosecuted throughout the Gulf of Maine, from Nantucket to eastern Maine and east to the Hague line, with the majority of landings from trips in the inshore Gulf of Maine between Gloucester and Portland. The vast majority of hagfish trips occur in the deeper waters (greater than 40 fathoms) of the Gulf of Maine, within a 60 nautical mile range of Gloucester, MA. The geographic range of the fishery and spatial distribution of hagfish trips have expanded since 1994, with vessels moving further offshore and trips more broadly distributed across the range of the fishery (Figure E5 and Map 1). Average trip duration, as reported via vessel trip reports, has generally increased since 1994. Nominal and standardized estimates of landings per unit of effort (LPUE) fluctuated from 1994 to 2002, with distinctions among LPUE trends for different seasons and statistical areas across the time period.

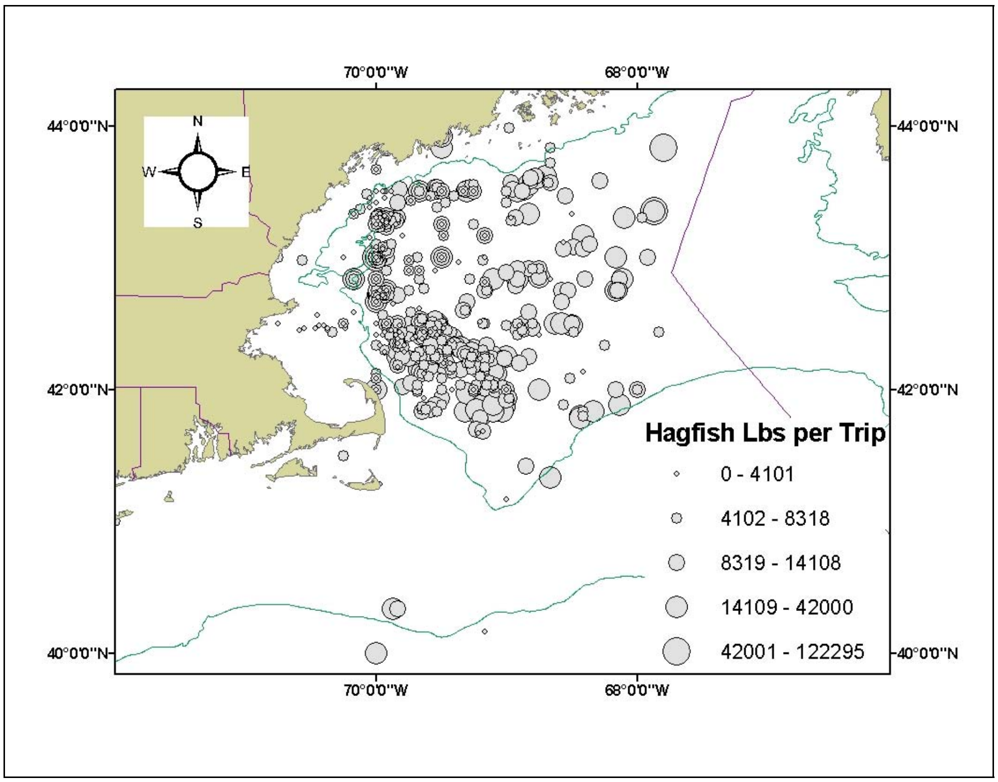
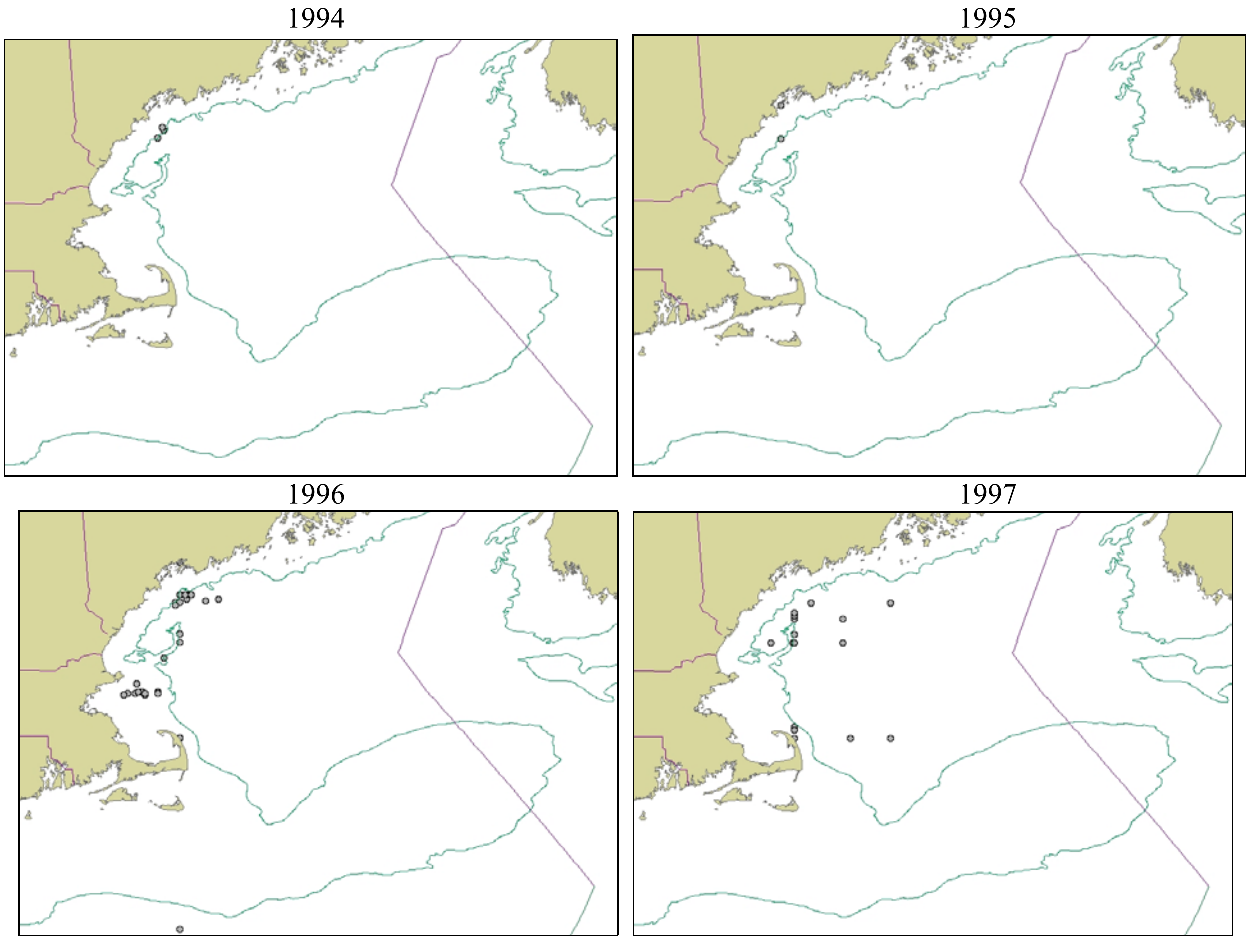
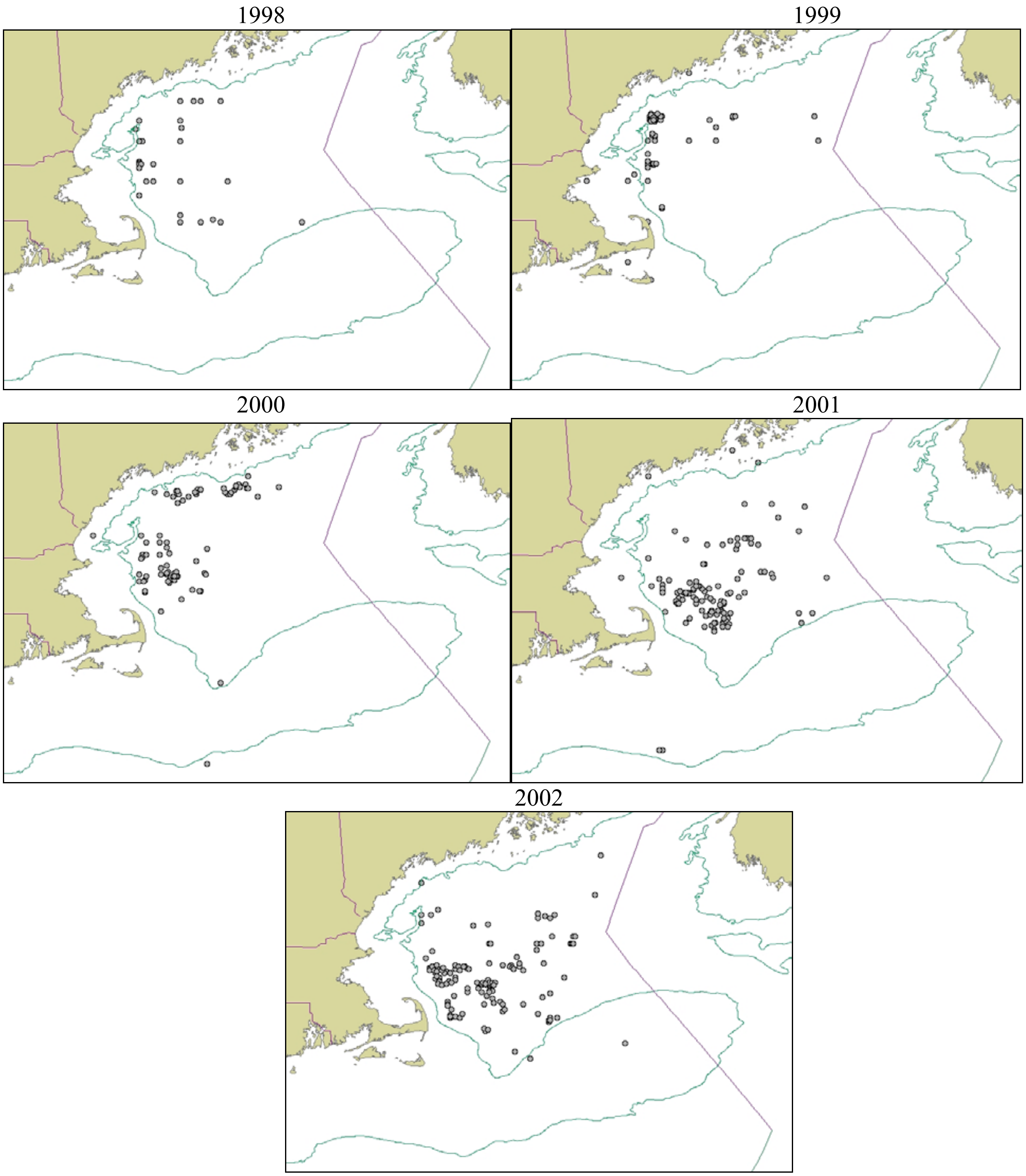


Figure E5 - Point estimates for hagfish landings based on reported trip lat/long (1994-2002 VTR data, n=1,571).



Map 1 - All trips reporting via VTR, 1994 - 2002.



Map 1 - All trips reporting via VTR, 1994 – 2002.
(continued)

Survey Information

Hagfish have been captured in low numbers in the Northeast Fisheries Science Center groundfish bottom trawl surveys since 1963 from the Gulf of Maine to Cape Hatteras. Based on these trawl survey data and Gulf of Maine shrimp survey data, it appears that hagfish abundance in the Gulf of Maine decreased from the mid-1970s through the mid-1980s and remained at a fairly consistent low level until the early to mid-1990s, with an increase during the late 1990s (Figure E6). The factors that contributed to the apparent decline in the 1970s are unknown. Hagfish captured in the Gulf of Maine groundfish trawl survey are generally larger than those captured in the deeper offshore survey strata south of Cape Cod. Mean lengths of hagfish from the spring and fall groundfish surveys were 40.5 cm and 42.6 cm, respectively. In the offshore survey area, hagfish averaged 34.7 cm in the spring and 34.6 cm in the fall. Hagfish are most commonly captured in the survey at depths of 150-250 meters and at temperatures of 5-10°C, but can be found across a broader range of depths and temperatures.

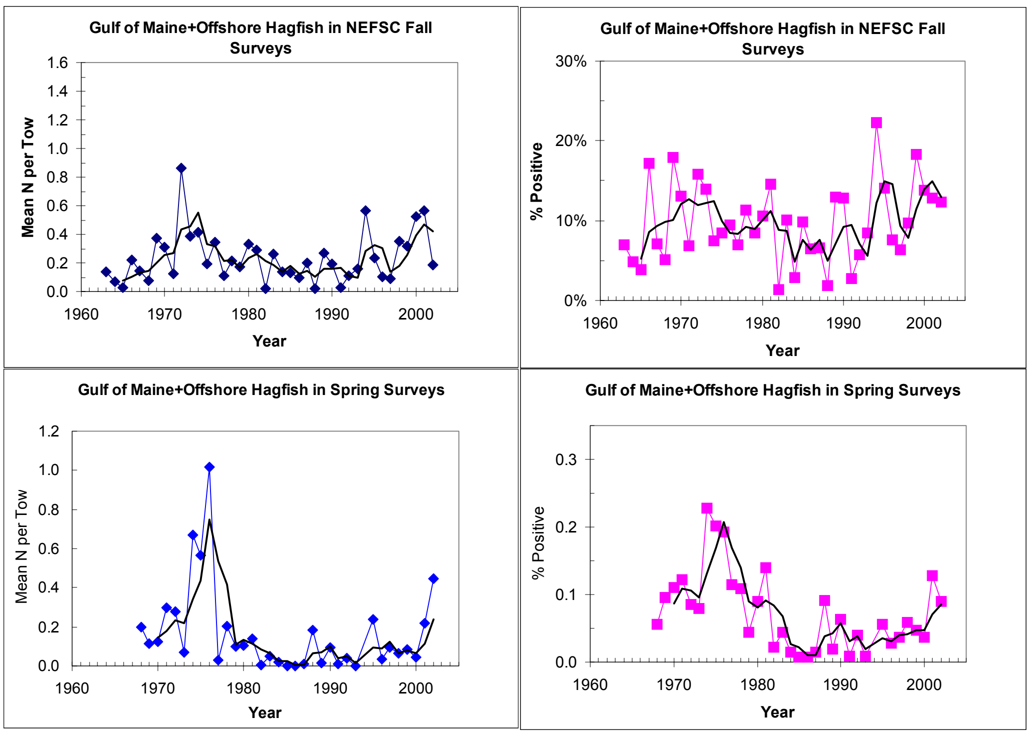


Figure E6 - Hagfish abundance in Gulf of Maine and offshore survey areas, fall (1963-2002) and spring (1968-2002). A 3 year moving average is also plotted.

Source: Northeast Fisheries Science Center

Life History

Little is known about the life history of hagfish. The age at maturity and lifespan of *Myxine* (in the Gulf of Maine and elsewhere), as well as timing, conditions and location of reproduction are not known. Hagfish have a limited reproductive potential, as suggested by the small number (20-30) of large, yolky eggs carried by the females. Hagfish serve an important ecological role, contributing to nutrient cycling, substratum turnover and removal of dead or dying organisms on the sea floor.

Developing a comprehensive understanding of the hagfish fishery and resource will require new scientific and fishery-dependent research and data collection efforts. A one-day working group that met to discuss hagfish science and management identified important information gaps and discussed a number of potential approaches to acquiring the data and information needed to fill them. Among these are the initiation of an at-sea observer program and port sampling for estimating discard levels and collecting length/weight data, tagging studies to estimate growth rates and examine movement of localized populations of hagfish, age and growth studies conducted in the laboratory, specialized broad-scale surveys of hagfish, investigation of spatial movement of the fishery through interviews with fishermen.

Several potential approaches for stock assessment modeling were also described. However, it is unlikely that conventional stock assessment approaches will provide significant information in the near future due to lack of data. There are many opportunities for development of industry-based research projects and further collaborative efforts among scientists, fishermen, administrators and policy analysts. Implementation of some of these recommendations may require adoption of a formal fishery management plan.

Discussion

Despite the rapid growth of the Atlantic hagfish fishery over the span of the last decade, there remain substantial gaps in basic information on fishery performance, as well as many fundamental unanswered questions on the biology and life history of the animal. The paucity of crucial data makes assessing the hagfish resource extremely problematic.

- Hagfish fisheries around the world have not been sustained and some have a history of overexploitation followed by fishery collapse. The level of a potentially sustainable fishery on Atlantic hagfish is uncertain.
- The working group has developed a set of data requirements necessary for stock assessment to determine the level of a sustainable fishery. A number of these are endorsed by the SARC and listed in the Research Recommendations section below.
- Based on the life history information that is currently available, there is a strong argument for a management system that, at a minimum, would cap effort and protect juveniles (smaller than 40-45 cm).

Research Recommendations

- Consider appropriate measures of "effective" fishing effort, including but not limited to soak time, number of traps, size of traps, number of hauls per trip, and fishing power differences between large and small vessels, that are directly related to fishing mortality;
- Look at LPUE in conjunction with survey data and use density measures from the surveys to estimate CPUE.
- Establish biological sampling in ports (length and weight, by sex to the extent possible).
- Collect commercial length frequency data for size composition of catch; seek additional information on the Nova Scotia hagfish fishery (landings, biological sampling data).
- Examine US export data for information on hagfish exports.
- Develop a study fleet with electronic reporting.
- Consider conservation engineering studies to minimize the catch of juveniles and the potential for ghost fishing.
- Conduct a directed population dynamics study, examining food web dynamics (stomach sampling data from survey), age and growth, maturation, fecundity and stock identification.
- Evaluate gillnet sea sampling data for evidence of hagfish eating gilled fish. (There may be spatial and temporal overlaps between discards in gillnet fisheries and hagfish that predate on the discarded fish.)

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