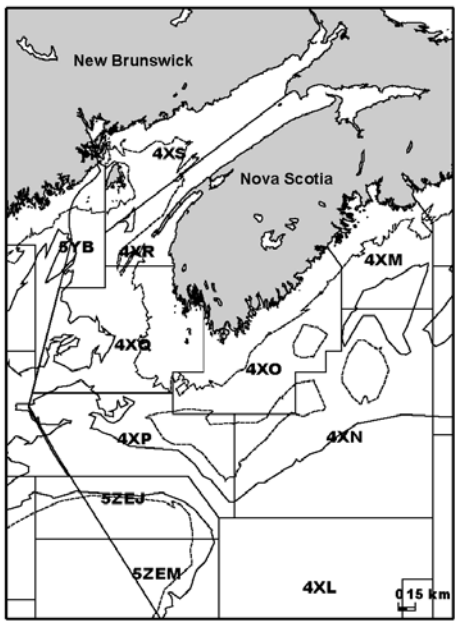
Haddock on the Southern Scotian Shelf and Bay of Fundy (Div. 4X/5Y)



Background

Haddock (Melanogrammus aeglefinus) are found on both sides of the North Atlantic. In the west Atlantic, they occur from southwest Greenland to Cape Hatteras. A major stock exists in the southern Scotian Shelf and Bay of Fundy area. This bottom-dwelling species is a member of the cod family and feeds mainly on small invertebrates. It is most common at depths of 25-75 fathoms (46-137m) and in bottom temperatures above 2°C. Although seasonal migrations are evident within the stock area, there is relatively little exchange between adjacent haddock stocks.

Young haddock in this stock are relatively fast growing, presently reaching 16 inches (41 cm) and 1.6 pounds (0.7 kg) by age 4 on average. Growth slows thereafter and haddock reach only about 21 inches (53 cm) in length by age 10. Haddock in the Bay of Fundy grow more rapidly than those on the southern Scotian Shelf. Approximately 50% of female haddock are mature by age 3; however the number of eggs produced by a female of this age is low and increases dramatically with age. Browns Bank is the major spawning area for the stock and peak spawning occurs in April/May.

Reported annual landings have been as high as 43,000t and the long-term average is about 18,000t. Landings have been below 11,000t since 1988. Historically this fishery has been dominated by mobile gear except during 1990-93 when the proportion of landings taken by fixed gear was greater. Quotas for this stock were introduced in 1970 and a spawning season/area closure has been in place since that time.

Summary

- The quota for 4X/5Y haddock has remained at 8,100t for the last 5 years. Reported landings have been close to the quota each year. The quota in 2003 is 10,000t.
- Abundance has been increasing since the early 1990s and is presently near the high levels observed in the late 1970s.
- Size-at-age and growth have decreased since 1970, particularly at older ages.
- Exploitation rate for ages 5-7 decreased from approximately 50% in the early 1980s to below 20% (corresponds to currently used $F_{0.1}$=0.25) since 1994.
- Partial recruitment has changed in recent years and fully recruited ages have changed from 5-7 to 8-10.
- Exploitation on fully recruited ages (8-10) has remained high at about 20%.

- The 1998 yearclass is estimated to be the largest observed in the time series, and the 1999 yearclass is also estimated to be very large; however due to the retrospective pattern these yearclasses may be substantially over-estimated.
- Spawning stock biomass (ages 4+) is estimated to increase to a high in 2004 and then decrease subsequently unless further strong recruitment occurs.
- Projected yield at $F_{0.1}$ in the 2004 fishing year is estimated to be 11,000t; however due to the retrospective pattern, this should be considered a maximum.
- Emphasis should be on how the potential yield from the current good recruitment is to be utilised over time.
- The catch of cod in the mixed groundfish fishery is a concern and conservation of cod should be considered in the management plan for this fishery.

The Fishery

Landings (000s t)

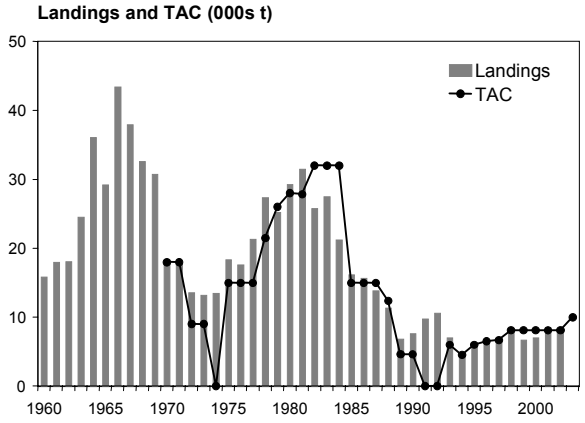
Year	1970-1979 avg.	1980-1989 avg.	1990-1998 avg.	1999[1]	2000[2]	2001[2]	2002[2]	2003[2]
TAC	14.7	21.4	4.7	9.8	8.1	8.1	8.1	10.0
TOTAL	18.6	19.6	7.3	9.3	7.8	7.4	8.0	

1. Fishing year, landings and TAC refer to the 15-month period from January 1, 1999, to March 31, 2000.
2. Commencing in 2000, fishing year, landings and TAC refer to the period April 1st of the current year to March 31st of the following year.

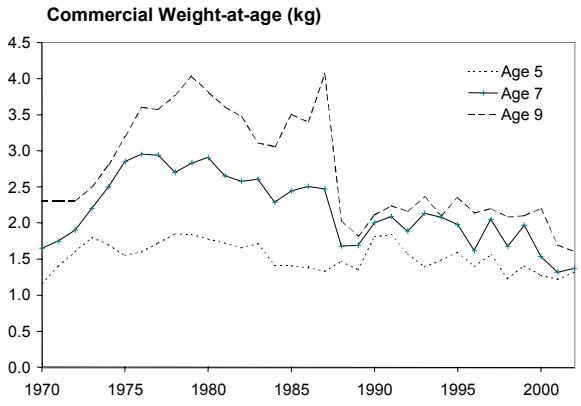
Nominal landings of 4X/5Y haddock in the fishing year ending March 31, 2003, were 7,964t relative to a quota of 8,100t. Haddock landings for the current fishing year to September 26, 2003, were 3,826t. This fishing year is progressing more slowly than last year, with haddock landings down 9% from the same period last year, while groundfish landings overall are down 11%. Some of this delay is due to the abundance of dogfish in 2003, particularly in eastern 4X. Low fish prices and uncertainty regarding a mid-season increase in the haddock quota also contributed to this delay.

Several recent changes to the management of this fishery have had a significant impact on the timing of the fishery. As a result of the change to an April-March fishing year in 2000, haddock landings in the first quarter (January-March) of 2000 and 2001 were the highest since 1992. Landings in the first quarter of 2002 and 2003 were also high. Both the fixed gear and mobile gear sectors indicate this is due primarily to the ability to direct for haddock with a minimal bycatch of cod at that time of year.

This change in timing of the fishery has also led to changes in the distribution of catches. The proportion of catches coming from 4Xn and 4Xp has been increasing in recent years. While the increase in 4Xn is largely a result of the increase in the winter fishery, the increase in catches in 4Xp reflects directing for larger haddock in deeper water, which generally returns higher market value and also is an area in which the bycatch of cod is relatively low.



Mean weights-at-age in the commercial landings have been variable with a modest decline since the early 1990s. The age 5 and younger weights-at-age in recent years are similar to those in the 1970s, but ages 7 and older are very low compared to the late 1970s and early-1980s. Similar declines in weights-at-age have been observed for a number of other species on the Scotian Shelf.



The 1998 yearclass began to recruit to the fishery in 2001. At age 4 in 2002, it made up 35% of the catch by weight. The 1999 yearclass began to recruit to the fishery in 2003 and made up 24% of the half-year catch by weight. The 1998 yearclass made up 37% of the half-year catch. As these yearclasses dominate the fishery, the proportion of small (<43cm) fish in the catch has increased, particularly in the winter fishery. The proportion of small fish in landings from 4Xmnop in the first quarter of 2003 was 24% and 38% for otter trawl and longline landings respectively.

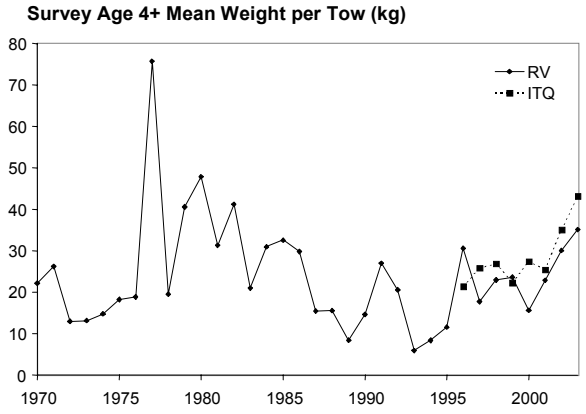
Industry Perspective

Reports from industry indicate that haddock abundance has been good throughout the stock area in recent years although there were reports of changes in inshore distribution in the last year or two. Catches of small fish have been prevalent, particularly in eastern 4X. Reports indicate that discarding and misreporting of 4X/5Y haddock have been minimal in recent years.

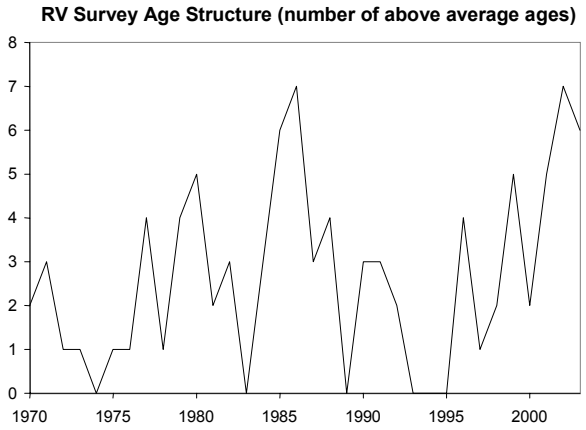
Resource Status

Information on the annual spatial distribution and size composition from the summer research vessel (RV) surveys is contained in Branton and Black (2003).

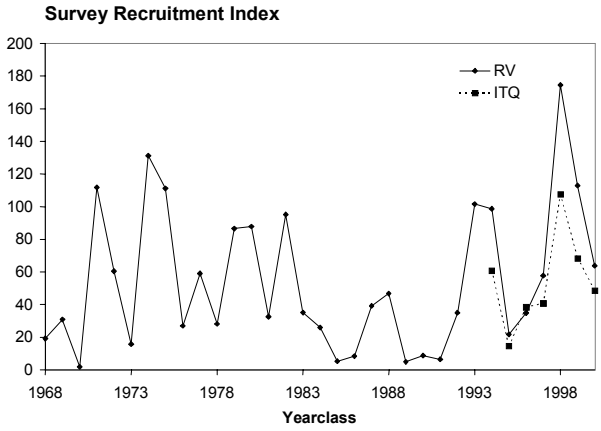
Abundance of ages 4+ haddock (proxy for spawning stock biomass) in the RV survey has shown an increasing trend since 1993 and in 2003 was near the high levels observed in the late 1970s. A joint industry/DFO resource survey of 4X has been conducted by the ITQ fleet since summer 1995. Abundance of ages 4+ in the ITQ survey has shown an increasing trend since 1996 and was the highest observed in 2003. In the RV survey, the 1998 and 1999 yearclasses made up approximately two-thirds of the 2003 ages 4+ biomass. In the ITQ survey, these yearclasses made up approximately three-quarters of the 4+ biomass.



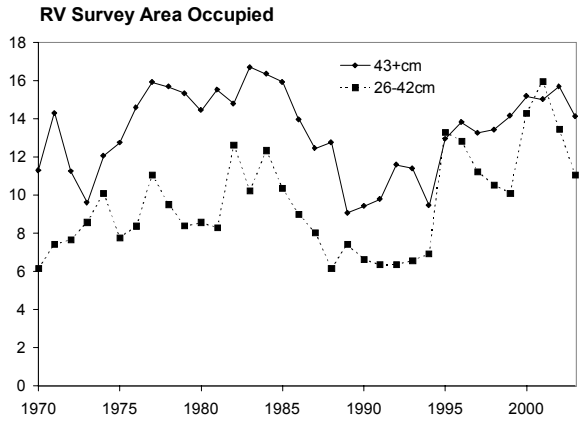
The **age structure** of a population reflects the quality of the population abundance. In general, a broader range of ages is more likely to represent a healthy stock. The number of above average yearclasses in the RV survey, ages 4-10, is a measure of age structure. This indicator has been increasing since 1996 and all ages were above average in 2002. This decreased by one age in 2003. This may not be the best indicator of age structure because it is insensitive to the relative contribution of older ages within the age distribution, which are thought to have a higher reproductive potential. Further research in the development of this index is required.



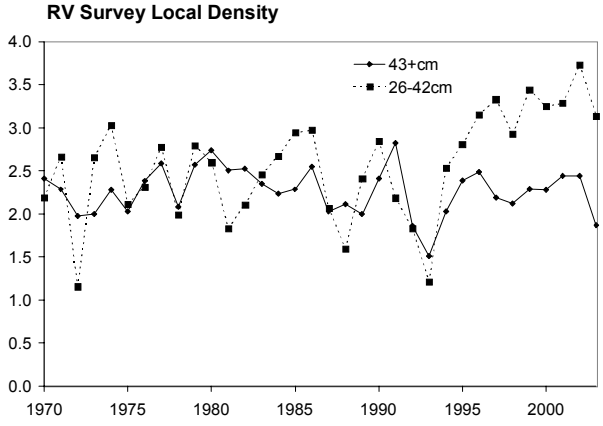
Recruitment, measured as catch per tow at ages 2 and 3 in the RV survey, was below average from 1983 to 1992, with the exception of the 1987 and 1988 yearclasses. The 1993 and 1994 yearclasses were strong. The 1998 yearclass is the largest in the RV survey series and the 1999 yearclass is the third largest. In the ITQ survey, the 1998 yearclass is also largest in the series and the 1999 yearclass is second largest.



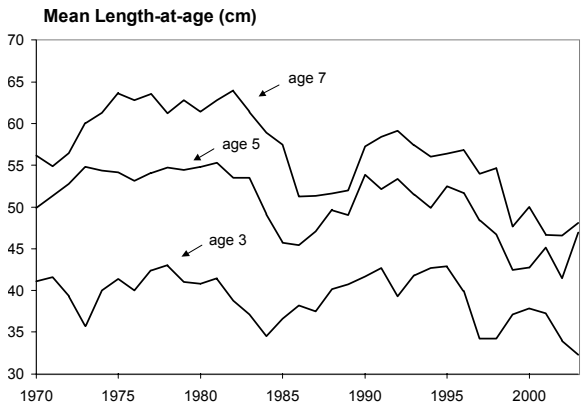
Several indices can provide insight into the distributional properties of abundance. The stratified proportion of the area associated with non-zero RV survey sets is a measure of the **area occupied** by a species. Area occupied by haddock 43cm and greater in length (approximates ages 4+) has shown an increasing trend since the late 1980s and is near the high levels seen in the late 1970s and early 1980s. The area occupied by haddock 26-42cm in length (approximates ages 2 and 3) has shown an increasing trend since the late 1980s and was at the highest levels observed in 2001. Although this indicator has decreased in the last 2 years, it is still above the long-term average.



The average catch rate in annual survey sets where a species occurs is an indicator of the **local density** of the species. Local density in the RV survey of haddock 43cm and greater has shown no trend over the entire time period. The local density in the RV survey of haddock 26-42cm has been increasing since the early 1990s and is near the highest levels observed in the series.

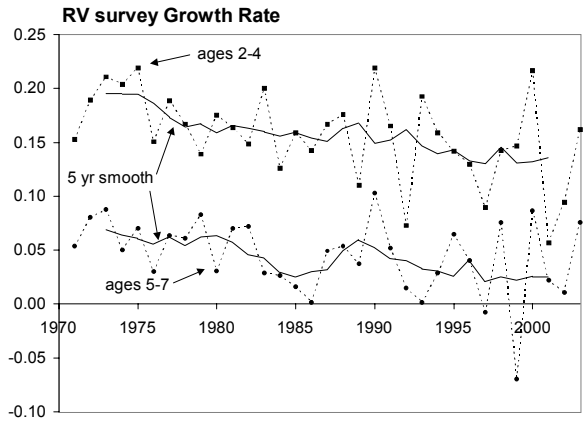


Mean lengths-at-age in the RV survey have been decreasing since the 1970s, particularly at older ages.



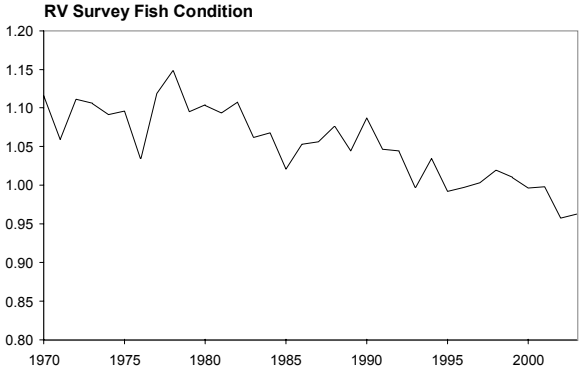
Mean weights-at-age show similar trends. Although most ages are below the long-term average length and weight and many are at or near the smallest size observed in the series, there are indications that this trend may be stabilising.

The instantaneous annual **growth rate (G)** calculated using length at ages 2-4 and 5-7 shows a long-term decreasing trend since the mid-1970s, but shows some signs of stabilising in the last few years.

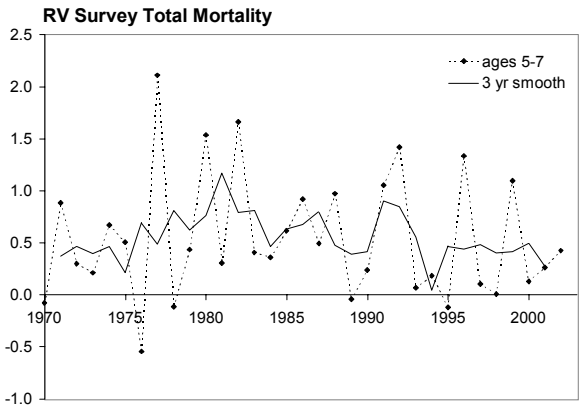


An index of **fish condition**, Fulton's K, developed from the RV surveys, has shown a decreasing trend since the early 1980s and reached a minimum in 2002. Low levels of this index in Atlantic cod have been related to poor reproductive success, and to post-

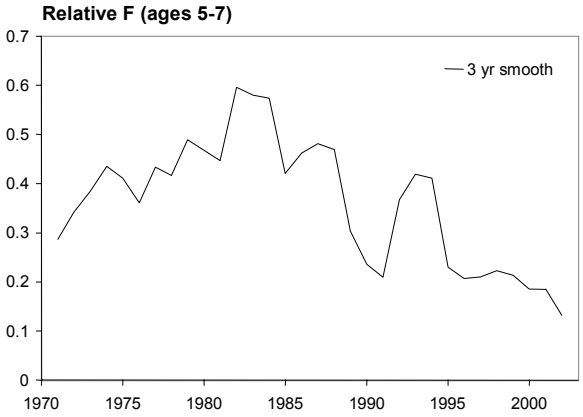
spawning mortality at very low levels. Similar experiments have not been conducted for haddock but should be. It would appear that the levels observed here for haddock have not affected reproductive success or survivorship. However, poor condition does reflect low productivity.



Total mortality (Z) estimated for ages 5-7 (historically fully recruited) from RV surveys was relatively stable in recent years with an implied fishing mortality of about $F_{0.1}$. Unlike a number of other stocks on the Scotian Shelf, this estimate of total mortality does not suggest that the natural mortality for 4X haddock has increased in recent years.

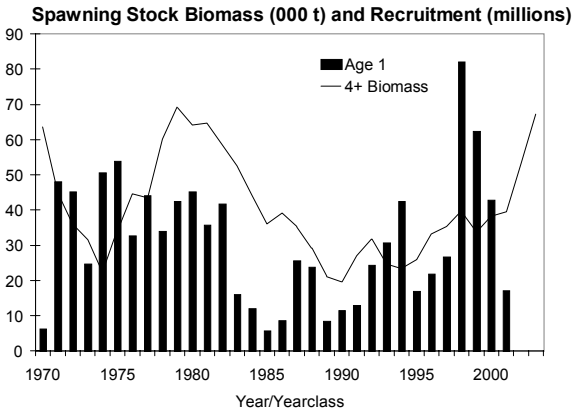


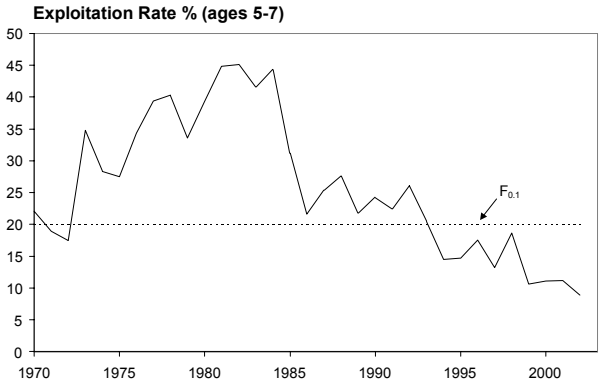
Relative fishing mortality (estimated for ages 5-7) showed an increasing trend through the 1970s to a maximum in the early 1980s, followed by a decreasing trend. Relative F increased in 1992-94, but decreased in 1995 and has remained relatively stable since then.



A **Sequential Population Analysis** (SPA) was conducted using both the RV and the ITQ surveys for fitting the model.

Recruitment in this stock was high through the 1970s and into the early 1980s. This was followed by a ten year period of below average recruitment, from 1983-92, although the 1987 and 1988 yearclasses were near-average in strength. Both the 1993 and 1994 yearclasses were above average. The 1997 yearclass was average, the 1998 yearclass is estimated to be the strongest in the time series, and the 1999 yearclass is estimated to be the second strongest. The model suggests that the 2000 yearclass is also strong.





Spawning stock biomass (ages 4+) decreased from a peak in 1979 and reached a low of 19,000t in 1990. The above average 1993 and 1994 yearclasses resulted in spawning stock biomass increasing to 40,000t in 1998. The average 1997 yearclass and the large 1998 and 1999 yearclasses are estimated to increase spawning stock biomass to 67,000t in 2003.

There appears to be no relationship between spawning stock biomass and recruitment over the biomass range observed.

The **exploitation rate** on ages 5-7 (historically fully recruited) increased from the 1970s to approximately 50% in the early 1980s. It declined to close to $F_{0.1}$ (20%, currently used value of $F_{0.1}$=0.25) in the late 1980s and dropped below $F_{0.1}$ in 1994. Exploitation rate on ages 5-7 dropped again in 1999. Partial recruitment has changed in recent years due to changes in the fishery or changes in size-at-age and fully recruited ages changed from 5-7 to 8-10. The exploitation rate on older ages has remained high at about 20%.

Management Considerations

Haddock is caught in a mixed species fishery for haddock, cod, pollock and flatfish, together with several other commercial species such as white hake, halibut, cusk and monkfish. Consideration of the catch of these other species is required in any management decisions. In particular, the bycatch of cod in the haddock fishery is a concern and cusk has been designated as threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Ecosystem Considerations

Marine species are exposed to interacting biophysical influences, such as temperature, currents and primary productivity that affect their growth, survival and reproductive success. Our current understanding of these effects on our estimates of fish populations and potential yield is poor. Fish species should be considered as living components of ecosystems, subject to changes in their environment. Reviews of comprehensive suites of biophysical data should be undertaken, to gain greater understanding of the relationship between fish and the environment in which they live.

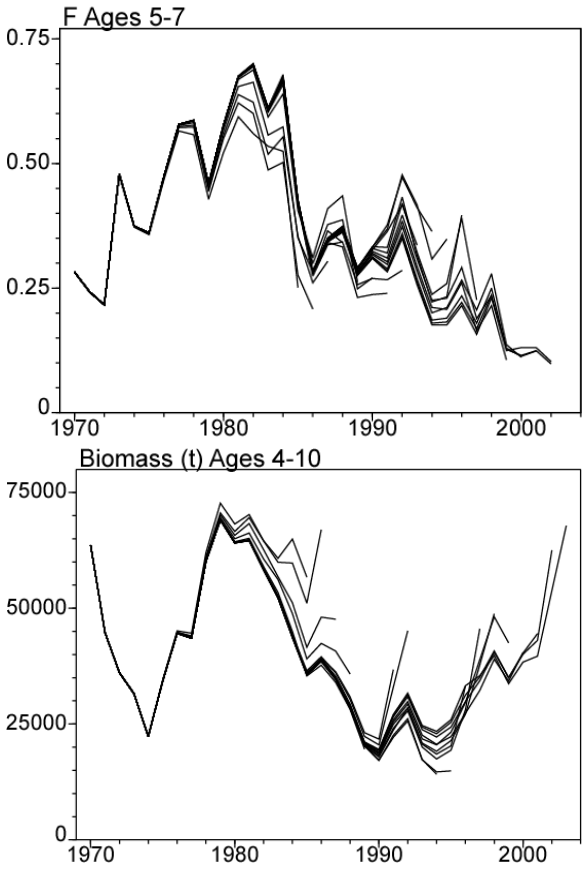
There appears to have been a widespread reduction in the productivity of demersal fish species on the Scotian Shelf. This is evident in the reduced growth for these species where it is measured and can be inferred from the accumulations of large numbers of small individuals for many other species where direct measures of growth are not available. Many of these species are also showing the onset of sexual maturity at small sizes. In a single-species context this implies a significant loss in potential yield relative to historical catches. Many of these species, including some that are subject to little or no fishing mortality, are showing similar patterns of change in productivity. This makes it likely that an environmental or ecological effect is responsible. What this may be is currently unknown.

All fisheries have the potential for discarding undersized specimens of targeted species or all size classes of non-target species, the mix of which is dependent on the gear used and the location of the fishery. The mix of species caught with the 4X haddock fishery is currently not completely known because landings information do not include discards and observer information is available for only a limited proportion of the fleet. The wider ecosystem effects of this fishery, in terms of total bycatch, can not be assessed at this time.

Fishing gears can have negative physical impacts on the seafloor, reducing epi-fauna and flora and damaging or modifying fish and invertebrate habitat. For the haddock trawl and longline fisheries, which account for 99% of haddock landed as main species, these potential impacts have not been assessed.

Sources of Uncertainty

Past assessments of this resource have exhibited a retrospective pattern. The pattern in exploitation estimates is variable and does not show a consistent over- or under-estimation. The biomass estimates do exhibit a general tendency of over-estimation of population abundance in the most recent year, particularly when strong yearclasses occur. In the most extreme cases, strong yearclasses may be over-estimated by a factor of 2. This analysis estimates the 1998 and 1999 yearclasses to be very strong, which may produce this retrospective pattern again.



In 1984/1985, there was a change in the methodology used to determine ages in this resource. Concerns have been expressed that the decreases in size-at-age observed in that period may be due to changes in the methodology, not to changes in growth rate. This was investigated and it does not appear the change in methodology was the cause of these decreases. The construction of the catch at age during this period will be investigated to determine if these decreases are a result of how the catch-at-age was produced. This would not effect just estimates of size-at-age, but also estimates of spawning stock biomass and exploitation rates during that period.

Outlook

The summer RV surveys have been the long-term, fishery-independent source of information on biomass, abundance and size-composition for many fish stocks including 4X haddock. For a variety of reasons the assessments have become more and more dependent on the survey data. Consistency has been maintained by standardised sampling protocols and calibration of the gears. In the past, changes in the survey vessel have been made after calibration experiments have provided information on the expected effects of the change. Due to the recent fire on the Alfred Needler, there is the possibility that an unplanned and uncalibrated vessel change may occur. This will create great uncertainty in any comparisons of subsequent survey results to the historical series for at least the next five years. It will also make it very difficult to determine how the stock may be responding to any particular management action.

Indicators of **abundance** (RV Survey wt/tow ages 4+, ITQ Survey wt/tow ages 4+, SPA Biomass ages 4+, RV Survey Age Structure) all show increasing trends in the most recent period and all indicate that the 2003 value is near the high levels observed in the late 1970s. The large increase in 2003 4+ biomass is a result of the 1998 and 1999 yearclasses.

Indicators of **recruitment** (RV Survey Recruitment Index ages 2+3, ITQ Survey Recruitment Index ages 2+3, SPA Recruitment age 2) all show that the 1998 yearclass is the strongest observed in the survey/SPA time series. The 1999 yearclass is also very strong and the 2000 yearclass is above average. Early indications of the 2001 yearclass suggest it is below average.

The **distribution** indicators (RV Survey Area Occupied 43+cm, RV Survey Local Density 43+cm, RV Survey Area Occupied 26-42cm, RV Survey Local Density 26-42cm) show that fish at lengths that approximate the spawning stock are near the widest area occupied observed although local density has shown no trend. The area occupied by fish at lengths that approximate recruits has decreased to but is still above the long-term average and the local density is high.

The indicators of **production** (RV Survey Growth Rate, RV Survey Fish Condition) have been decreasing since the late 1970s to early 1980s and are at or near the lowest levels observed but may be showing signs of stabilising.

The indicators of **mortality** (RV Survey Total Mortality ages 5-7, SPA Exploitation ages 5-7, Relative Fishing

Mortality ages 5-7) show that mortality has been low in recent years.

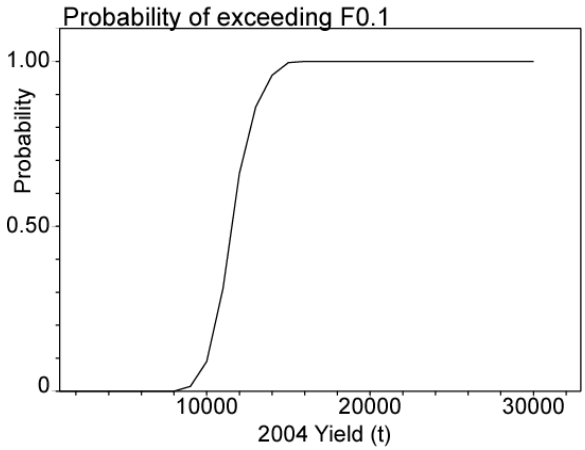
Projected yield was calculated using the recent partial recruitment pattern and recent weights-at-age from the fishery. Weights-at-age in the fishery are currently larger than those indicated for the population by the RV survey. Spawning stock biomass was calculated using recent weights-at-age from the RV survey. The projected yield at F=0.25 (currently used for $F_{0.1}$) for the 2004 fishing year is 11,000t and the projected spawning stock biomass (ages 4+) at the beginning of the 2004 fishing year is 67,000t.

This analysis indicates that landings of 10,000t (TAC) in the 2003 fishing year will result in an exploitation rate close to $F_{0.1}$.

If fished at $F_{0.1}$, spawning stock biomass is estimated to increase to a high in 2004 and then decrease subsequently, unless further strong recruitment occurs.

Given the retrospective pattern observed in this resource in the past when strong yearclasses were present, this assessment likely over-estimates biomass and projected yield.

It is possible to estimate the uncertainties from the model regarding stock size and then use these in a **risk analysis**. The risk plot incorporates the discrepancy between the accepted model and the data. Other uncertainties not considered in this risk analysis include errors in the model assumptions, changes in fishing practices, and environmental effects on survivorship.



The spawning stock biomass is currently near the high levels observed in the late 1970s; therefore a change in spawning stock biomass is not an immediate concern. Accordingly the risk analysis is done only to measure if we are keeping fishing mortality at a moderate level. The steepness of the curves indicates that the risk analysis results are relatively robust to estimation error for abundance.

Although we have observed high recruitment and recruits that are widely distributed at high local density, the spawners exhibit low growth rate, below average size-at-age, and lower condition. It is uncertain how this will impact future production.

In summary, high exploitation in the early 1980s, despite good recruitment, led to declines in spawning stock biomass. Although exploitation decreased to near $F_{0.1}$ in the late 1980s, declining production and poor recruitment resulted in further declines in spawning stock biomass. Improved recruitment and low exploitation in the early 1990s started stock rebuilding. Continued low exploitation since 1994 and the above average 1993 and 1994 yearclasses allowed spawning stock

biomass to continue to rebuild. The very strong 1998 and 1999 yearclasses continued this trend.

Spawning stock biomass is currently near the high levels observed in the late 1970s, due to record high levels of recruitment and low recent exploitation levels but will decrease unless further strong recruitment occurs. Emphasis should be on how the potential yield from the current good recruitment is to be utilised over time, and on the implications of that decision for 4X cod conservation as a result of the mixed fishery issue. Based on this, caution should be exercised in setting the quota for 2004 and the potential yield of 11,000t should be considered a maximum.

For more Information

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