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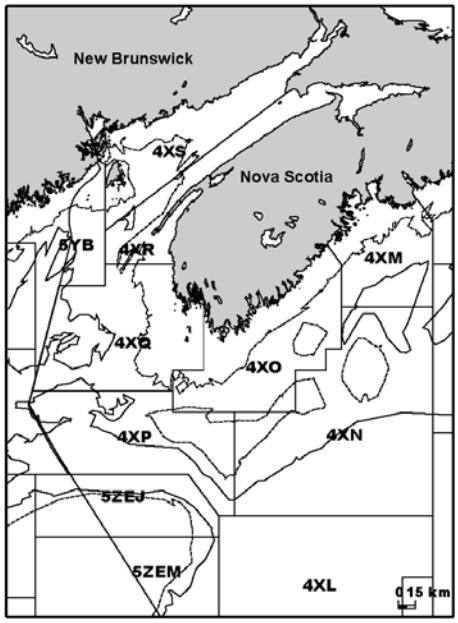
Maritimes Region **Stock Status Report A3-07(2002)**

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.
- Abundance has been increasing since the early 1990s and is presently high.
- Production has been decreasing since the late 1970s and is presently low.
- Exploitation rate for ages 5-7 decreased from approximately 50% in the early 1980s but dropped below 20% (corresponds to currently used $F_{0.1}$=0.25) in 1994 to the present.
- Partial recruitment has changed in recent years and fully recruited ages have changed from 5-7 to 8-10.
- Exploitation on fully recruited ages in the 2002 fishing year will be below $F_{0.1}$ if the TAC is not exceeded.

- The 1998 yearclass is estimated to be the largest observed in the time series, and the 1999 yearclass is estimated to be very strong.
- These yearclasses may be over-estimated by a factor of 2, due to the retrospective pattern.
- Spawning stock biomass (ages 4+) is estimated to increase to a high in 2003 and then decrease subsequently unless further strong recruitment occurs.
- Projected yield at $F_{0.1}$ in the 2003 fishing year ranges from 9,000-15,000t depending upon the weights-at-age used to calculate yields.
- Emphasis should be on how the potential yield from the current good recruitment is to be utilized over time, and on the implications of that decision for 4X cod conservation as a result of the mixed fishery problem.

The Fishery

Landings (000s t)

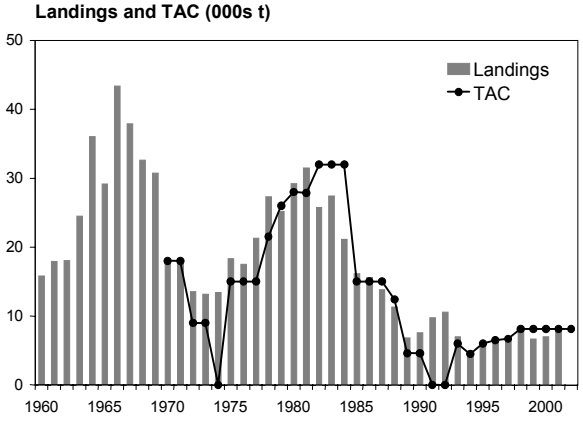
Year	1970-1979 avg.	1980-1989 avg.	1990-1997 avg.	1998	1999[1]	2000[2]	2001[2]	2002[2]
TAC	14.7	21.4	4.3	8.1	9.8	8.1	8.1	8.1
TOTAL	18.6	19.6	7.2	7.8	9.3	7.8	7.4	

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.

Reported landings of 4X/5Y haddock in the fishing year ending March 31, 2002, were 7,411t relative to a quota of 8,100t. Haddock landings for the current fishing year to October 24, 2002, were 4566t. This fishing year is progressing much like the previous two years. Although most fishermen are attempting to avoid catching cod, 70% of the overall cod quota had been landed by October 24th, while only 56% of the haddock quota had been landed.

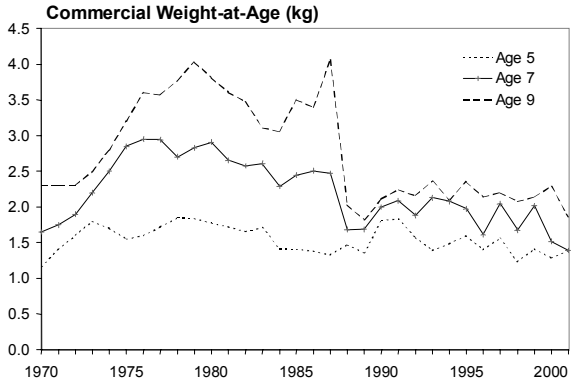
Several recent changes to the management of this fishery have had a significant impact on the timing of the fishery. As a result of the change to an April-March fishing year in 1999, haddock landings in the first quarter of 2000 and 2001 were the highest since 1992. Landings in the first quarter of 2002 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. The introduction of sharing arrangements in the fixed gear sector, as a result of Community Management, has also contributed to this change.

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 likely reflects directing for larger haddock in deeper water.



Mean weights-at-age in the commercial landings have been variable with a modest decline since the early 1990s. The age 5 weight-at-age in recent years is similar to that since 1970, but ages 7 and older are very low compared to the

late 1970s and early-1980s. The degree to which this difference is due to methodology of age interpretation is under investigation.



The 1998 yearclass began to recruit to the fishery in 2001. At age 4 in 2002, it made up 34% of the half-year catch by weight.

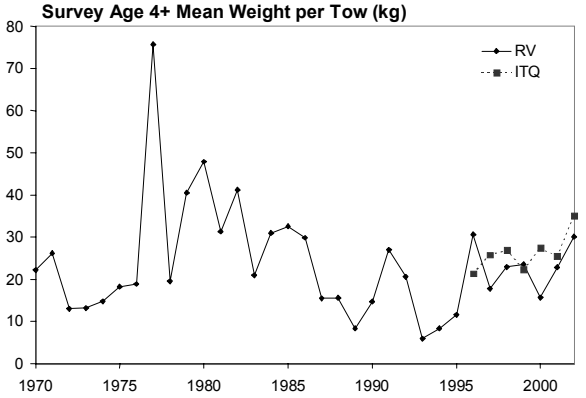
Industry Perspective

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. 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.

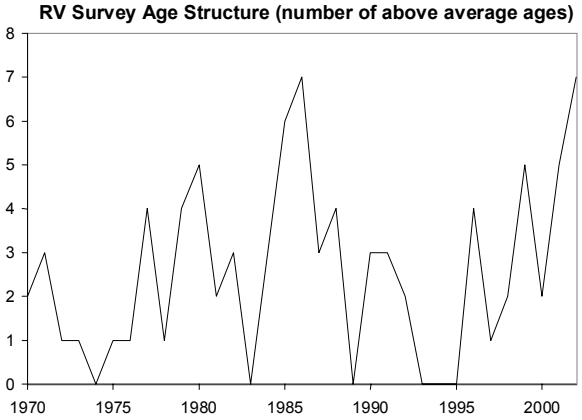
Resource Status

Information on the annual spatial distribution and size composition from the July research vessel surveys is contained in Branton and Black (2002).

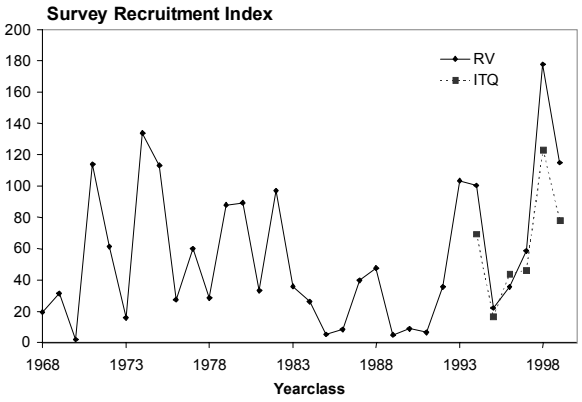
Abundance of ages 4+ haddock (proxy for spawning stock biomass) in the summer research vessel survey has shown an increasing trend since 1993 and was above the long-term average in 2002. A joint industry/DFO resource survey of 4X has been conducted by the ITQ fleet since summer 1995. Abundance of ages 4+ in the ITQ survey has shown an increasing trend since 1996 and was the highest observed in 2002. In both surveys, approximately half of the 2002 ages 4+ catch consisted of the 1998 yearclass.



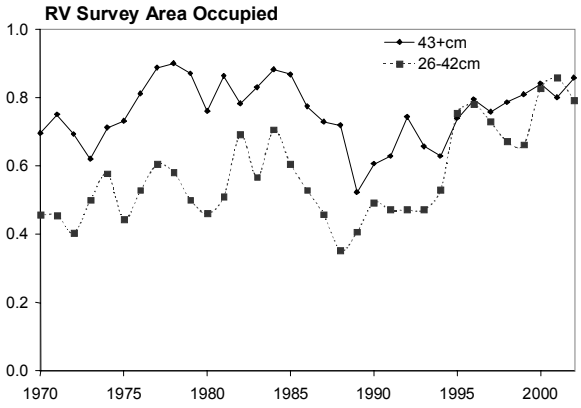
The **age structure** of a population reflects the quality of the population abundance. In general, a broader range of ages is more likely to represent a healthy stock. The number of above average yearclasses in the research vessel survey ages 4-10 is a measure of age structure. This indicator has been increasing since 1995 and all ages were above average in 2002. 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 is required in this area.



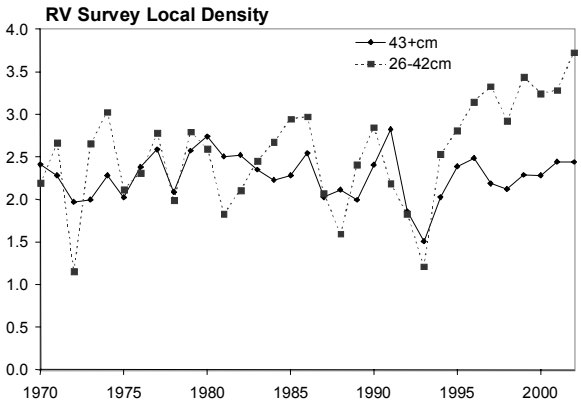
Recruitment, measured as catch per tow at ages 2 and 3 in the research vessel survey, was below average from 1983 to 1992, with the exception of the 1987 and 1988 yearclasses. The 1993 and 1994 yearclasses were strong. The 1998 yearclass is the largest in the summer research vessel survey series and 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.



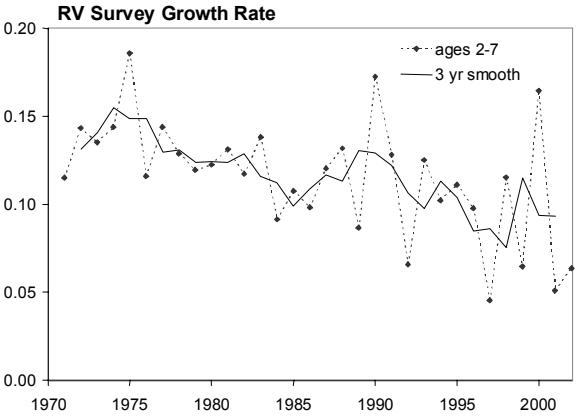
Several indices can provide insight into the distributional properties of abundance. The proportion of annual survey sets where a species occurs (non-zero sets) is a measure of the **area occupied** by the species. Area occupied in the summer research vessel survey by haddock 43cm and greater in length (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 in the summer research vessel survey by haddock 26-42cm in length (approximates ages 2 and 3) has shown an increasing trend since the late 1980s and is at the highest levels observed in the series.



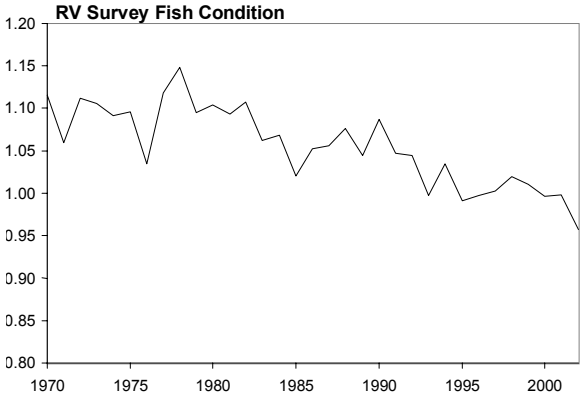
The average catch rate in annual survey sets where a species occurs is an indicator of the **local density** of the species. Local density in the summer research vessel survey of haddock 43cm and greater has shown an increasing trend since the early 1990s and is about average in 2002. The local density in the summer research vessel survey of haddock 26-42cm has been increasing since the early 1990s and is at the highest levels observed in the series.



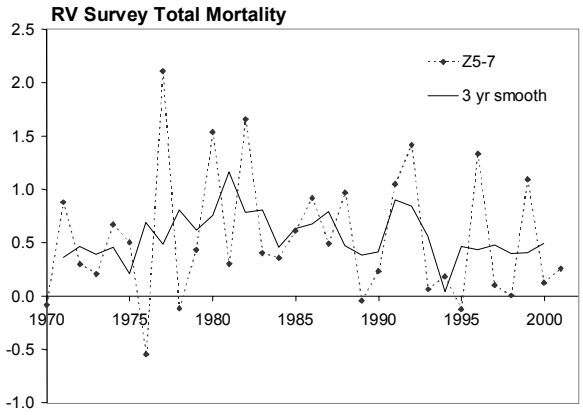
Mean lengths-at-age in the summer research vessel survey have been decreasing since the early 1990s, particularly at older ages. Mean weights-at-age show similar trends. Many ages are below the long-term mean length and weight and some are at the smallest size observed in the series. The instantaneous annual **growth rate (G)** calculated for length at ages 2-7 shows a long-term decreasing trend since the mid-1970s but shows some signs of stabilizing in the last few years.



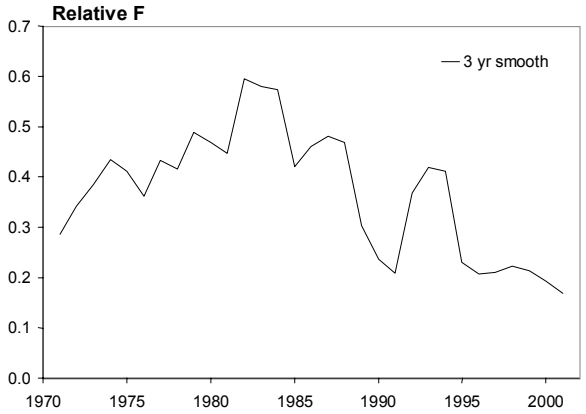
An index of **fish condition**, Fulton's K, developed from the summer research vessel surveys, has shown a decreasing trend since the early 1980s and reached a minimum in 2002. Low levels of this index in Atlantic cod have been related to poor reproductive success, and to post-spawning mortality at very low levels. Similar experiments have not been conducted for haddock. It would appear that the levels observed here for haddock have not affected reproductive success. However, poor condition does reflect low productivity.



Total mortality (Z) estimated for ages 5-7 (historically fully recruited) from summer research vessel surveys were relatively stable in recent years with an implied fishing mortality of about $F_{0.1}$ (assuming a natural mortality of 0.2).

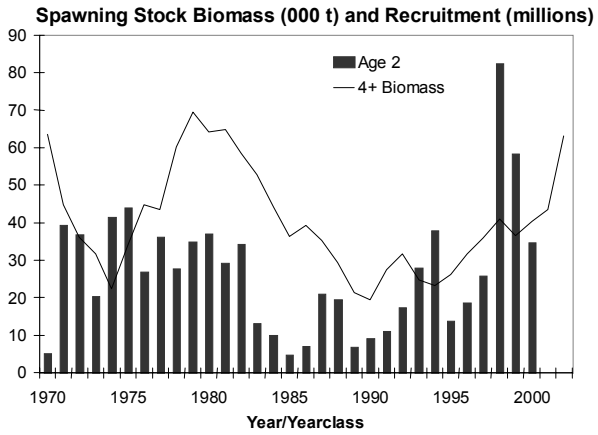


Relative fishing mortality showed an increasing trend through the 1970s to a maximum in the early 1980s, followed by a decreasing trend. Relative F increased 1992-94, but decreased in 1995 and has remained relatively stable since.



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

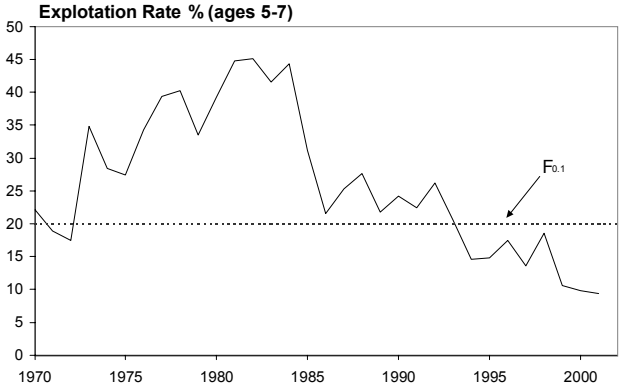
Recruitment from 1983-92 was below average, although the 1987 and 1988 yearclasses were near-average in strength. Both the 1993 and 1994 yearclasses were above average. The 1997 yearclass was average and the 1998 yearclass is estimated to be the strongest in the time series. The model suggests that the 1999 yearclass is also very strong and the 2000 yearclass is above average.



Spawning stock biomass (ages 4+) decreased since 1979 and reached a low of 19,000t in 1990. The above average 1993 and 1994 yearclasses resulted in spawning stock biomass increasing to 41,000t in 1998. The average 1997 yearclass and the large 1998 yearclass are estimated to increase spawning stock biomass to 63,000t in 2002.

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

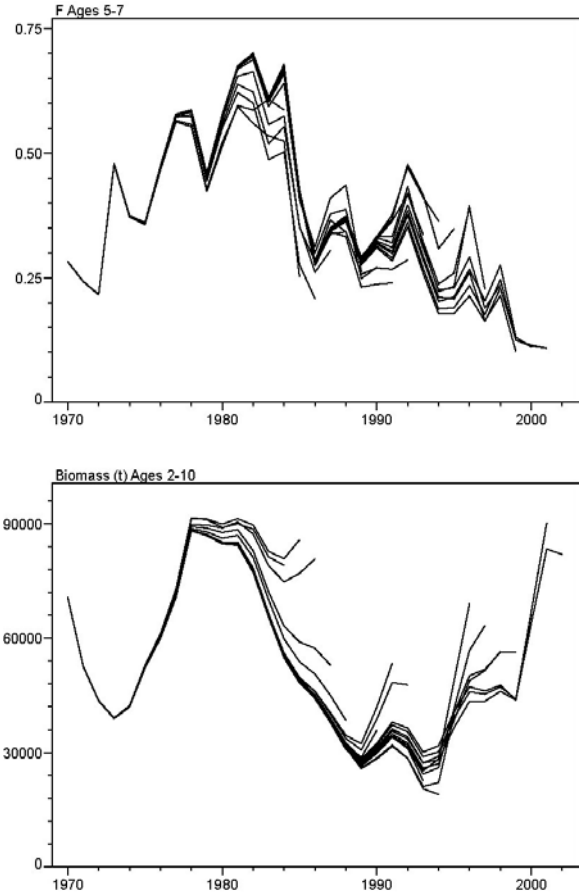
The **exploitation rate** on ages 5-7 (historically fully recruited) increased from the 1970s to approximately 50% in the early 1980s. It declined to close to $F_{0.1}$ (20%, currently used value of $F_{0.1}$=0.25) in the late 1980s and dropped below $F_{0.1}$ in 1994. Exploitation rate on ages 5-7 dropped again in 2000 and 2001. Partial recruitment has changed in recent years and fully recruited ages changed from 5-7 to 8-10. The exploitation rate on older ages has remained high at about 22%.



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 consistent pattern of over-estimation of population abundance in the most recent year, particularly when strong yearclasses

occur. This analysis estimates the 1998 and 1999 yearclasses to be very strong, which may produce this retrospective pattern again. These yearclasses may be over-estimated by a factor of 2.



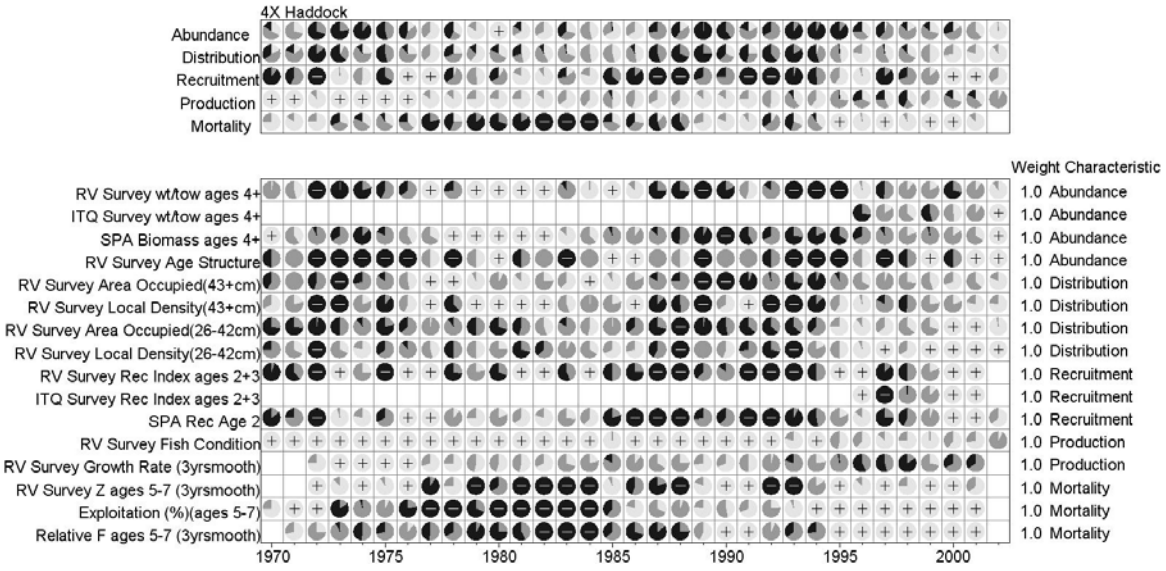
Projected yield and spawning stock biomass were calculated using recent average weights-at-age. Weights-at-age in this resource have been declining since the mid 1990s. If this trend continues, then yield and spawning stock biomass will be over-estimated. A shift in the proportion of landings from the Bay of Fundy to the Scotian Shelf where growth is slower would also result in yield being over-estimated.

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, and this will be investigated. This would not just effect estimates of size-at-age, but also estimates of spawning stock biomass and exploitation rates during that period.

Traffic Light Analysis

The **Traffic Light** table summarises the indicators of stock status shown above. This table shows the annual values of each indicator as a combination of three lights depending on whether they are among the best values for that indicator, among the worst or in between. For indicators such as stock biomass and recruitment, high values are good and have a green light + and low values are bad and have a red light −. However, for indicators such as mortality, high values are bad and are assigned a red light whereas low values are good and receive a green light. Intermediate values (midpoint between red and green) are yellow ●. A value between red and yellow is expressed as a pie with increasing amounts of red in the pie as the value approaches the red threshold or cut point. Similarly, a value between the midpoint and the green cut point becomes increasingly green in the pie as the green cut point is approached. Empty cells in the table indicate no observation for that year. Uncertainties about the appropriate cut point resulted in a broad yellow zone.

In the traffic light analysis, indicators are summarised into groups, which emphasise specific aspects of the resource. These groupings are called characteristics. The following outlook is cast in terms of these characteristics and each is shown in bold.



* See Appendix 1 for a description of traffic light indicators, boundary points, weights and rationales for 4X/5Y haddock.

Outlook

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 2002 value is above average. The large increase in 2002 4+ biomass is a result of the 1998 yearclass.

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 may be above average. The 1993 and 1994 yearclasses were above 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 and the local density is about average. The area occupied by fish at lengths that approximate recruits is at the widest observed and the local density is also at the highest.

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.

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. While the very strong incoming 1998 and 1999 yearclasses may result in an increase in the partial recruitment to the fishery at ages 4 and 5 in 2003, the

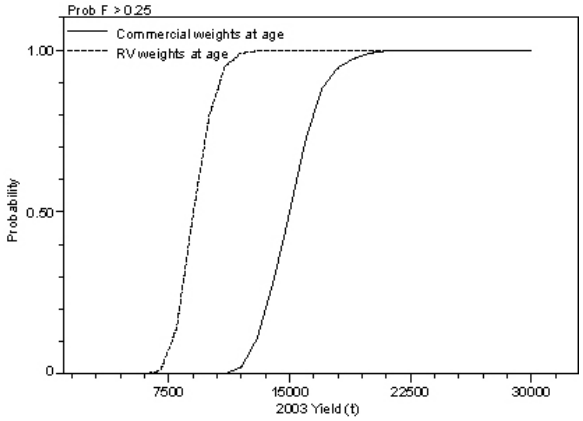
extent of this is uncertain. Therefore the projected yield was calculated using the 1999-2001 average partial recruitment. Weights-at-age in the fishery are currently larger than those indicated for the population by the research vessel survey. Projected yield was calculated using recent weights-at-age from the fishery, but also using weights-at-age from the research vessel survey to approximate the anticipated increased contribution of catch from the Scotian Shelf stock area, if quotas and catches increase significantly. Projections using the survey weights-at-age are considered a lower bound and results closer to those using recently observed fishery weights-at-age are more likely. The table below shows projected yield at F=0.25 (currently used for $F_{0.1}$) for the 2003 fishing year and the spawning stock biomass (ages 4+) at the beginning of the 2003 fishing year.

This analysis indicates that landings of 8,100t (TAC) in the 2002 fishing year will result in an exploitation rate below $F_{0.1}$.

Weight-at-age	2003 SSB (t)	2003 Yield (t)
high	79,000	15,000
low	77,000	9,000

If fished at $F_{0.1}$, spawning stock biomass is estimated to increase to a high in 2003 and then decrease subsequently, unless further strong recruitment occurs.

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 and model formulations, changes in fishing practices, and environmental effects on survivorship.



The spawning stock biomass is currently near historically high levels; therefore a change in spawning stock biomass in 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 but the distance between them indicates they are sensitive to assumptions of fishery weights-at-age.

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

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 have allowed spawning stock biomass to continue to rebuild. The very strong 1998 and 1999 yearclasses are expected to continue this trend.

The resource is rebuilding, due to record high levels of recruitment and low recent exploitation levels. Spawning stock biomass is near the high levels of the late 1970s/early 1980s and is projected to exceed these levels in 2003 but will decrease unless further strong recruitment occurs. Thus emphasis should be on how the potential yield from the current good recruitment is to be utilized over time, and on the implications of that decision for 4X cod conservation as a result of the mixed fishery problem.

For more Information

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Appendix 1. Description of traffic light indicators, boundary points, weights and rationales for 4X/5Y haddock.

The traffic light approach provides a framework that allows us to incorporate multiple indices of stock status and other relevant indicators. Colour boundaries corresponding to good and bad periods can be established qualitatively for some indicators, but remain problematic for others. For most indicators, the history of the index is short relative to the ecological and evolutionary history of the fish populations or of the ecosystems within which they occur. In the absence of quantitative information to specify colour boundaries they have been established by a process of deliberation, where the weight of expert opinion is used to determine the most reasonable estimates. These represent the best available estimates; however all are subject to improvement through ongoing research.

The time period 1970-2002 was used to establish colour boundaries for the 4X/5Y haddock stock status indicators. During this period, abundance of the stock was relatively high during the late 1970s and early 1980s, and relatively low during the late 1980s and early 1990s. Recruitment was relatively good during the mid-1970s through to the early 1980s, but was poor from the mid-1980s to the mid-1990s. Production in terms of growth in the population has decreased throughout the period. Mortality rates were high from the mid-1970s to the mid- to late 1980s. Colour boundaries were set to correspond to these general trends.

Indicator	Green (+) Boundary	Red (-)Boundary	Characteristic	Weight
RV Survey wt per tow ages 4+ (kg)	31: Consistent with highs observed in late 1970s/early 1980s	13: Consistent with lows observed in late 1980s/early 1990s	Abundance	1
ITQ Survey wt per tow ages 4+ (kg)	30: This is a short time series and thus its true range is uncertain. The boundaries were set to be consistent with those for SPA 4+ biomass	20: This is a short time series and thus its true range is uncertain. The boundaries were set to be consistent with those for SPA 4+ biomass	Abundance	1
SPA Biomass ages 4+ (t)	55000: Consistent with highs observed in late 1970s/early 1980s	20000: Consistent with lows observed in late 1980s/early 1990s	Abundance	1
RV Survey Age Structure –above average ages 4-10	5: Consistent with highs observed in late 1970s/early 1980s	1: Consistent with lows observed in late 1980s/early 1990s	Abundance	1
RV Survey Area Occupied 43+cm	0.88: Consistent with highs observed in late 70s/early 80s	0.62: Consistent with lows observed in late 1980s/early 1990s	Distribution	1
RV Survey Local Density 43+cm	2.5: Consistent with highest observed	2: Consistent with lowest observed	Distribution	1
RV Survey Area Occupied (26-42cm)	0.8: Consistent with highest observed	0.4: Consistent with lowest observed	Distribution	1
RV Survey Local Density (26-42cm)	3.2: Consistent with highest observed	1.6: Consistent with lowest observed	Distribution	1
RV Survey Recruitment Index ages 2+3	87,000: Set to be consistent with those of SPA age 2 recruitment	18,000: Set to be consistent with those of SPA age 2 recruitment	Recruitment	1
ITQ Survey Recruitment Index ages 2+3	62,000: Set to be consistent with those of SPA age 2 recruitment	26,000: Set to be consistent with those of SPA age 2 recruitment	Recruitment	1
SPA Recruitment age 2	40,000,000: Consistent with highs observed in late 1970s/early 1980s	10,000,000: Consistent with lows observed in late 1980s/early 1990s	Recruitment	1
RV Survey Fish Condition (Fulton's K)	1.02: It is unlikely that K values in the range observed were low enough to have affected reproductive success or mortality, but they do reflect reductions in production	0.90: It is unlikely that K values in the range observed were low enough to have affected reproductive success or mortality, but they do reflect reductions in production	Production	1
RV Survey Growth (G) ages 2-7 3yr smooth	0.14: Consistent with highest observed	0.07: Consistent with lowest observed	Production	1
RV Survey Total Mortality (Z) ages 5-7 3yr smooth	0.45: Based on $F_{0.1}$ limit + M (0.2)	0.70: Twice $F_{0.1}$ limit + M (0.2)	Mortality	1
Exploitation (%) (ages 5-7)	20: Moderate F level ($F_{0.1}$)	36: Twice $F_{0.1}$ limit	Mortality	1
Relative Fishing Mortality (Ages 5-7) 3yr smooth	0.25: $F_{0.1}$ limit	0.50: Twice $F_{0.1}$ limit	Mortality	1