



Eastern Scotian Shelf Haddock (Div. 4TVW)

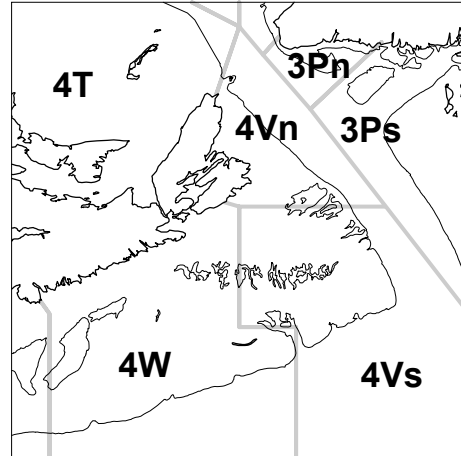
Background

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 50 m to about 350 m, 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 45 cm 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 5-10 cm (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

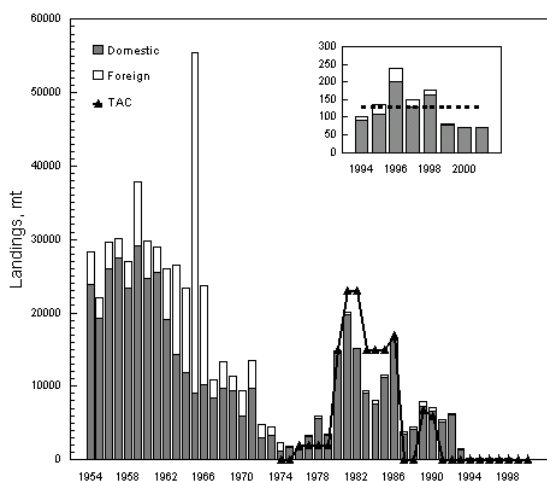
- Since closure of the fishery, spawning biomass has steadily increased but remains below the long-term average.
- Abundance of haddock has increased greatly but this has been predominantly by fish less than 42 cm. The abundance of haddock 42 cm (the historical fishable size limit) and larger has remained very low throughout the 1990s.
- Recent recruitment looks particularly strong. The 1998 year-class is the highest observed since 1970 and the 1999 year-class appears strong as well.
- The area occupied by adult haddock has been declining since the mid-1980s and currently the stock is concentrated in the closed area.
- Poor growth, low condition, early maturity and high natural mortality have typified this stock in recent times.
- Minimization of removals continues to be appropriate in the short term.

The Fishery

Landings, t

| Year | 1970-79 | | 1980-89 | | 1990-96 | 1997 | 1998 | 1999 | 2000 |
|-------|---------|--------|---------|------|---------|-------|-------|-------|-------|
| | Avg. | Avg. | Avg. | Avg. | | | | | |
| TAC* | 1,333 | 12,970 | --** | --** | --*** | --*** | --*** | --*** | --*** |
| Total | 5,023 | 11,254 | 3085 | 151 | 177 | 81 | 71 | | |

* = no TAC from 1970-73
 ** = no TAC from 1991-96, 1990 TAC was 6000t
 *** = by-catch only



Annual **landings** averaged about 25,000t from 1960 to 1969, 5,000t from 1970 to 1979, and 11,400t from 1980 to 1989. Since 1987, the fishery has been regulated through a combination of 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 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 140 t. Landings to September 2001 have amounted to 75 t. The year-round nursery ground closure (mainly Emerald and Western banks) imposed in 1987 remains in effect to present.

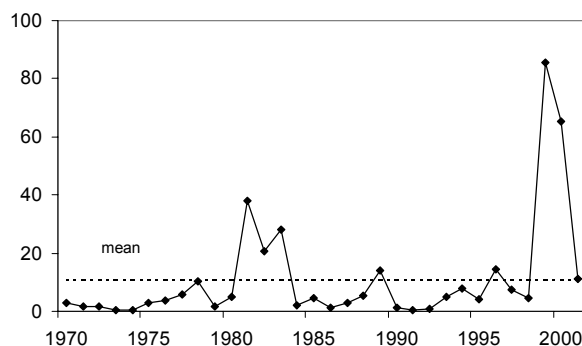
Resource Status

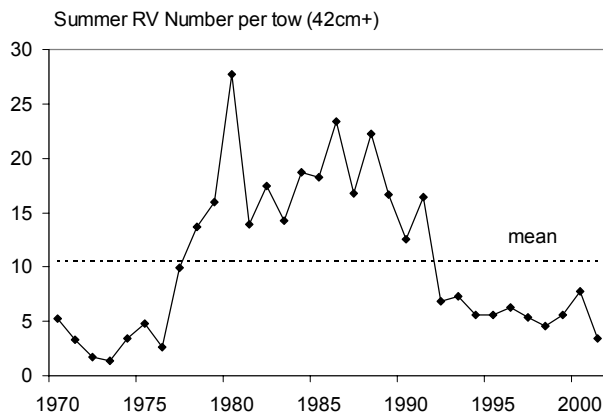
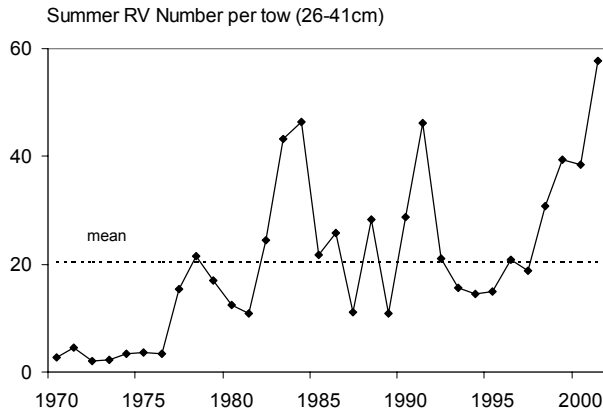
The evaluation of stock status was derived from reported landings, shore and at-sea based samples taken from commercial landings for size and age composition, research vessel (RV) surveys conducted in March and July, and a fixed-gear Sentinel Survey conducted in the fall.

The **commercial catch** at age was reconstructed from sampling conducted since the last full assessment in 1997. The 1970 to 1984 catch at age has remained unchanged. Changes occurred in the 1985 to 1989 re-construction because ageing information from commercial samples was available, which was not the case in the previous assessment. Revisions to Canadian and foreign landings data since the last assessment also resulted in differences in the catch at age since 1985.

Abundance trends for three size categories (1-25, 26-41, and 42 cm +) of haddock, derived from the DFO research vessel summer **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 and longer 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.

Summer RV Number per tow (1-25 cm)

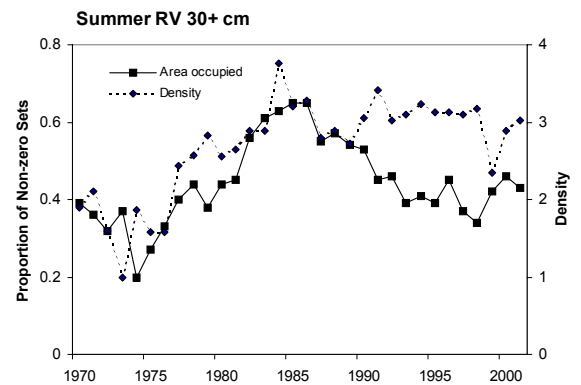
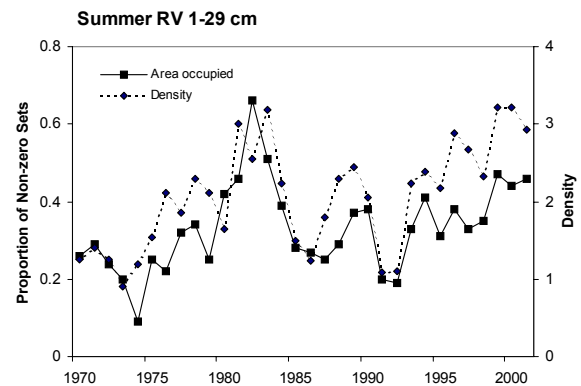




Recent **recruitment**, based on the number per tow at age 1, was slightly above average in 1995 and near average in 1996. The 1998 year-class was above average and comparable to some previously large year-classes. It should be noted that the age 2 estimate of the 1998 year-class in 2000 was the highest observed in the survey series. The 1999 year-class is extraordinary, exceeding any previous year-class estimate at age 1 by more than a factor of two.

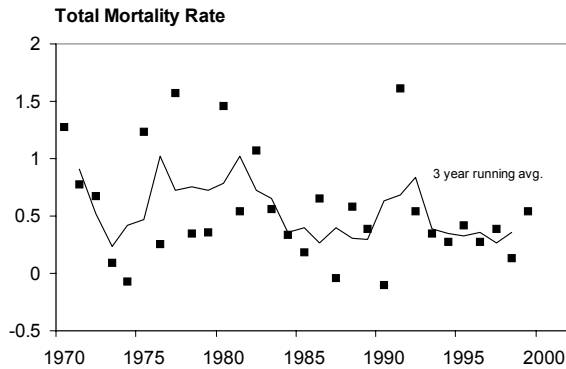


A measure of how widely a stock is distributed within its historical geographical range (**area occupied**) was evaluated for two haddock size groups: 1-29 cm - a reflection of recent recruitment and a larger size group - 30cm+. Local **density** or the average number of haddock within the area occupied was also evaluated. Since the early 1990s, haddock 1-29 cm 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.



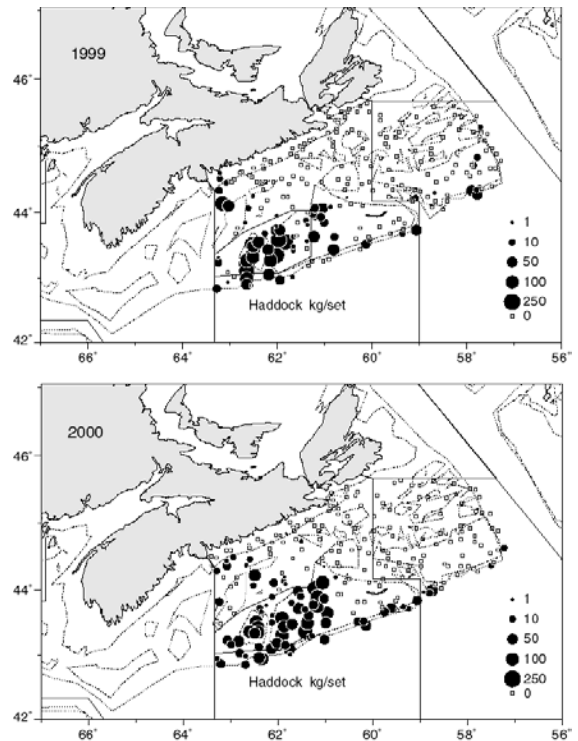
Total mortality estimates for adult haddock were derived from the summer survey. Mortality has averaged about 0.35 since the

mid-1980s, which includes the recent period of fishery closure. Total mortality during this recent period provides an estimate of natural mortality (including predation, disease, immigration/emigration) which is substantially higher than the assumption in past assessments of 0.2.

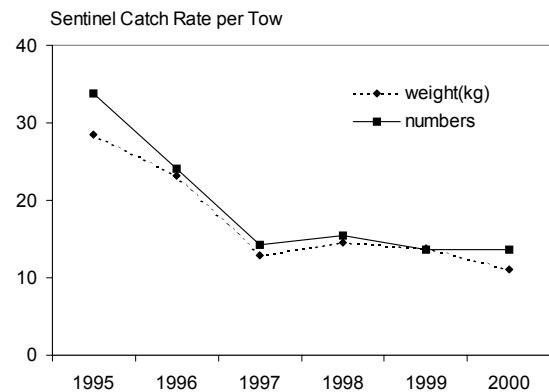


A fixed gear **Sentinel Survey**, involving 6 commercial long-line vessels, has been in place in Div. 4VsW since 1995. It is based on a stratified, random survey design, utilizing the same stratification scheme as the DFO July RV survey. Approximately 250 pre-selected set locations are occupied, starting in September of each year.

The geographic patterns of haddock catches were remarkably consistent from year to year. In the most recent surveys (1999 and 2000), haddock were concentrated within the Emerald/Western bank closed area and around its perimeter. Smaller catches occurred to the east along the flanks of Sable and Banquereau bank and the Gully. The annual percentage of haddock inside the closed area for each year ranged from 53 to 86%.



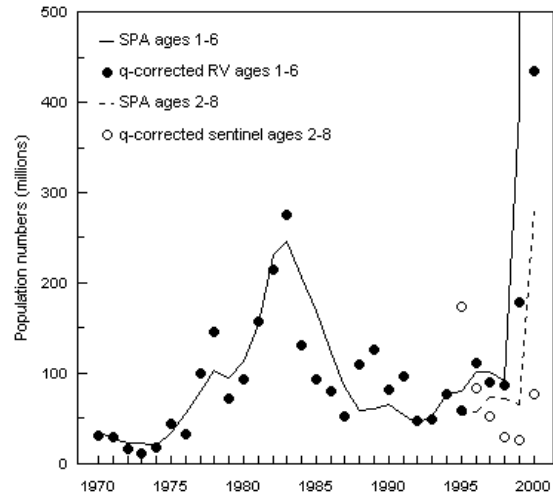
The stratified mean catch rate revealed a declining trend. Catch rates were highest in 1995 (> 25 kg/set), declined in 1996 and 1997 and have remained low (< 15 kg/set) since. Trends in numbers per set paralleled this pattern.



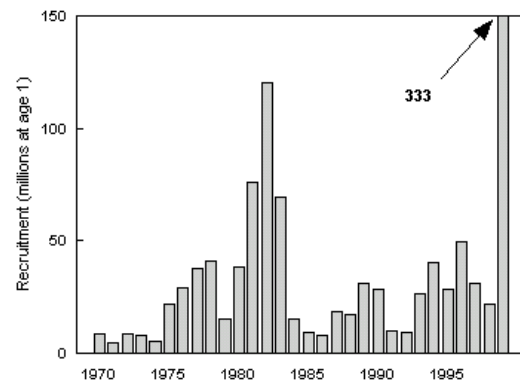
A single mode in the length composition was evident in 1995 and 1996 with catches peaking around 42-46 cm and falling off rapidly at larger sizes. In subsequent years, catches were lower across most sizes. In 2000, the size composition of the catch was skewed towards smaller sizes.

A **sequential population analysis (SPA)** was conducted using both the July RV survey and the September Sentinel Survey. Previous assessments assumed a constant **natural mortality (M)** of 0.2. 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 2000. 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. In comparison to the previous assessment of this stock, the current one was considered to be a significant improvement.

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.

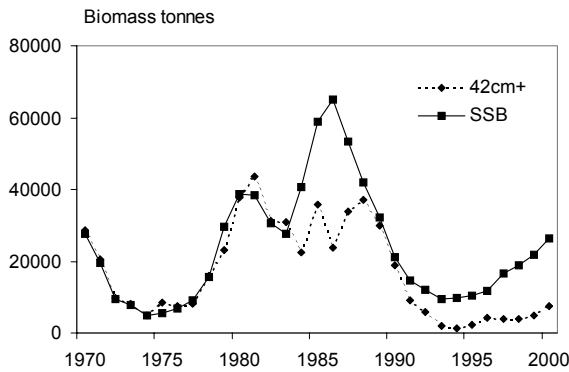


The SPA estimates of **recruitment** have been improving since the closure of the fishery. The 1995 year-class is above the 1970-1998 average. The 1998 year-class, which takes into account the age 1 estimate in 1999 and age 2 estimate in 2000 from the July RV, appears to be exceptional, exceeding the largest previous year-class in 1981 by about three-fold.

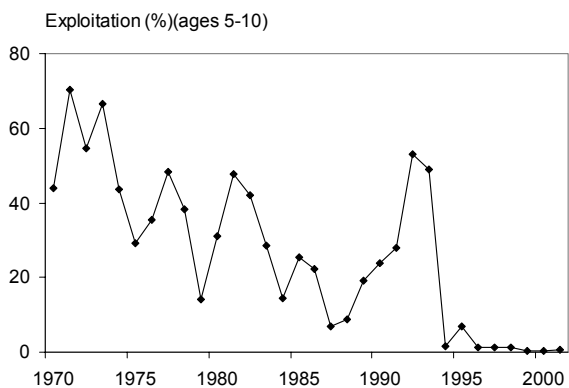


Spawning stock biomass (SSB) has been increasing since closure of the fishery and is now slightly above the 1970-2000 average of about 24,000 mt. The long-term (1948 - 2000) average SSB for this stock is about 39,000 mt. The fishable biomass, based on historical size limits of 42 cm and larger, has increased only slightly and remains well-below the 1970-2000 average of 17,000 mt. Because of declining size at age (see Section

on *Population Considerations*), the age groups contributing to the fishable portion of the population has 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.

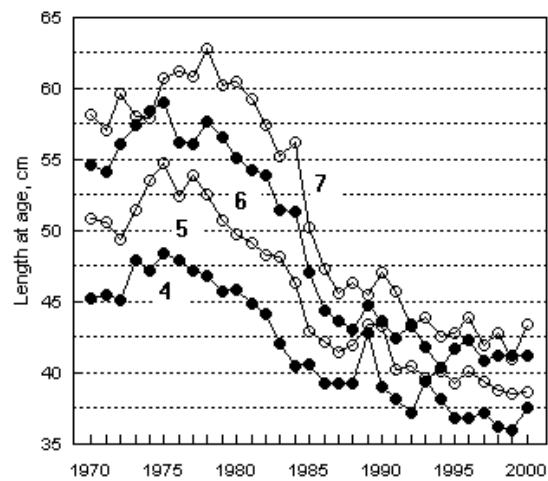


The **exploitation rate** was very high during the early 1970s when the fishery was unregulated. Exploitation declined after 1974 when catch quotas were first imposed, reaching a low in 1987 when mobile gear effort was eliminated from the Emerald/Western bank juvenile haddock closed area. Exploitation 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.

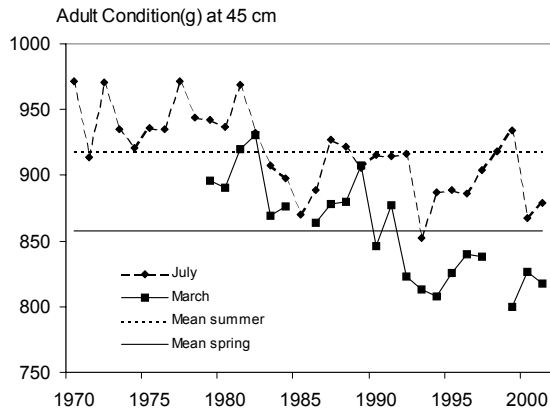


Population Considerations

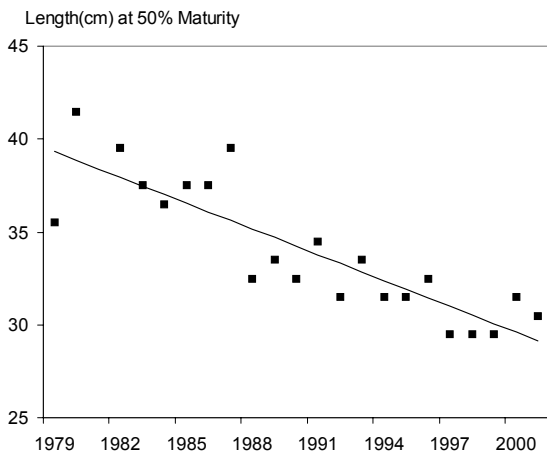
Substantial long-term declines in **size at age** are evident in haddock age 4 and older. At present, very few fish in the stock are larger than 43 cm (17 inches). Haddock are now exhibiting considerably slower growth rates than those seen during the 1970s to mid-1980s. One implication of this finding is that if slow growth persists, it will take 6-7 years for new year-classes to reach 42cm +, the historical fishable size limit.



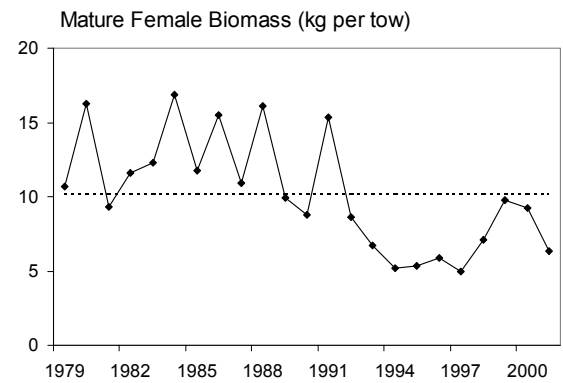
Condition, the relative weight of the fish at a given length (an index of the health of the fish in a stock) is derived from the July and March RV surveys. Adult haddock exhibited higher than average weight throughout the 1970s and early 1980s whereas during the remainder of the series, weights were generally below average. Since 1993, adult haddock body weight has been below average in seven out of nine 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 22-31 cm 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.

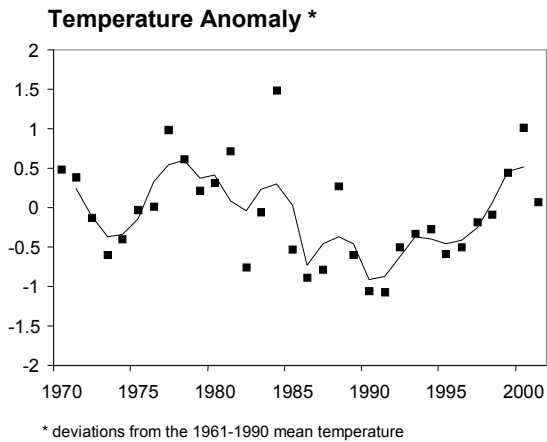





Adjusting the survey biomass per tow at length data from the July RV survey by the proportion mature at length, yielded an index of spawning stock biomass, or in the present case, **mature female biomass**. Mature female biomass has remained below the 1970-2001 average since 1991 and in 1999 and 2000 rose to near-average levels.



Further, a recent study was completed on the length-specific **fecundity** (egg production) of female haddock in 4TVW. This new data, in combination with the proportion mature at length, permitted an estimate of total egg production. Total egg production increased two-fold from 1997 to 1999. In addition, surface and bottom temperatures generally increased in 1999 and 2000 to above average. Such favorable environmental conditions and/or increased egg production could have contributed to the extraordinary 1999 year-class (estimated at age 1).

Temperature conditions at 100 m 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.

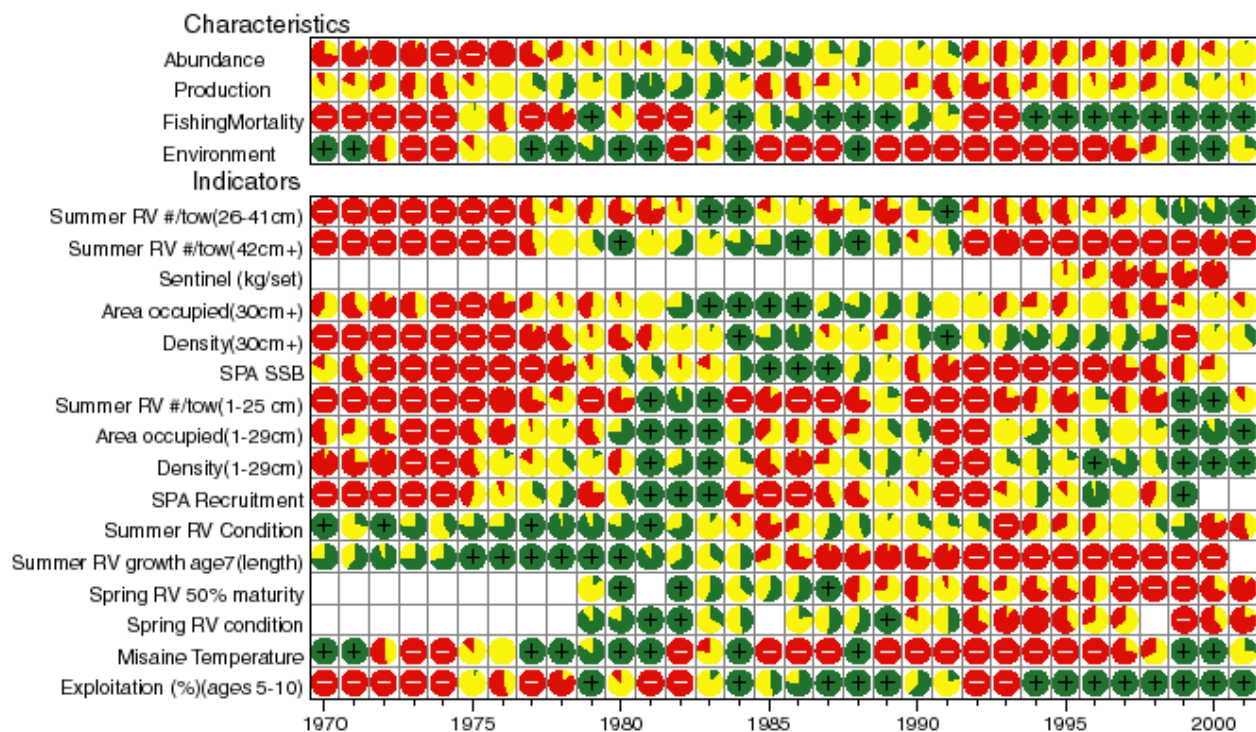


However, for indicators such as mortality, high values are bad and are assigned a red light  whereas low values are good and receive a green light . Intermediate values (midpoint between red and green) are yellow . A value between red and yellow is expressed as a pie with increasing amounts of red in 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.

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.

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.



Outlook

Indicators of **abundance** revealed that the number per tow (1-29 cm) from the July RV rose dramatically in 1999 and 2000, reflecting the strength of recent incoming year-classes. Intermediate sized haddock (26-41 cm) have been steadily increasing and the highest value in the series occurred in 2001. The summer RV number per tow of haddock 42 cm +, the historical fishable size limit, has remained very low throughout the 1990s, and the 2001 estimate is among the lowest observed. Spawning stock biomass (based on the SPA) has been steadily increasing since closure of the fishery and in 2000 exceeded the 1970-2000 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, which selects for larger haddock, exhibited a declining trend since the initiation of the survey in 1995. Area occupied of 30 cm + haddock is largely restricted to closed area. Annual estimates of the percentage of haddock inside the closed area, derived from the sentinel survey, range from 53 to 86%. Local density of 30 cm+ haddock has not shown a trend since the mid-1980s.

Some of the **production** indicators have been increasing since closure of the fishery. SPA estimates of recruitment at age 1 shows that the 1995 year-class is above the 1970-1998 average while the 1998 year-class appears very strong. Survey estimates at age 1 suggest that the 1999 year-class is also strong. Area occupied of 1-29 cm haddock has been increasing since 1995, and the 1999 to 2001 estimates are comparable to the early 1980s estimates when strong year-classes occurred. Local density of 1-29 cm haddock has been increasing since 1992. Condition factors have generally been below average since the early 1990s. Growth, 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, 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. 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.

Currently, Div. 4VW haddock is an early maturing, geographically constricted stock plagued by poor growth (both under-weight and under-length) and high natural mortality that 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.
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