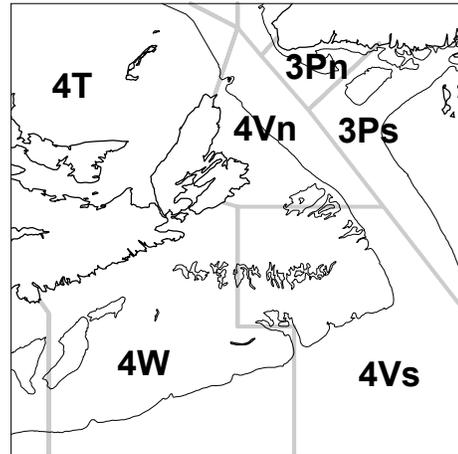




Eastern Scotian Shelf Haddock (Div. 4TVW)



Background

The haddock (*Melanogrammus aeglefinus*) resource on the eastern Scotian Shelf and southern Gulf of St. Lawrence is considered a single management unit distinct from the adjacent stock in 4X. The majority of 4TVW haddock occur on the offshore banks of the Scotian Shelf ranging from Emerald Bank in the west to Banquereau in the east.

Haddock prefer hard sand or gravel bottoms at depths ranging from less than 50m to about 350m, and temperatures ranging from 4-8°C. During summer haddock are distributed on the tops of banks while in winter months they move to deeper waters to avoid cold temperatures. Spawning occurs in spring and the principal spawning areas are the complex of banks in 4W including Emerald, Western and Sable Island banks. In the past, these spawning aggregations were the target of intense fisheries until the imposition of a closed area, which encompasses Emerald and part of Western banks in 1987.

Recent studies on haddock egg production have revealed that female haddock produce fewer eggs at a specified length than any other stock in the North Atlantic. For example, a 45cm haddock produces about 150,000 eggs each year. The eggs, which are liberated near the bottom, rise to the surface during an average incubation period of two weeks. During the first year of life, young haddock actively feed on plankton in the surface waters and gradually descend to the bottom as juveniles in mid-summer. Thereafter, they remain on bottom, feeding and growing at a rate of about 5-10cm (2-4 inches) in length per year. When sexual maturity is reached after 3-5 years, growth rates diminish. Haddock are relatively long-lived (>10 years) and age is determined from the pattern of rings in their otoliths (earbones).

Since 1987, the haddock fishery has been regulated through a combination of by-catch restrictions and trip limits. The year-round nursery ground closure established in 1987 (initially exempt to fixed gear) remains in effect. In 1993 the area was closed to all groundfish fishing.

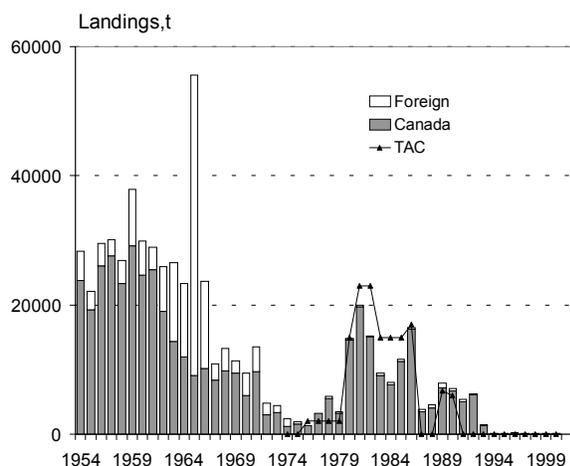
Summary

- Since closure of the fishery, spawning biomass has steadily increased and is now slightly above the 1970-2001 average.
- Abundance of haddock has increased greatly but this has been predominantly by fish less than 42cm. The abundance of haddock 42cm and larger has remained very low throughout the 1990s.
- The 1998 yearclass is above average and the 1999 yearclass is exceptional.
- The area occupied by 30+cm haddock declined in the mid-1980s and recently has stabilized near the average of the RV time series.
- Poor growth, low condition, maturity at a smaller size and high natural mortality have typified the production of this stock in recent times.
- Minimization of removals continues to be appropriate in the short term.

The Fishery

Landings, t							
Year	1970-79 Avg.	1980-89 Avg.	1990-97 ¹ Avg.	1998	1999 ²	2000 ³	2001
TAC	1,333	12,970					
Total	5,023	11,254	2718	177	81	71	98

- 1 1990 TAC was 6000t, by-catch or closure since.
- 2 Fishing year, landings, and TAC refer to 15-month period from January 1, 1999, to March 31, 2000.
- 3 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.



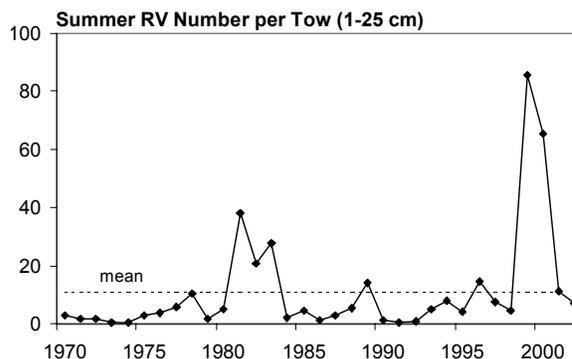
Annual **landings** averaged about 25,000t from 1960 to 1969, 5,000t from 1970 to 1979, and 11,300t from 1980 to 1989. Since 1987, the fishery has been regulated through a combination of TAC, by-catch restrictions and trip limits. The fishery was closed in the fall of 1993. The FRCC has repeatedly recommended that there be no directed fishery, that closure of the haddock box to all groundfish sectors remain in effect, and that restrictive by-catch measures be maintained in all fisheries directed at other species. All of these measures have been adopted. Strict by-catch restrictions have been in existence, with a 5% overall cap (percentage of the total of all other quota groundfish species) for mobile gear and a 10% overall cap on fixed gear. A small fish protocol also exists and haddock less than 43 cm are

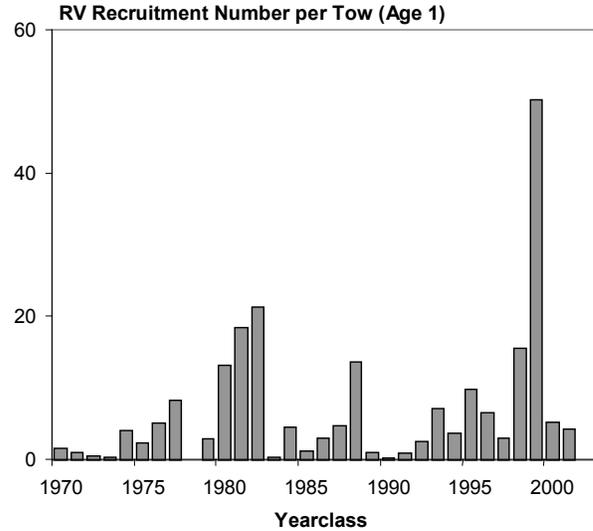
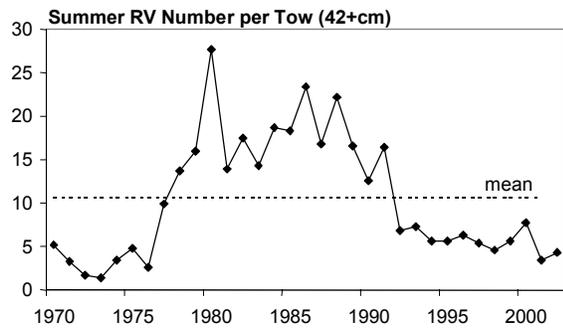
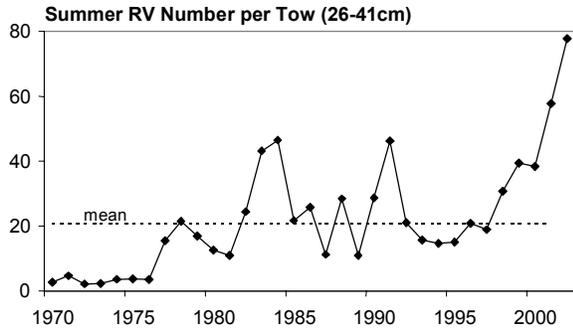
considered to be undersized. Average total landings from 1994 to 2000 were about 140t. Landings to October 24, 2002, have amounted to 69t. The year-round nursery ground closure (mainly Emerald and Western banks) imposed in 1987 remains in effect to present.

Resource Status

The evaluation of stock status was derived from reported landings, shore and at-sea based samples taken from commercial landings for size and age composition, research vessel (RV) surveys conducted in March and July, and a fixed-gear Sentinel Survey conducted in the fall.

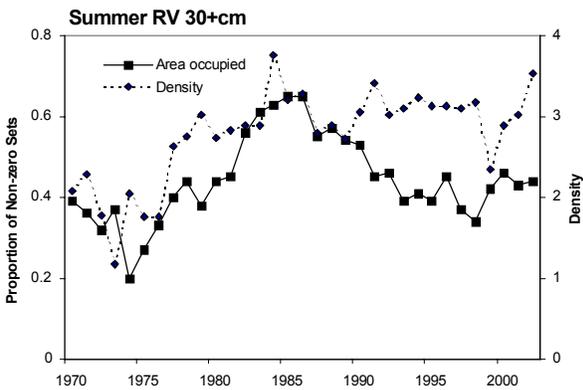
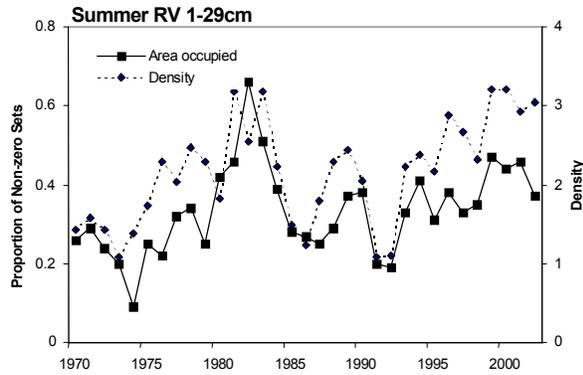
Abundance trends for three size categories (1-25, 26-41, and 42+cm) of haddock, derived from the DFO **summer RV survey**, were examined. Abundance of the smallest sizes increased dramatically in 1999 and 2000, exceeding any previous observation in the series. Abundance of the intermediate sizes have also increased, having risen steadily since 1997. The abundance of haddock 42+cm was considered an index of the fishable component of the stock. Number per tow has remained consistently below the long-term average of 10.6 fish per tow since 1992.



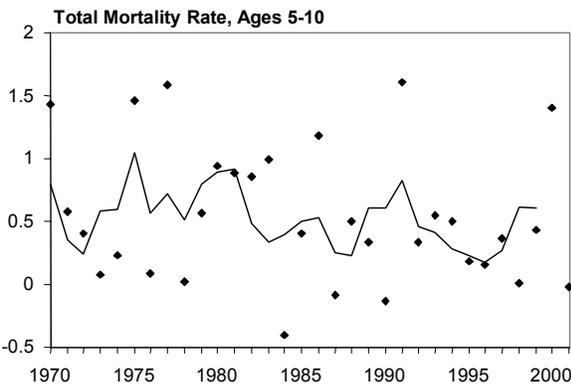


Recent **recruitment**, based on the number per tow at age 1, was slightly above average in 1995 and near average in 1996. The 1998 yearclass was above average and comparable to some previously large yearclasses. It should be noted that the age 2 estimate of the 1998 yearclass in 2000 was the highest observed in the survey series. The 1999 yearclass is exceptional, exceeding any yearclass estimate at age 1 by more than a factor of two since 1970. The 2000 and 2001 yearclasses are estimated to be slightly below average

A measure of how widely a stock is distributed within its historical geographical range (**area occupied**) was evaluated for two haddock size groups: 1-29cm - a reflection of recent recruitment and a larger size group - 30+cm. Local **density** or the average number of haddock within the area occupied was also evaluated. Since the early 1990s, haddock 1-29cm have become increasingly widely distributed. Local density has also increased during this time period, reaching levels similar to those observed during the early 1980s. Since the mid-1980s, the area occupied by 30+cm haddock exhibited a declining trend whereas local density has remained relatively stable over the same period. Recent RV surveys show that the principal areas of distribution continue to be the offshore banks associated with the haddock box for both haddock size groups.

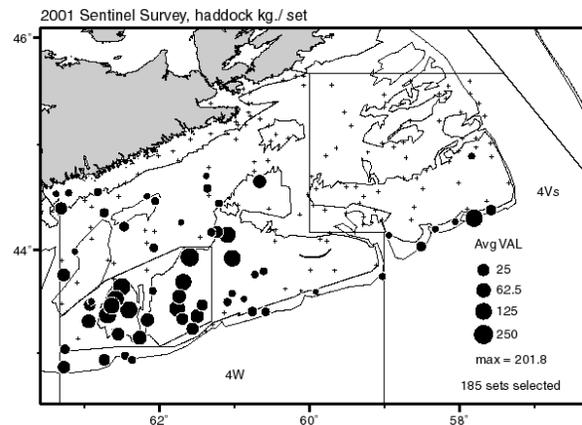


Total mortality estimates for adult haddock were derived from the summer survey. Mortality has averaged about 0.35 since the mid-1980s, which includes the recent period of fishery closure. Total mortality during the period since closure provides an estimate of natural mortality (including predation, disease, immigration/emigration) which averages 0.38 for the period 1994-2001.

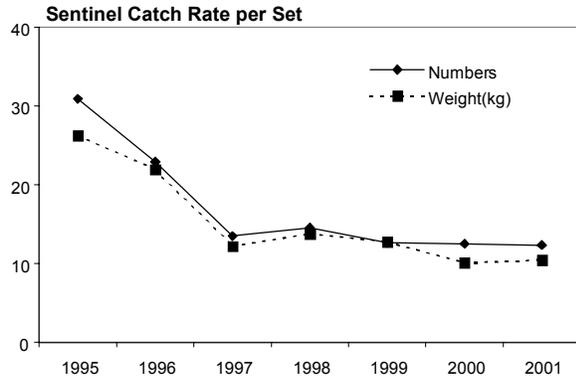


A fixed gear **Sentinel Survey**, involving commercial long-line vessels, has been in place in Div. 4VsW since 1995. It is based on a stratified, random survey design, utilizing the same stratification scheme as the DFO July RV survey. This design allocated 237 pre-selected set locations up until 2000, and 185 thereafter. The survey starts in September of each year.

The geographic patterns of haddock catches have been consistent from year to year. In the 2001 Sentinel Survey, haddock were concentrated within the Emerald/Western closed area and around its perimeter. Smaller catches occurred to the east along the flanks of Sable and Banquereau banks and the Gully. The annual percentage of haddock inside the closed area for each year ranged from 53 to 86%.



Stratified mean catch rates were highest in 1995 (>25 kg/set), declined in 1996 and 1997 and have remained low (<15 kg/set) since. Trends in numbers per set paralleled this pattern.

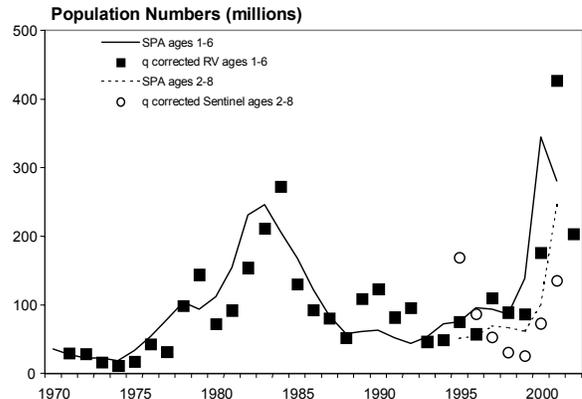


A single mode in the length composition was evident in 1995 and 1996 with catches peaking around 42-46cm and falling off rapidly at larger sizes. In subsequent years, catches were lower across most sizes.

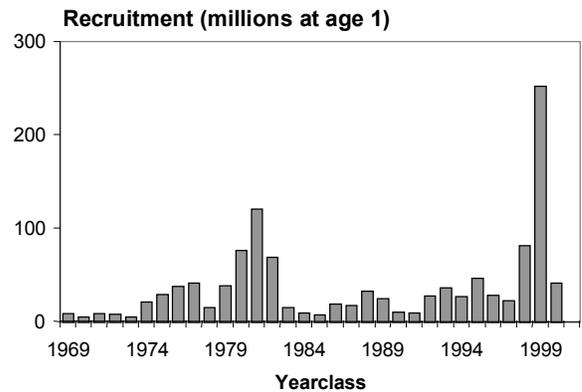
A **sequential population analysis (SPA)** was conducted using both the July RV survey and the September Sentinel Survey. Prior to the 2001 assessment, **natural mortality (M)** of 0.2 was assumed to be constant. However, estimates of M have averaged about 0.35 since the mid-1990s, which includes the recent period of fishery closure. In addition, growth and maturity differed before and after the mid-1980s: haddock exhibited relatively high growth/late maturity compared to the later period of low growth/early maturity. It is for these reasons that M for all age groups was set at 0.2 from 1970 to 1984 and 0.35 from 1987 to 2001. An incremental ramp in M was used for the intervening years. The fit of the model was better than that using either a constant M of 0.20 or 0.35. Population trajectories were similar for all models.

Comparisons were made between the SPA model predictions and observations of population abundance from the July RV and Sentinel Survey, corrected for the estimated catchability

(q). Good agreement was evident between the model and July RV results. However, the model fit to the sentinel survey abundance estimates was not as good. This can be attributed, in part, to the shortness of the time series. Other model diagnostics were deemed acceptable.

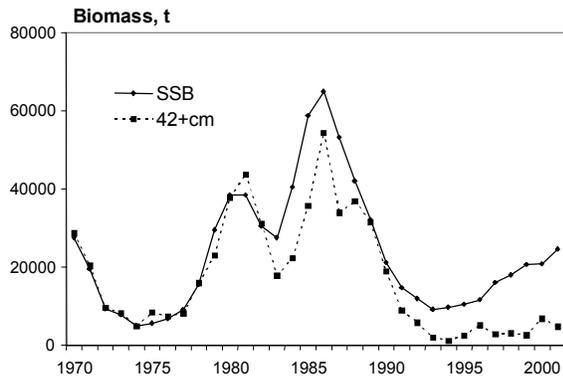


The SPA estimates of **recruitment** have been improving since the closure of the fishery. The 1998 yearclass is above average and the 1999 yearclass is exceptional.

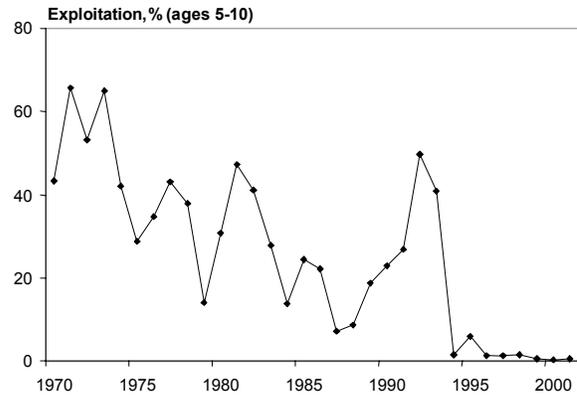


Spawning stock biomass (SSB) has been increasing since closure of the fishery and is now slightly above the 1970-2000 average of about 24,000mt. The long-term (1948 -2000) average SSB for this stock is about 39,000mt. The fishable biomass (42+cm), has increased only slightly and remains well

below the 1970-2001 average of 18,000mt. Because of declining size at age (see Section on *Population Considerations*), the age groups contributing to the fishable portion of the population have changed and included ages 4 and older during 1970-1983, ages 5 or 6 and older from 1984-1992, and ages 7 and older from 1993 to present.

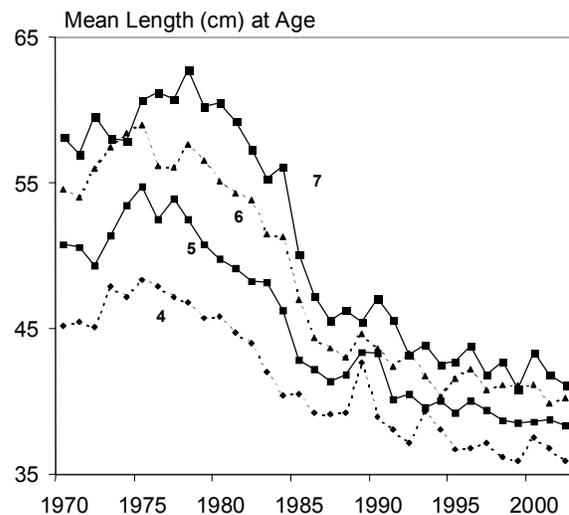


The **exploitation rate** was very high during the early 1970s when the fishery was unregulated. Exploitation declined after 1974 when catch quotas were first imposed, reaching a low in 1987 when mobile gear effort was eliminated from the Emerald/Western juvenile haddock closed area. Exploitation rates rose steadily thereafter and peaked in 1992 at >50%. This pattern reflected the expansion of the fixed gear fishery inside the closed area and a declining resource. Concern over the intensive effort resulted in removal of the fixed gear fishery from the closed area in 1993. Since the closure of the fishery in 1994, exploitation rates have been very low.



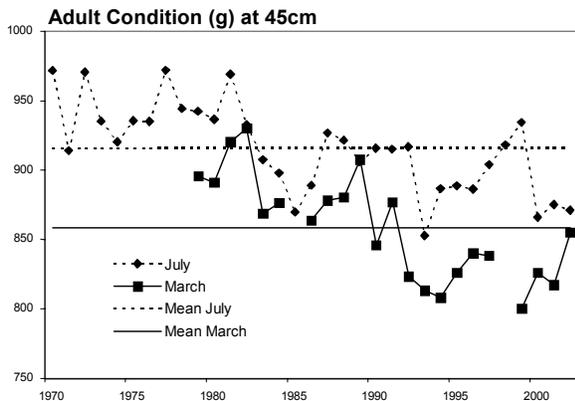
Population Considerations

Substantial long-term declines in **size at age** are evident in haddock age 4 and older. At present, very few fish in the stock are larger than 42cm (17 inches). Haddock are now considerably smaller at age than those seen during the 1970s to mid-1980s. One implication of this finding is that if slow growth persists, it will take 6-7 years for new yearclasses to reach 42+cm.

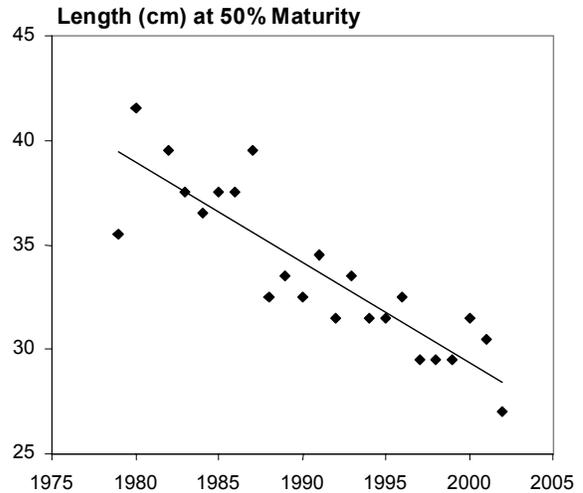


Condition, the relative weight of the fish at a given length (an index of the health of the fish in a stock) is derived from the July and March RV surveys. Adult haddock exhibited higher than average weight throughout the 1970s and early

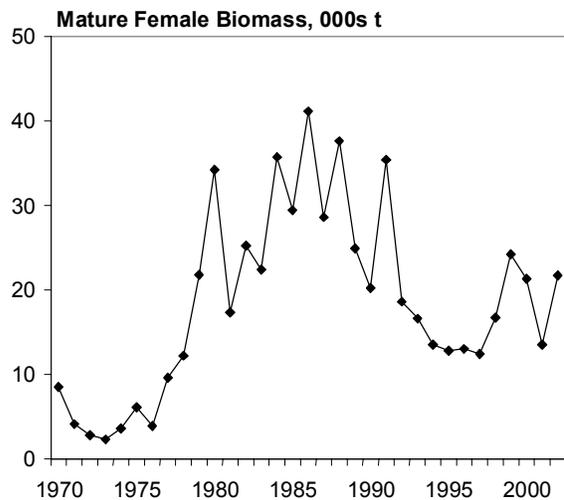
1980s whereas during the remainder of the series, weights were generally below average. Since 1993, adult haddock body weight has been below average in eight out of ten years. Unlike the adults, juvenile haddock do not show trends in condition.



Maturity at length data has been collected during the March survey since 1979. It has revealed that the length at 50% maturity has been declining. Also, an increasing proportion of females ranging in size from 22-31cm are becoming mature in recent times (currently between 20-30% compared to less than 10% during the 1980s). Maturing at such a small size and lower age could be contributing to the reduced growth potential of haddock.

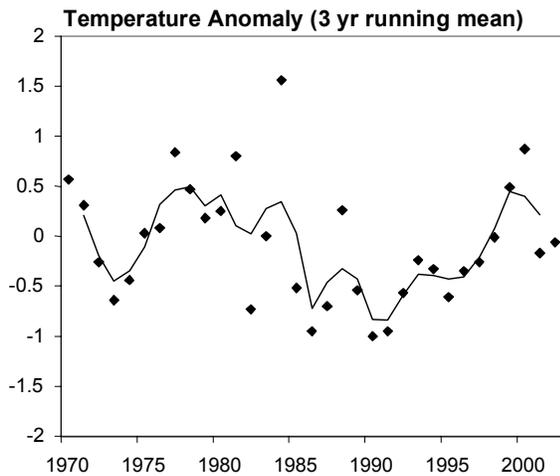


Adjusting the survey biomass per tow at length data from the July RV survey by the proportion of mature females at length, yielded an index of spawning stock biomass. **Mature female biomass** has remained below the 1970-2001 average since 1991 and since 1999 are at near-average levels.



Temperature conditions at 100m from the Misaine Bank region are considered to be representative of the sub-surface thermal conditions on the northeastern Scotian Shelf (Div. 4Vs) and eastern sections of Div. 4W. Temperatures peaked during the later half of the 1970s and slowly declined to a minimum in the

early 1990s. Temperatures have since been rising and have reached above the 1961-1990 average during the last three years. The general trends in temperature, with the exception of the last three years, parallels the changes in size at age seen in age 3 haddock and older with higher growth being associated with warmer temperature and lower growth with colder temperatures.

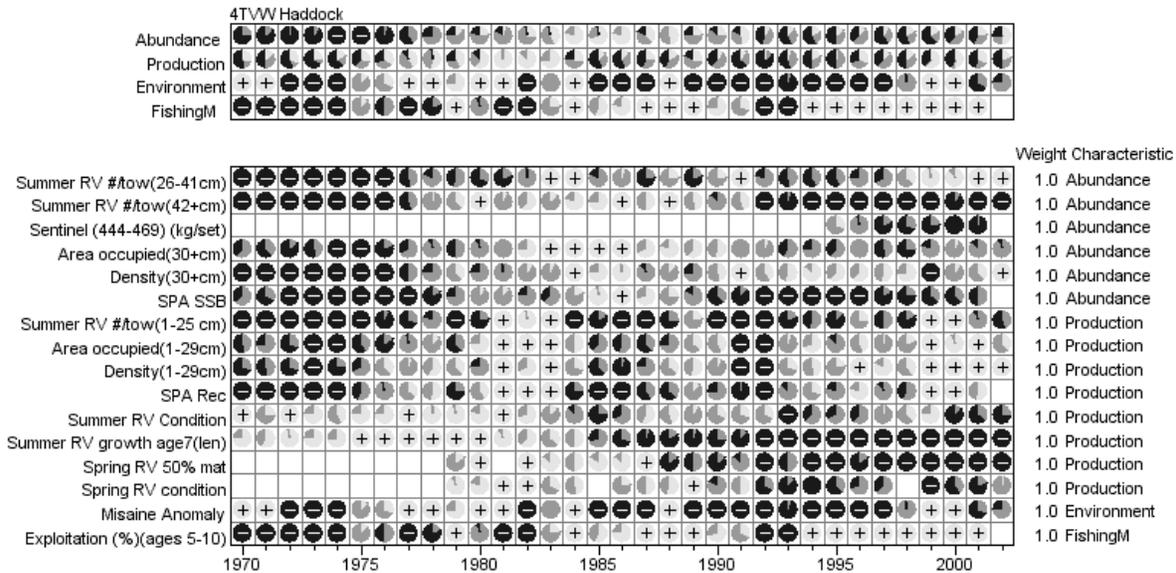


Traffic Light Analysis

The **Traffic Light** table summarizes 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 description of traffic light indicators, boundary points, weights and rationale.

Outlook

Indicators of **abundance** include information from the summer survey, the Sentinel Survey and a SPA reconstruction of the stock. Intermediate sized haddock (26-41 cm) (summer RV #/ tow (26-41cm)) have been steadily increasing and the highest value in the series occurred in 2002. The summer RV number per tow of haddock 42+cm (summer RV #/tow (42+cm)) has remained very low throughout the 1990s, and the 2002 estimate is among the lowest observed. Spawning stock biomass (SPA SSB), based on the SPA,) has been steadily increasing since closure of the fishery and in 2001 slightly exceeded the 1970-2001 average. Recent survey estimates of SSB show a similar increasing trend, although the 2001 estimate was below the 1979-2001 average. The Sentinel Survey catch rate (Sentinel (444-469)(kg/set)), which selects for larger haddock, exhibited a declining trend since the initiation of the survey in 1995.

Area occupied of 30+cm haddock (Area occupied (30+cm)) is largely restricted to the closed area and is near the average of the time series. Local density of 30+cm haddock (Density (30+cm)), has not shown a trend since the mid-1980s.

Some of the **production** indicators have been increasing since closure of the fishery. SPA (SPA Rec) and RV (summer RV #/tow (1-29cm)) estimates of recruitment at age 1 show that the 1998 yearclass is above average, while the 1999 yearclass is exceptional. Area occupied of 1-29 cm (Area occupied (1-29cm)) haddock has been increasing since 1995, and the 1999 to 2002 estimates are comparable to the early 1980s estimates when strong yearclasses occurred. Local density of 1-29 cm haddock (Density (1-29cm)) has been increasing since 1992. Condition factors (Summer RV condition) have a general downward trend and have been below average since the early 1990s. Growth (Summer

RV growth age7 (len)), based on size at age 7, steadily declined throughout the late 1980s/1990s, which was preceded by a more rapid decline during the mid-1980s.

Since closure of the fishery, **fishing mortality** rates (Exploitation (%)(ages 5-10)), expressed as exploitation, have been low (less than 2% since 1995). Prior to the collapse of the fishery, exploitation rates were more than twice the $F_{0.1}$ level of 20%.

Temperature anomalies from the Misaine Bank region were positive during 1999 to 2001 for the first time since 1985 (Misaine Anomaly). They provide an indicator of the **environment** of the eastern Scotian Shelf and have coincided with changes in the productivity of haddock and other stocks in the region. Declining productivity (e.g. poor growth and high natural mortality) has been evident in both haddock and cod in the region since the initiation of the cooling trend in the mid-1980s. Recent increases in bottom temperature conditions may change this trend in productivity.

In summary, Div. 4VW haddock currently is an early maturing stock exhibiting poor growth (both under-weight and under-length) and high natural mortality. The area occupied by the 30+cm portion of the stock is near the average of the time series. However, the stock has recently produced good to excellent recruitment. The next few years will be pivotal to this stock given recent strong recruitment and improvement in environmental conditions. If growth and survival improve, this could lead to a rapid increase in biomass and recovery of historical productivity. If, however, poor growth, early maturity and high natural

mortality persist, there will be a slow or negligible increase in biomass and low stock productivity dominated by small fish. At this time, it is uncertain which production scenario the stock will follow. In either case, minimization of removals continues to be appropriate in the short term.

For More Information

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- Frank, K.T., R. K. Mohn, and J.E. Simon. 2001. Assessment of Div. 4TVW haddock. DFO Can. Sci. Adv. Sec. Res. Doc. 2001/100.

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

Indicator	Green (+) Boundary	Red (-) Boundary	Characteristic	Weighting
Summer RV #/tow (26-41cm)	40 – Top four estimates observed; all preceded by strong yearclasses	7 – Lowest observed (1970-76)	Abundance	1
Summer RV #/tow (42+cm)	20 – Top three estimates when stock at peak levels during 1980s	7 – Low values that coincide with periods of collapse	Abundance	1
Sentinel (444-469) (kg/set)	35 – Never observed in survey; considered good catch rate	10 – Near to lowest catch rates recorded in past few years	Abundance	1
Area occupied(30+cm)	0.6 – Contains top four observations when stock widely distributed in 1980s	0.3 – Encompasses two observations during the early 1970s	Abundance	1
Density(30+cm)	3.3 – Contains two highest observations; may be unresponsive indicator	2.4 – Contains estimates associated with 1970-1976	Abundance	1
Summer RV #/tow (1-25 cm)	21 -- Contains early 1980s and recent peaks	3 -- Contains lowest observed values in 1970s, 1980s and 1990s	Production	1
SPA SSB	60000 – Based on historical series and similarity of mid-1980s SSB to that earlier period	12000 – Captures both mid-1970s and mid-1990s minimum	Abundance	1
Area occupied (1-29cm)	0.45 – Captures strong yearclasses in early 1980s and recent ones with wide distribution	0.2 – Associated with three lowest values and lowest R estimates	Production	1
Density (1-29cm)	2.8 – Contains early 1980s and late 1990s observations	1.2 – Among lowest observed	Production	1
SPA Rec	50000 – Based on historical series; captures early 1980s and recent strong yearclasses	10000 – Among lowest observed	Production	1
Summer RV Condition	945 – Contains several observations during 1970s/early 1980s when stock recovered rapidly	860 – Contains one observation	Production	1
Summer RV growth age7(len)	60 – Largest body sizes observed during 1970s/early 1980s	45 – Contains most of the data from early 1990s onward	Production	1
Spring RV 50% maturity	38 – Larger sizes associated with higher fecundity and better egg quality	32 – Small sizes associated with low fecundity and poor egg quality	Production	1
Spring RV condition	900 – Among highest observed	808 – Among lowest observed	Production	1
Misaine Temperature	0.25 – Captures high values in the late 1970s/early 1980s when condition and size at age were high	-0.25 – Associated with mid-1980s/mid-1990s when capelin and other cold-water sp. flourished	Environment	1
Exploitation (%) (ages 5-10)	20 – F0.1 reference level	40 – Twice F0.1 reference level	Fishing Mortality	1