



Eastern Scotian Shelf Cod

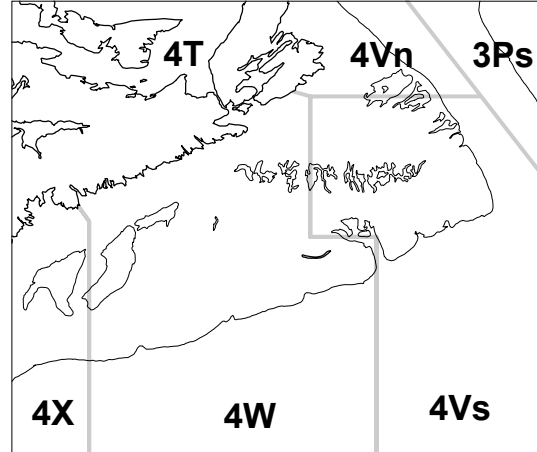
Background

The cod resource on the Eastern Scotian Shelf is a complex of spawning components including at least two major offshore groups (Western/Sable and Banquereau), smaller offshore groups (Middle Bank, Canso Bank) and a chain of smaller coastal spawning groups. The situation is complicated by the presence of both spring and fall spawning in several of the spawning components (Sable/Western offshore and various inshore areas).

Growth rates differ between 4Vs and 4W so that in the 1970's fish in 4Vs fish reached 68cm at age 7 while in 4W reached 72cm. In the mid-1980's growth declined in both areas and the average length at age 7 dropped to 59 and 54 cm respectively from 1985 to 1995.

The fishery for 4VsW cod was prosecuted primarily by foreign vessels until the extension of jurisdiction in 1977. Since that time, the Canadian offshore trawler fleet accounted for 70-75% of the landings and longliners most of the rest. Catches from 1958-79 were about 40-50% from 4Vs, however, as the stocks rebuilt in the early 1980s, the fishery shifted more to the east each year and 4Vs accounted for 60-80% of the landings from 1980-93.

The fishery was closed in September 1993 and has remained closed since then. Catches are limited to restricted bycatches in other fisheries and removals by the Sentinel program.



The most recent full assessment of this stock (DFO, 1998; Mohn *et al.* 1998) was in 1998 and was updated annually until 2002.

Summary

- The fishery has been under moratorium since 1993 and the total removals (bycatch and Sentinel program) have been less than 300 t per year since 1998.
- There are no indications that stock recovery is occurring or imminent.
- Since the moratorium, the spawning stock biomass has declined steadily in the absence of a fishery and is at or near its all-time low.
- Natural mortality on both adults and juveniles is extremely high.
- The size at age in the stock has been small but stable in recent years, providing little growth production. The fish condition has improved in the last two years although it has not translated into improved growth.
- Recruitment has been very low for more than a decade. The 1999 yearclass appears to be the largest since 1990 but is still substantially below the overall mean.

- Under the current productivity conditions (low recruitment, poor growth and high natural mortality) biomass projections indicate continuing decline for the medium term. A substantial reduction in natural mortality is required to even stabilize the projected biomass.
- The current stock size is far below any minimum biomass limits based on the stock-recruit history of this stock.

The Fishery

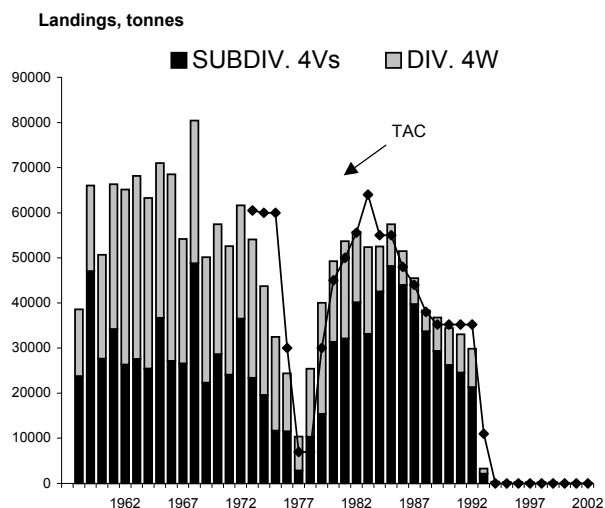
Landings (000's tonnes)

Year	58-69	70-79	80-89	90-97	1998	1999	2000	2001	2002
	Avg	Avg	Avg	Avg					

TAC	None	36.4	49.0	14.6	0*	0*	0*	0*	0*
4Vs	31.1	18.4	37.4	9.4	0.11	0.21	0.09	0.09	0.03
4W	30.7	21.8	11.9	3.4	0.16	0.09	0.07	0.06	0.06
Total	61.9	40.2	49.3	12.7	0.27	0.30	0.16	0.15	0.08

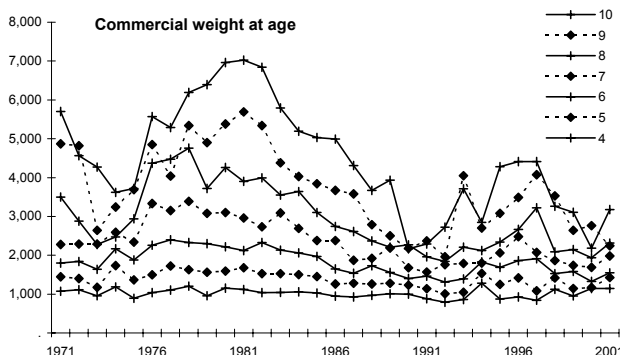
* bycatch only

The fishery has been limited to a restricted bycatch in other 4VsW fisheries (halibut, redfish and flounder) since September 1993. Current removals also include a Sentinel program which conducts a stratified longline survey and commercial index. Total catches in the Sentinel program have been less than 30 t since 1999.



Estimation of the age composition of the catch since the moratorium has been hampered by a lack of commercial or observer samples. Given that there is no directed fishery, cod landings are small, scattered and unpredictable. The catches at age for 1998 to 2002 were constructed using all available samples in a single key for each year. While this is not ideal there is insufficient sampling to partition the age-length keys and the catches themselves are small.

As with the catch at age itself, the commercial mean weights at age are poorly estimated since the fishery moratorium in 1993. The weights had begun to increase slightly in the mid-1990's but have declined again at most ages and continue to be very low. Changes in the commercial weights at age are confounded with changes in the dominance of the gears catching the cod.



Prior to the moratorium, trawlers accounted for 50-70% of the landings while since 1993 they have

accounted for 10-40%. Also the change from a directed fishery to a bycatch species has altered the distribution and timing of the little catch there has been.

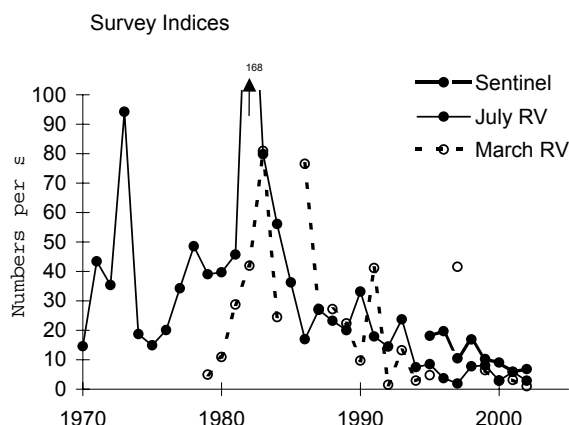
Seal Predation Removals

The potential impact of seal predation is considered here using the model of Mohn and Bowen (1996). This is the same seal population growth and total consumption assumptions as in the previous assessment. There is no indication that the growth of the grey seal population has changed from the 11% per year used in the last assessment and thus the total food consumption by grey seals is estimated to now be about 310,000t. The proportion of cod in the seal diet has been re-estimated for recent years based on Quantitative Fatty Acid Signature Analysis (QFASA). The pattern of prey fatty acids can be thought of as a prey signature that is deposited within the blubber of marine mammals in a predictable way. Fatty acids stored in blubber represent the integration of feeding over periods of weeks to perhaps months depending on the rate and degree of lipid storage. This means that the diets determined from fatty acids should not be biased by where the samples are collected. Preliminary results indicate that capelin and sand lance are dominant prey in the diets. Cod is occurring at only trace levels on average (i.e., less than 1%) suggesting that the modelled proportion of cod in grey seal diets (2.5-4% estimated for the period 1993-1997 in the last assessment), based on faecal sample data from Sable Island, was too high for the population as a whole. A constant 1% cod in the seal diet since 1993 results in an estimate of 3100t of cod consumed by grey seals in 2002. The age composition of the seal diet is still based on the estimates obtained from analysis of fish otoliths and other hard parts in the seal diet in the last assessment. Ages 1 and 2 make up over 50% by weight (>90% by numbers) of cod in the seals diet although ages up to 8 are observed.

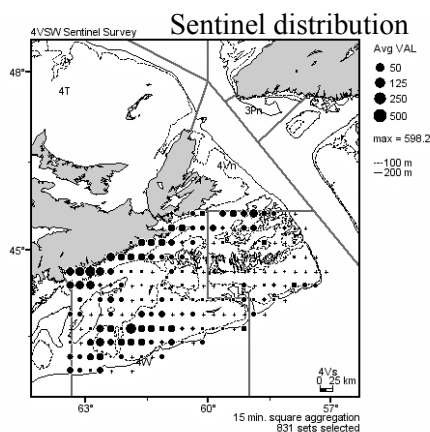
Indices of Abundance

There are now three useful indices of abundance for this stock. The July RV series runs from 1970 to 2002 without exception (recent results in Branton and Black, 2002) and the March RV series runs from 1979 to 2002 however several years were missed. The newest survey series is the 4VsW Sentinel Survey which has been conducted in

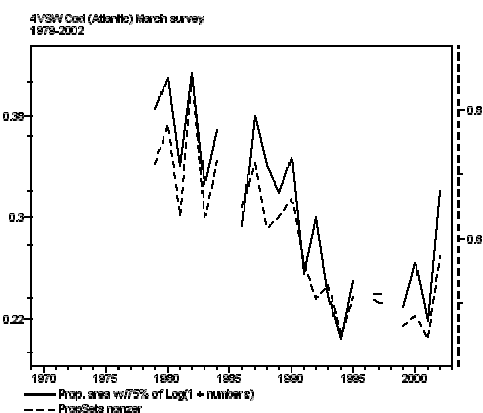
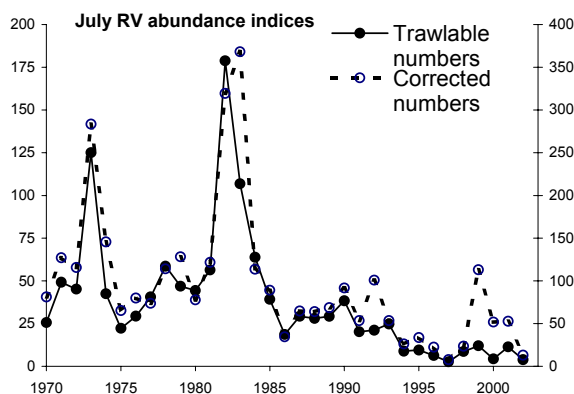
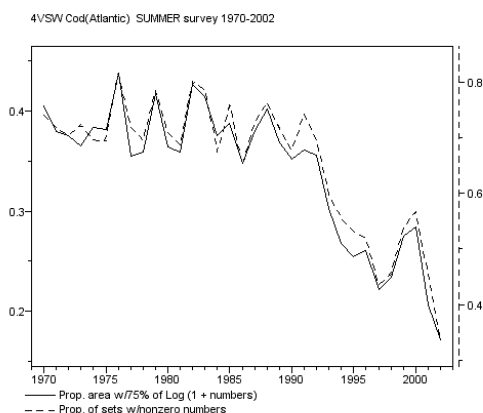
Sept.-Oct. since 1995. All three surveys use stratified random survey designs although there are some differences in the stratification schemes employed. The stratified mean catch per set in all three surveys has declined since the late 1990's and are all at or near their lowest values.



Spatial distribution of catches in all three surveys has become quite restricted. In addition to the concentration on Sable/Western Banks, the Sentinel surveys in September-October have consistently indicated an autumn aggregation in inshore strata, an area not sampled by the RV surveys.



Indices of distribution in the two RV surveys have been at low values in recent years although the March distribution appears to have expanded in 2002.

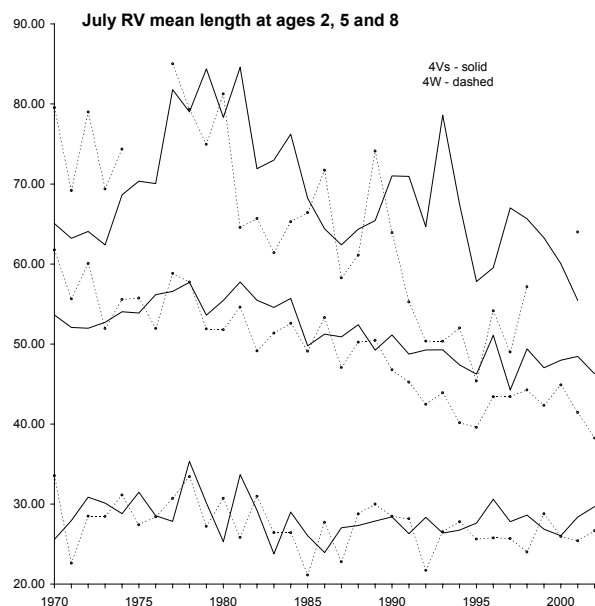


Given the very low catch in recent years the ADAPT model used in the last assessment has not been used as the primary basis for this assessment. The corrected July survey data has been used in this assessment to estimate the important population parameters.

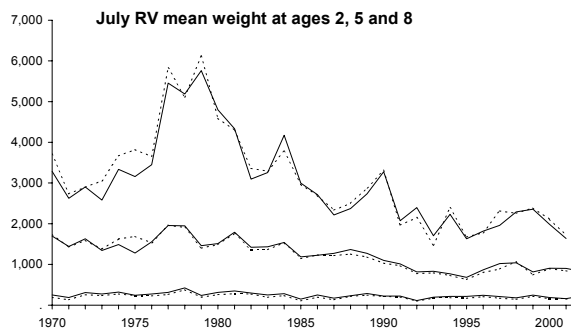
Growth and Maturity

The growth and condition of fish differs between 4Vs and 4W. The mean length at age has varied over years as well as differing between divisions. Mean lengths were higher in the period from the mid-70's to the mid-80's and have generally declined since then. The difference in mean length between 4Vs and 4W has increased in recent years with 4Vs fish larger than those in 4W.

The trawl survey data are generally used only to produce relative indices of abundance because the catchability at length, even for a species as well studied as cod, is poorly known. A length-specific catchability correction is applied to the July survey data to account for the very low catchability of small individuals. The resulting corrected survey total numbers at age are a reasonable proxy for total population estimates. Comparison of trawlable (i.e. uncorrected for catchability) and corrected estimates shows that the corrected numbers (left axis) are about double the trawlable estimates (right axis).

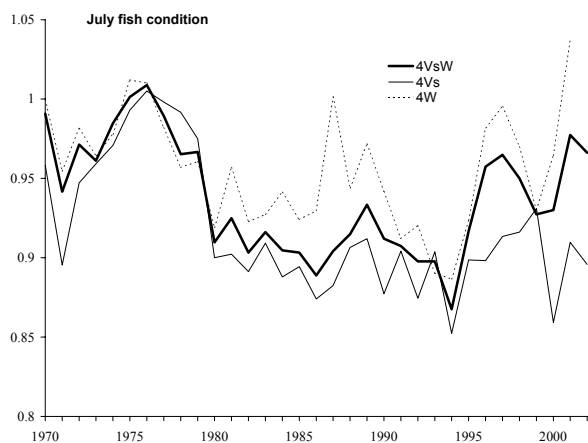


minor and the corrected weights are used subsequently for consistency with the corrected RV numbers. The mean weights of younger ages show little trend and are generally close to the long-term mean. Older ages (3+) are well below their long term means ranging between 60% and 80% of the averages.



This must be interpreted carefully as it comes from very small sample sizes in 4Vs. The bulk of the survey catches are taken in 4W (>85% of numbers since 1999) and those sizes are more representative of the population as a whole.

Fish condition is estimated from survey length and total weight data. Overall condition has been improving in 4VsW since the mid-1990's, more so in 4W than 4Vs.



Mean weights at ages 2, 5 and 8 are compared between estimates based on the stratified survey length frequencies (solid) and catchability corrected length frequencies (dashed). The difference in mean weights between the methods is generally

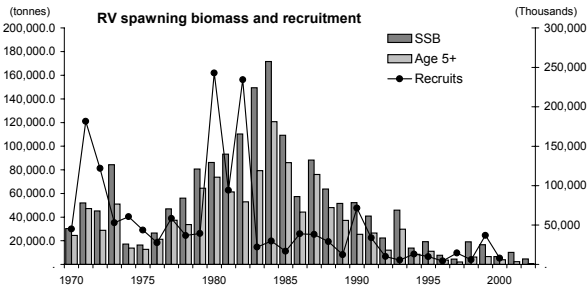
Maturity at length has increased for smaller fish since the 1970's. The changes in maturity at length are somewhat offset by reduced length at age but the age at 50% maturity has declined. In previous assessments the age 5+ biomass was used as a proxy for SSB but this is not appropriate when trends exist in both size at age and size at maturity. Based on the March survey data (near the spring spawning time) the maturity schedule has been revised to account for the changes noted.

Maturity schedule for 4VsW cod SSB

	Ages 0-2	Age 3	Age 4	Age 5+
prior to 1979	0.0	0.0	0.5	1.0
1979-1994	0.0	0.25	0.75	1.0
after 1994	0.0	0.5	1.0	1.0

Resource Status

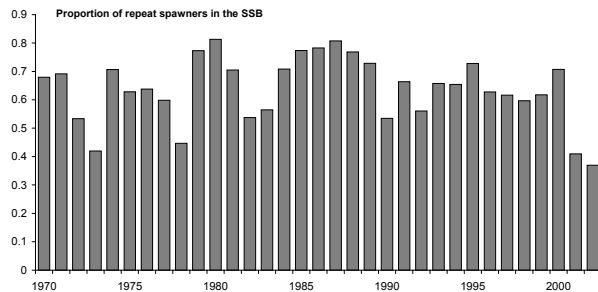
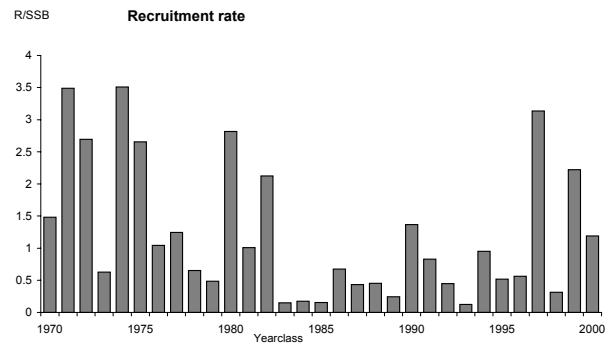
The SSB is calculated from the *q*-corrected survey numbers, the survey weights at age and the new maturity schedule. The effect of the change in maturity is seen by comparing the SSB to the age 5+ biomass. The corresponding age 2 recruitment estimates are from the corrected survey numbers. The biomass estimates for 2002 are at or near the lowest values for either SSB or 5+. The 1999 yearclass at age 2 appears to be the largest since 1990 but is still substantially below the overall mean.



The recruitment rate (recruits/kg of spawners) shows that several recent yearclasses have been at or above the average. The 1999 yearclass has shown up strongly above average at ages 0 and 2. The estimate of the 1997 yearclass is questionable as it comes from a single strong estimate at age 2 and corresponds to a very low estimate of SSB i.e. a survey year effect. In spite of the various caveats, it seems likely that at least one or more recent yearclasses have been more productive (i.e. higher R/SSB) than those from 1983 to 1996.

Recent work has shown that the reproductive potential of a stock is not fully described by the SSB. It is affected by the size, condition and reproductive history of the individuals in the spawning stock. Larger, older and repeat spawners make disproportionately larger contributions to production of viable eggs and larvae.

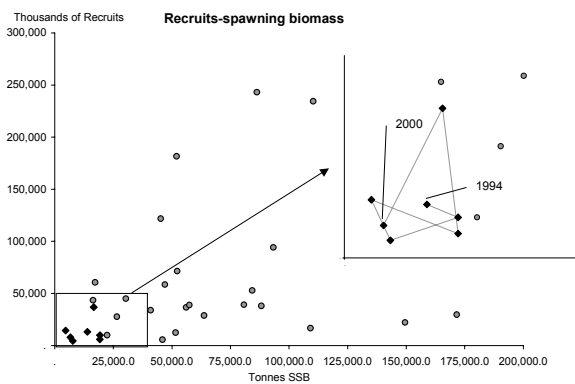
The proportion of the SSB made up of repeat spawners in the population is currently at the lowest proportion in the survey series.

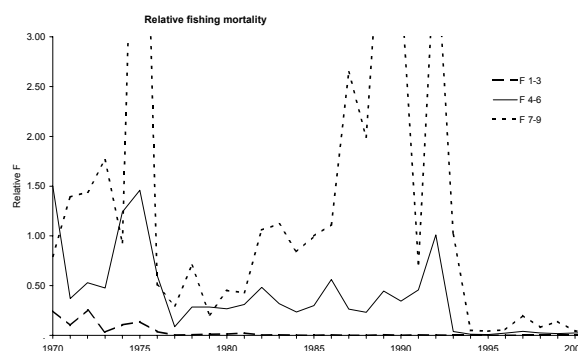
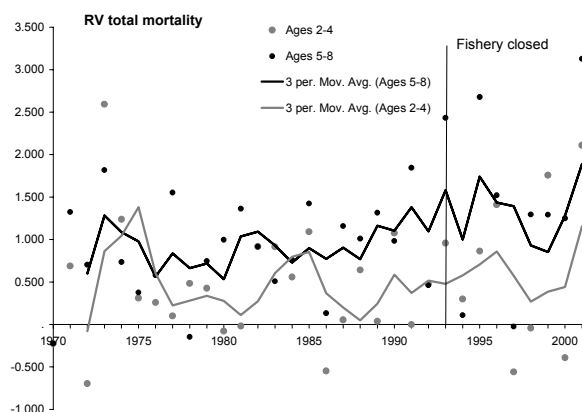


Total Mortality

Estimates of total mortality (Z) between ages along cohorts were computed from the q -corrected survey population numbers. The means of two age groups (ages 2-4 and age 5-8) are representative of the trends in the younger and older parts of the stock.

The stock-recruit plot based on the q -corrected survey data indicates that all the recent yearclasses (1994 to 2000) are near the origin i.e. with both low SSB and low recruitment.





The Z's appear to have been increasing more or less continuously since the mid-1980's (ages 5-8) or late 1980's (ages 2-4). Although the younger group would not likely have been targeted in the fishery, the older group was the main part of the catch. In spite of that, neither age group shows a noticeable decrease in Z with the closure of the fishery in late 1993.

The Z since 1993 can be taken as an estimate of natural mortality (M) as the fishery catches have been negligible and indeed F is almost inestimable with SPA. The M (=Z) on the older ages has been about 1.0 and trending up. While the younger age group is lower, about 0.5, it is an underestimate due to changing catchability with age (see below) and is also trending upward.

The fact that the mean Z at younger ages averaged over years since the fishery was closed is higher than for older ages suggests that the correction applied is insufficient for the younger ages.

Fishing Mortality

The relative fishing mortality is computed as the ratio of the catch numbers at age over the q -corrected July RV numbers at age. If the RV catchability corrections were completely accurate these mortality estimates would be absolute estimates of fishing mortality although still affected by the high variability in the RV estimates. Given the bias in the catchability corrections noted above the estimates for the youngest age group are likely overestimates of the actual F. There has been a steady increase in F over the period from 1977 to the closure of the fishery in 1993. Fishing mortality has been essentially zero since then.

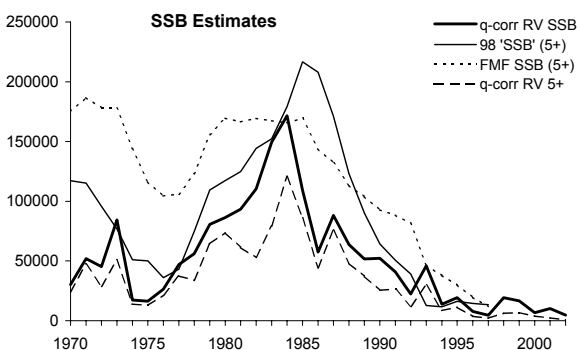
Surplus Production

The stock surplus production is the amount of biomass potentially available for fisheries yield in a given year. It is estimated as the change in biomass between two years plus the catch. Over the 10 years since the moratorium, the stock has lost on average more than 5000 t in biomass per year even without a fishery.

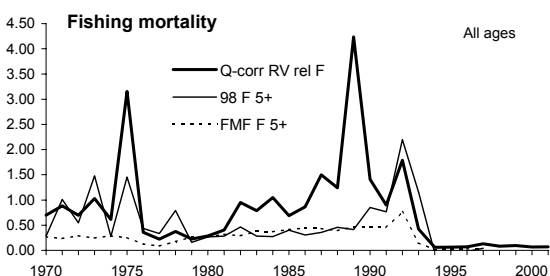
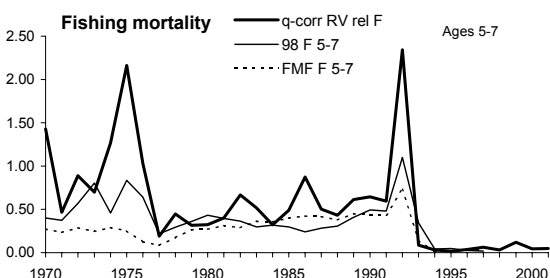
Under the current productivity conditions (low recruitment, poor growth and high natural mortality) biomass projections indicate continuing decline for the medium term. A substantial reduction in natural mortality is required to even stabilize the projected biomass. The current stock size is far below any minimum biomass limits based on the stock-recruit history of this stock.

Comparison with other studies

In addition to the RV based estimates of population parameters presented in this assessment there are population reconstructions from other studies. The results of the current assessment are compared with those from the last assessment of this stock (Mohn *et al.* 1998) ('98') and a recently published analysis (Fu *et al.* 2001) (FMF). The impact of the new maturity schedule used in this assessment (q -corr RV) is included by showing the 5+ biomass as used in the earlier reconstructions. All of the analyses agree that the current SSB has declined to a small fraction of what it was in the 1980's. The FMF model suggests a much higher historical SSB than any of the other estimates but is consistent with the others since the mid-1980's.



The fishing mortality estimates from the current assessment and the two earlier reconstructions are highly consistent for ages 5-7 through the time series. The closure of the fishery in 1993 has reduced the fishing mortality to nearly 0. When all ages are considered i.e. average 5+ F, there is a substantial difference between the estimates in the 1980's and early 1990's where the relative F from the q-corrected survey was indicating much higher mortality than either population reconstruction estimated.



stock although all estimates agree that the 1980's was an improvement over the mid-1970's.

The *q*-correction estimates used in this assessment incorporate various assumptions in both the underlying estimates and the meta-analysis. It appears that the implicit mortality assumptions in those *q*'s are still inadequate to fully correct the RV estimates for catchability at the younger ages (i.e. smaller sizes).

Predation mortality by grey seals on both juvenile and adult cod has been estimated based on a small amount of data and numerous assumptions. The resulting diet and consumption estimates are undoubtedly better than making no estimates of seal consumption but the specific estimates used here can be improved with more information.

Outlook

The outlook from the last Stock Status Report (DFO, 1998) for this stock, based on assessment of the stock (Mohn et al., 1998) was as follows:

“The short-term prospects for this fishery remain dismal. The productivity of the stock is very low, there are several factors causing increased mortality overall as well as seal predation on the younger age groups. The spawning stock biomass, while not declining, has not rebuilt since the closure of the fishery.”

There are no indications that stock recovery is occurring or imminent. Moreover, it is obvious that the spawning stock biomass has declined steadily in the absence of a fishery and is at or near its all-time low. Natural mortality on both adults and juveniles is extremely high. The size at age in the stock has been stable at small sizes providing little growth production. The fish condition has improved in the last two years although it has not translated into improved growth. Recruitment has been very low for more than a decade. The 1999 yearclass appears to be the largest since 1990 but is still substantially below the overall mean.

Sources of Uncertainty

A variety of means of determining stock status show considerable agreement with respect to the current very poor status of this stock. There is greater uncertainty about the historical size of the

For More Information

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