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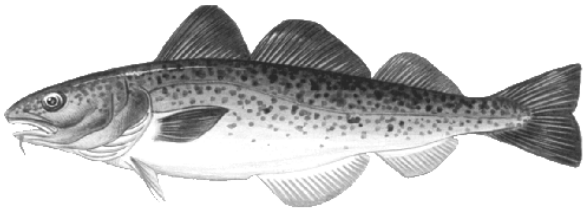
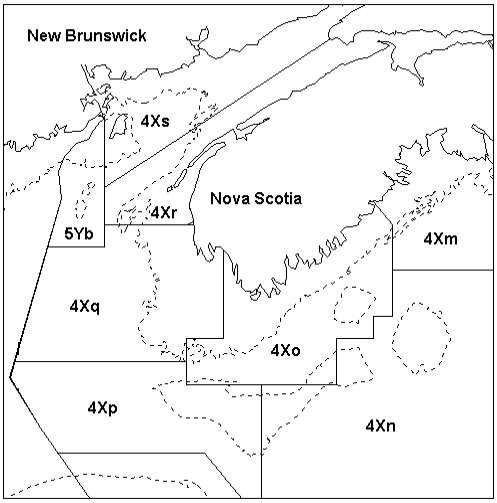
(Revised)

Maritimes Region **Stock Status Report A3-05(2002)**





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

Background

Atlantic cod (Gadus morhua) is a bottom dwelling fish occurring on both sides of the North Atlantic. In the Canadian Atlantic, cod range from northern Georges Bank to northern Labrador. There are several concentrations of cod within this range, including those on the southern Scotian Shelf and Bay of Fundy (NAFO Division 4X and Canadian portions of 5Y).

Juvenile cod feed on a wide variety of invertebrates and as they grow include fish in their diet. Seasonal movements associated with spawning occur and a number of spawning areas exist in this management area with the largest occurring during winter on Browns Bank. Cod in this area reach on average 53 cm (21 inches) by age 3 years and increase to 72 cm (29 inches) by age 5 and 110 cm (43 inches) by age 10. Growth rates, however, vary among cod in this area with more rapid growth noted in the Bay of Fundy. Age at first reproduction generally occurs at 3 years and individuals tend to spawn several batches of eggs during a single spawning period.

Cod has supported a commercial fishery in this area since the 1700s and until the 1960s was primarily an inshore fishery. Following extension of jurisdiction to 200 miles by coastal states in 1977, only Canada has made substantial landings of cod from this area. Minimum mesh size and hook size regulations have been enacted to reduce the catch of juvenile cod. Closure of Browns Bank is in place from 1 February-15 June.

Summary

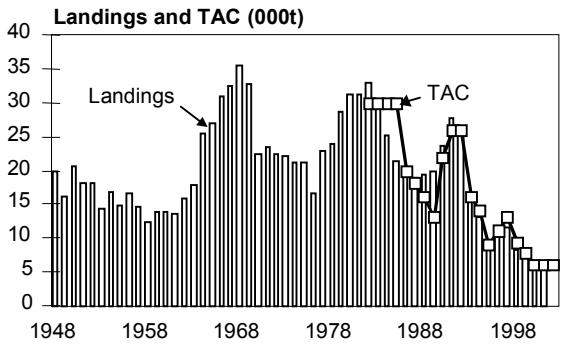
- Reported landings and TAC declined through the 1990s and were 6000t annually from 2000-2002.
- Recruitment has improved starting with the 1998 yearclass, but remains below average.
- Biomass has increased since the late 1990s but remains low.
- Growth rate and condition show no trends.
- Total mortality has remained high despite restrictive TAC's.
- High mortality does not appear to indicate increased natural mortality but is consistent with anecdotal reports of discarding and unreported landings of cod.
- Given the improved recruitment, biomass should continue to increase. The full benefit of the 1998-2000 yearclasses toward stock rebuilding will not be realized if mortality cannot be reduced to moderate levels.

The Fishery

Landings (000s t)

Year	1970-1979 Avg.	1980-1989 Avg.	1990-1997 Avg.	1998	1999[1]	2000[2]	2001	2002
TAC	-	23.4	17.1	9.3	7.9	6	6	6
Total	22.5	24.9	11.1	8.2	7.4	5.9	5.9	

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 refers to the period April 1st of the current year to March 31st of the following year.



Landings increased through the 1960s as large offshore trawlers became active in the fishery. Total allowable catch (TAC) dropped to the lowest on record in 2000. Recent landings are a reflection of the TAC which declined from 26,000t in 1992 to 6,000t in 2000. The quota has been held at 6,000t for 3 years as part of a rebuilding strategy for 4X cod. As of October 24, 2002 4,200t of cod has been landed; this includes 80% of the <45' fixed gear quota, and 60% of the mobile gear ITQ fleet quota. This is slightly ahead of the same time in 2001.

The fishery takes place year round, peaking in June and July. Landings from the winter declined after 1992, with many fishing sectors treating cod as a by-catch as they pursued other species. Since 2000, the quota year has run from April 1st. With this change in fishing year, and the increase in haddock quotas relative to cod, the winter haddock fishery has increased, and winter landings of cod, taken as by-catch, have also increased.

In 2001 and 2002, the cod fishery is reported to have improved in most areas. Most groups reported no difficulty in catching their quota despite the fact that many were directing their effort primarily for haddock. Hook and line vessels in the Bay of Fundy caught their quotas in 2001 for the first time in 4 years. Fishing in inshore areas of 4Xo, however, a much larger sector of the fishery, was poor for both cod and haddock, with fishermen having to travel further offshore. In 2002, fishing is reported to have been poor in most coastal areas, but further improved in deeper water.

The number of vessels active in the fishery in 4X continues to decline, particularly for handline, and reported **fishing effor**t for groundfish is low for all gear sectors. These changes may not be directly related to fish abundance.

Catch rates for otter trawlers have increased annually since 1999, and are now the highest since 1991. Gillnet catch rates doubled in 2002, and are now more than 5 times as high as in 1996. Catch rates for longline and handline vessels shows little change since 1996. Due to changes in fishing patterns and the impact of management measures, it has been argued that catch rates may have limited information value regarding cod abundance.

In both 2001 and 2002 the 1998 yearclass dominated the landings of 4X cod. The contributions from ages 6 and over were below average.

Industry Perspective

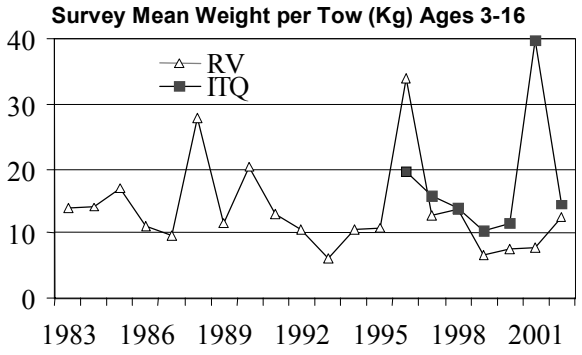
Since 2000, fishermen in the traditional groundfish fishery (cod, haddock and pollock) have maintained that the cod quota is very restrictive and that they have difficulty remaining within their quota for cod while pursuing other species. Mobile gear fishermen report increases in both cod and haddock abundance. Most feel that they can balance quotas by directing effort to areas where haddock are abundant, but indicate some are not making this effort and may be discarding cod. Some express frustration at the low cod quota and indicate it is leading to discarding. Fixed gear fishermen (20 fishermen interviewed) indicated that cod abundance has increased but they see little increase in haddock in the areas they fish. Many of those interviewed felt it was impossible to catch a mix of cod and haddock appropriate to their specific quotas, except during the winter, and stated that cod were being discarded and landed unreported. In 2001, the fixed gear <45' quota sector in 4X landed 97% of their cod quota but only 77% of their haddock quota. There are a wide range of cod to haddock allocation ratios among community management boards and individual quota holders; matching these ratio in landings will not be uniformly difficult for all.

Reports of cod being **discarded or landed unreported** to avoid exceeding the quota have increased. These anecdotal reports have been received from all sectors of the fishing fleet, with some indicating that the amount of cod recorded in landings data may be significantly less than is killed in the fishery in some areas. These reports bring into question the efficacy of quota management for cod in 4X, and the reliability of analyses which are dependent on landings data.

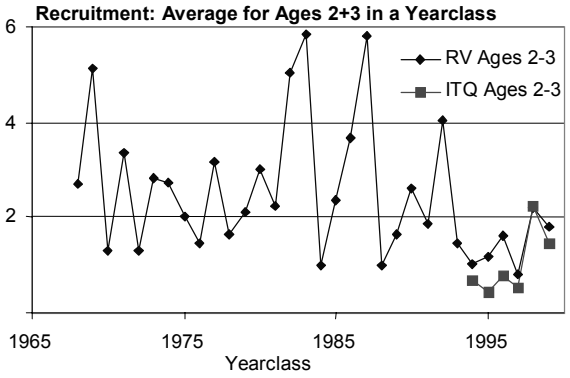
Resource Status

The catch per tow of cod aged 3 and over for the **research vessel** (RV) survey in 4X increased in 2002 to above the median. Catches were above the median at all lengths in the Bay of Fundy, but below the median at lengths less than 75cm on the Scotian Shelf.

ITQ survey catch declined in 2002 from an anomalously high level in 2001. Catches were low at fixed stations in inshore areas and in much of the Bay of Fundy. Catches at the stations on much of the Scotian Shelf and in the deep water of the Gulf of Maine were above the median for those sites (1996-2002)

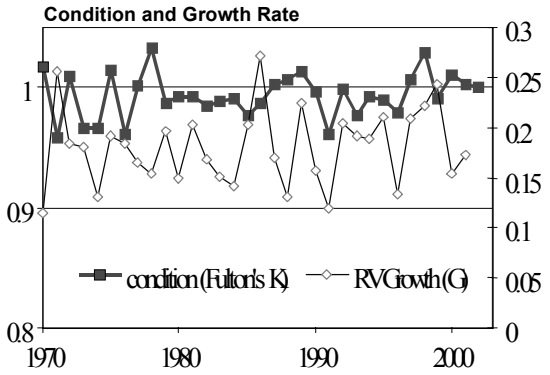


Recruitment has been below average since the 1992 yearclass. Recruitment for the 1998 and 1999 yearclasses has improved from recent lows. These two yearclasses are much larger than any since 1992.

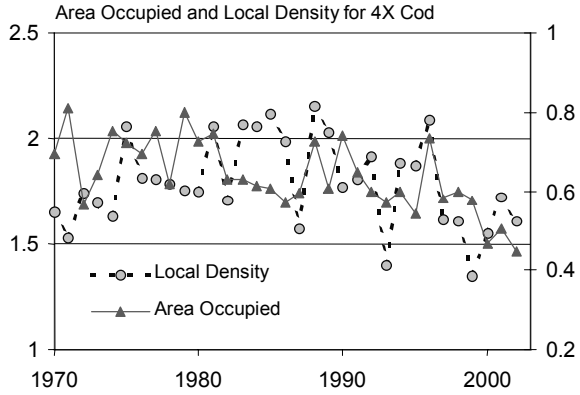


Catches of the 2000 yearclass at age 2 were among the highest in the RV series, but below average for the ITQ in 2002 (not shown). Initial indications for the 2001 yearclass are positive, with above average catches in both the RV and ITQ surveys.

Condition has changed little over time for cod in 4X, and is currently above average. The instantaneous **growth rate** (G) for cod aged 2-7 in 4X is variable but without trend.



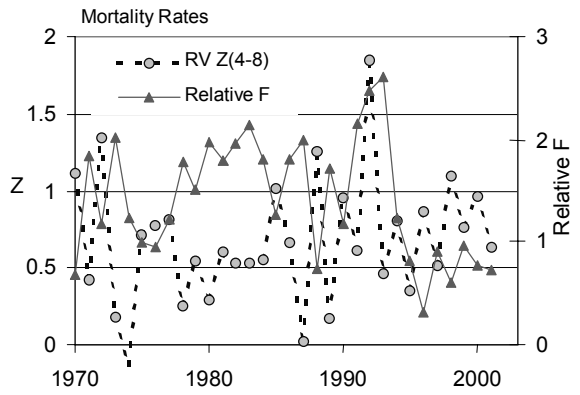
The proportion of RV survey sets where cod are caught **(area occupied**) was highest in the 1970s, lower in the 1980s and 1990s, and particularly low for 2000-2002. In contrast, the proportion of sets where cod is caught in the ITQ survey has varied little since 1996, remaining about 75%.



Local Density was low in the 1970s, increased for the 1980s and 1990s, and in recent years has declined to levels similar to those in the 1970s.

Total mortality (Z) as calculated from the RV survey has considerable inter-annual variability. There is no trend apparent in total mortality, which remains high despite the reductions in reported landings. For ages 2 and 3, Z has followed a declining trend, however there is no trend for commercial aged cod.

Dividing commercial landings by survey biomasss is an estimate of **relative fishing mortality**. Assuming that landings are accurate, this would suggest that exploitation has been relatively low in recent years.

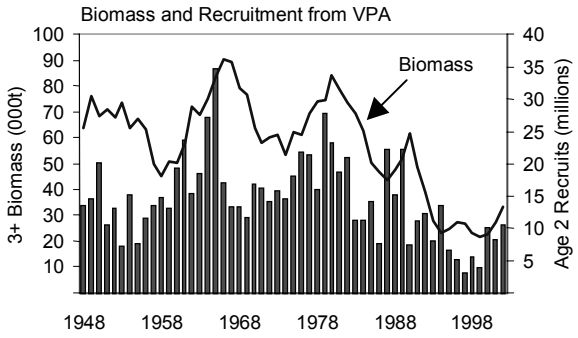


While the relative fishing mortality declined sharply after 1992 and has

remained low since, the total mortality (Z) from the RV survey suggests mortality has remained high in recent years. This divergence is indicative of unaccounted for mortality on this stock. The anecdotal reports of discarding and unrecorded landings of cod suggest that much of this discrepancy is likely additional fishing mortality rather than increased natural mortality.

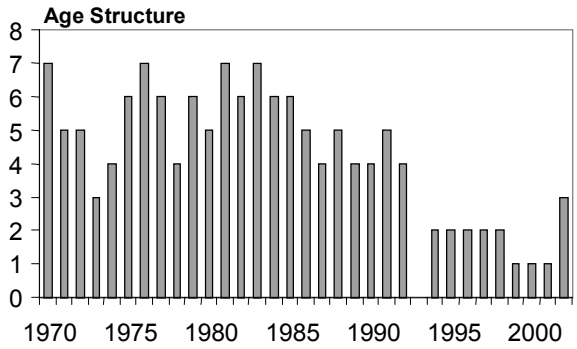
A **Sequential Population Analysis** (SPA) was conducted using the research vessel survey (1983-2002) and the ITQ survey (1996-2002) for fitting the model. Catch at age data from 1948 to mid-year 2002 were used.

Population biomass is estimated to have been low but stable from 1995-2000, with increases in each of 2001 and 2002. These increases are due to the contributions from the 1998 and 1999 yearclasses.

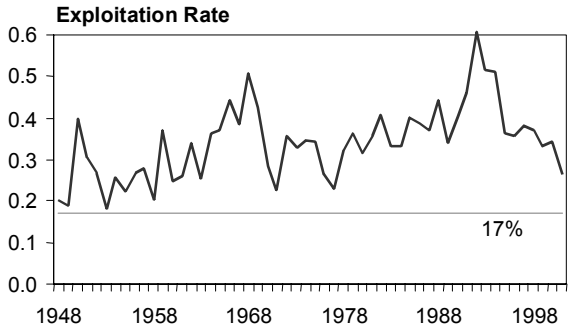


Recruitment has been below average since the 1992 yearclass. The 1993 to 1997 yearclasses are the five lowest in the series. The 1998, 1999 and 2000 yearclasses each appear to be about double the size of the 5 yearclasses which preceded them.

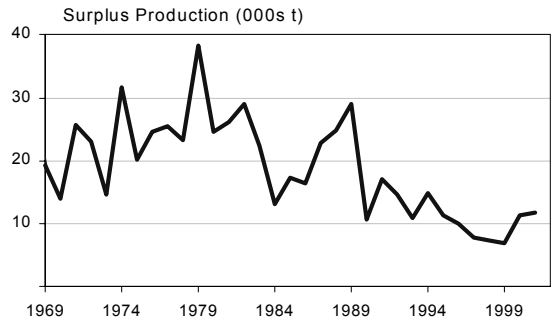
The number of ages where catch is above average for mature cod (ages 3-10) in the RV survey is an indicator of **age structure**. This has been low for 4X cod since 1992, increasing in the last year.

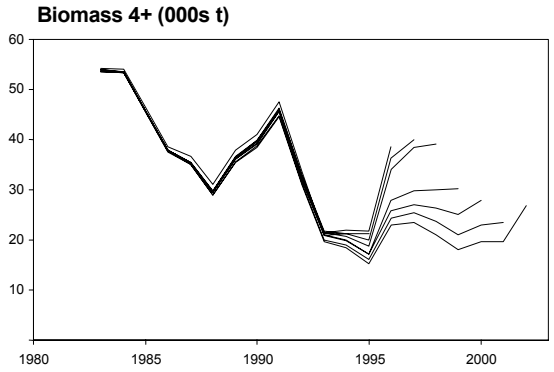


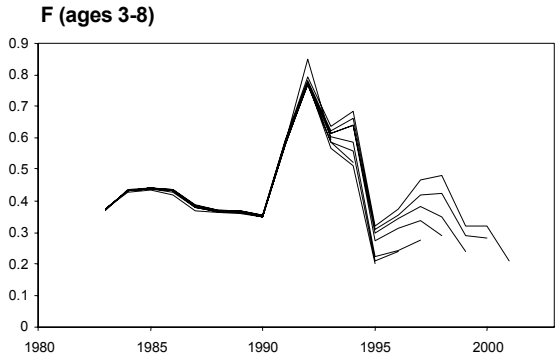
The **exploitation rate** estimated for ages 4-5 has consistently been well over twice the $F_{0.1}$ mortality of 17%, reaching a high of 60% in 1992. Exploitation rate declined after 1994, but remained close to 30%, declining in 2001.



Surplus production is a measure of total production for the stock from recruitment and fish growth minus the amount lost to natural mortality. Surplus production declined through the 1990s to a historical low, then increased in 2000 and 2001 with improved recruitment.







Sources of Uncertainty

The principal source of uncertainty in our evaluation of stock status in 4X cod is the actual removals in each year. Reports of current and historical discarding and under-reporting indicate that these vary from year to year due to stock condition and fishermen's perceived incentives and risks. Prior to the mid-1980s misreporting could also have included over-reporting of landings from other species or areas as 4X cod.

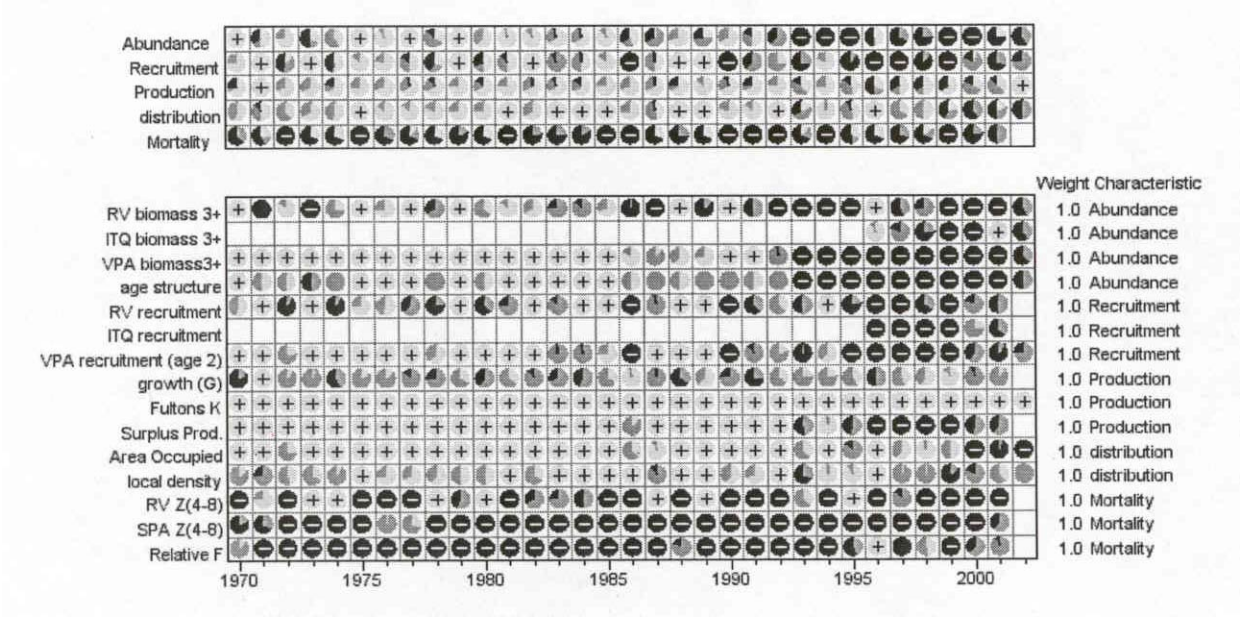
This population reconstruction has a pronounced **retrospective** problem in recent years, where population estimates for a given year decline and fishing mortality estimates increase with additional years of data. This pattern is quite marked since 1998, and suggests that there is additional mortality of 4X cod beyond what is accounted for in the data used in the analysis. If the retrospective is caused by change in under-reporting of the fishery catch, the tendency to over-estimate can be less severe for the abundance of recruiting yearclasses than it is for biomass. Furthermore, the initial high estimates may be a more accurate reflection of actual recruitment than are subsequent estimates, which may be under-estimates due to missing catch.

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 can be summarised into groups which emphasise specific aspects of the resource. These groupings are called characteristics.



See Appendix 1 for a description of traffic light indicators, boundary points, weights and rationales.

Outlook

Indicators of **abundance** for 4X cod are 3+ biomass estimated from RV, ITQ and SPA and age structure. These all indicate that abundance has been low in recent years. All indicate abundance has increased from a low in the 1990s, and all but the ITQ survey indicate improvement in 2002.

Recruitment as indicated from the surveys and VPA appears to have improved for the 1998 and later yearclasses, following 5 years of poor recruitment.

Distribution indicators (local density and area occupied) have declined and are now low for 4X cod.

Production indicators are condition, growth rate and surplus production. Growth rate and condition shows no trends for 4X cod and have remained good. Surplus production has been low since 1992, but has increased recently, reflecting the improved recruitment since the 1998 yearclass.

Indicators of **mortality** show some recent divergence for 4X cod. Mortality levels have generally been high, but Relative F and SPA Z have declined in recent years while there is no trend in RV Z.

The divergence in mortality indicators is consistent with unreported catch. The continuance of high Z for commercial ages in the survey while Z for younger ages has declined is inconsistent with

high natural mortality due to predation since we would expect to see this primarily for smaller cod. There is also no indication that condition is poor and thus condition is unlikely to be leading to increased mortality for older cod in recent years. It therefore seems probable that the apparent high mortaltity shown by RV Z is primarily reflecting unreported fishing mortality.

Projections and risk analyses of the consequences of alternate TAC's (total allowable catch) cannot be provided for situations with pronounced retrospective patterns suspected to be caused by substantial problems with reported catch.

In summary, some increase in biomass for 4X cod seems likely in the short-term. Given the improvements in recruitment in the last 3 years, spawning stock biomass will increase for this stock in the coming year. If recruitment continues to exceed the levels experienced in the mid-1990s, as seems indicated from survey catches, this growth will continue for the following year. The full benefits of these recruiting yearclasses towards stock rebuilding will not be realized if mortality cannot be reduced to moderate levels. Enhanced enforcement may have mitigated the under-reporting to some extent in 2002.

Restrictive quotas for 4X cod have not been effective at reducing total mortality. The ratio of cod to haddock fishing mortality can vary greatly among gears and areas, and it will take an active effort on the part of fishermen to change their fishing patterns to alter the relative fishing mortality for these species. This alone may not be sufficient to bring F for cod below that for haddock. Fishing mortality has been higher for cod than for haddock since the early 1980's. This should be flagged as an issue to be considered in future when making management decisions.

Longer-term biomass increase and improvements in age structure for this stock are dependent on reductions in mortality rate. For this stock to return to levels observed in earlier decades, further improvement in recruitment to the long-term average is also needed.

For More Information

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Clark, D.S., S. Gavaris, and J. Hinze. 2002. Assessment of Cod in Division 4X in 2002. Can. Sci. Adv. Sec. Res. Doc. 2002/105.

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Appendix 1. Description of traffic light indicators, boundary points, weights and rationale for 4X cod.

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.

Indicator	Green (+) Boundary	Red (-) Boundary	Characteristic	Weight
Summer RV survey mean weight per tow for ages 3+	15 Consistent with the highest values	10 Consistent with the low abundance in the 1990s	Abundance	1
ITQ survey mean weight per tow for ages 3+	25 The boundaries were set by scaling it to the RV series	17 scaled to the RV series	Abundance	1
VPA SSB (ages 3+)	50000 The boundaries were set by scaling it to the RV series	30000 Scaled to the RV series	Abundance	1
RV survey age structure	6 Consistent with the highest values in the series	2 Consistent with the low abundance in the 1990s	Abundance	1
RV survey recruitment (average for ages 2+3 in a cohort)	3000 Consistent with the largest recruitment pulses	1200 Consistent with the smallest observed values	Recruitment	1
ITQ survey recruitment (average for ages 2+3 in a cohort)	16,000 Consistent with the largest recruitment pulses	10,000 Consistent with the smallest observed values	Recruitment	1
VPA recruitment (age2)	15,000 Consistent with the largest recruitment pulses	8,000 Consistent with the smallest observed values	Recruitment	1
RV survey Instantaneous Growth Rate (ages 2-7)	0.25 Consistent with the highest observed values	0.1 Below the lowest observed value	Production	1
Condition (Fulton's K)	0.9 Consistent with levels where condition is considered good in laboratory studies	0.8 Condition below which impaired spawning success is anticipated	Production	1
Surplus Production	15000 Sufficient production to sustain a healthy fishery	10000 Consistent with low production in the 1990s	Production	1
Design Weighted Area Occupied	0.7 Consistent with highest values observed	0.5 Consistent with lowest values observed	Distribution	1
RV survey local density	1.9 Consistent with highest values observed	1.3 Consistent with lowest values observed	Distribution	1
RV survey mortality (Z)	0.4 FRCP F target plus 0.2 for natural mortality	0.6 Double F target plus 0.2 for natural mortality	Mortality	1
VPA mortality (Z)	0.2 FRCP F target plus 0.2 for natural mortality	0.4 Double F target plus 0.2 for natural mortality	Mortality	1
Relative F (ages 4-8)	0.5 Boundary chosen for consistency in the 1990s with the VPA Z	0.9 Boundary chosen for consistency in the 90's with the VPA Z	Mortality	1