ASSESSMENT OF NORTHERN SHRIMP ON THE EASTERN SCOTIAN SHELF (SFA 13-15)

(J. Domm 2006)

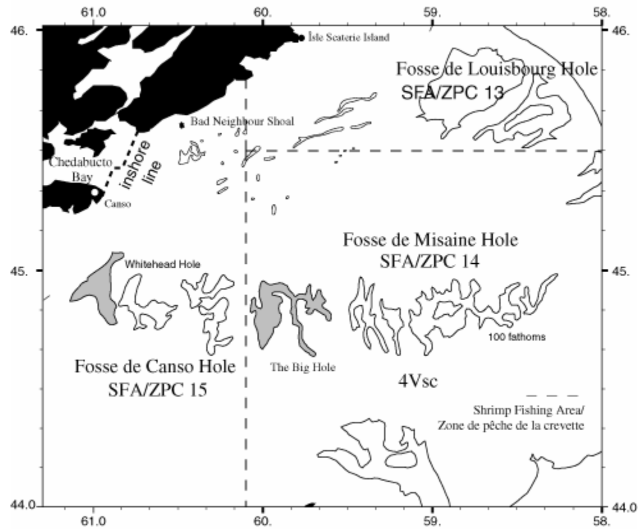

Figure 1. Shrimp fishing areas (SFAs) on the eastern Scotian Shelf.

Context:

Advice on the status of the eastern Scotian Shelf shrimp stock is requested by DFO Fisheries and Aquaculture Management and industry to help determine a Total Allowable Catch (TAC) that is consistent with the management plan. Annual assessments are required because of rapid changes in abundance, variable recruitment to the population and fishery, and changes in the size of shrimp available for harvest. The resource is near the southern limit of the species' distribution where it is thought to be more vulnerable to significant and rapid declines, as has been observed in the adjacent Gulf of Maine stock. The current report provides information and advice for management of the 2011 fishery.

The trawl fishery on the Scotian Shelf currently occurs primarily during late spring and early summer with some fishing during fall, in the deep offshore shrimp "holes", and on an inshore area near the Bad Neighbour Shoal. The main management tools are limits on the number of licenses and size of vessels used, minimum codend mesh size (40mm), use of a Nordmøre separator grid, and a TAC. This fleet (about 20 active trawlers) is divided into two sectors, a midshore sector consisting of about 7 active vessels 65-100' Length Over All (LOA) based in New Brunswick in the Gulf Region, and an inshore sector consisting of vessels mainly <65' LOA based in the Maritimes Region. A trap fishery, currently consisting of 1-2 active vessels is restricted to Chedabucto Bay. All licenses except traps operate under Individual Transferable Quotas (ITQs). Stock assessments are conducted annually based on indicators from commercial, scientific survey, and environmental monitoring data.

SUMMARY

- Point estimates of the 2010 total and spawning stock biomasses decreased from the near-record high 2009 estimates, but remain above the average values of the 2000-2009 high-productivity period.
- In 2010, consistent decreases in all three Catch per Unit Effort (CPUE) based indices, coupled with decreases in the area of highest catch-rates, provide compelling evidence of a biomass downturn.
- The abundance of Age 4 male shrimp increased in 2010. An abundance of Age 4+ males in 2009, probably representing late maturing males from the 2001 year class, provided females to the spawning population in 2010 and should continue to do so in 2011. Taken together, these indices suggest good recruitment to the spawning stock biomass in 2011.
- Total (13.2%) and female (16.8%) exploitation indices increased but remain below the 20% limit reference point.
- Indices of dispersion suggest that shrimp are beginning to aggregate on the fishing grounds, as would be expected during a biomass downturn.
- Indicators of shrimp size continue towards larger maximum, female and sex-transition sizes and lower counts.
- The continuation of a Total Allowable Catch (TAC) of 5000 mt for 2011 is supported by the current assessment, with the proviso that a TAC reduction may be required for 2012 if exploitation indices approach or exceed 20% in 2011. A moderate decrease in the TAC would, of course, decrease the likelihood of over-running the exploitation limit reference point in 2011 should the biomass downturn continue.

BACKGROUND

Species Biology

The northern or pink shrimp, *Pandalus borealis*, is the only shrimp species of commercial importance in the Maritimes Region. Shrimp are crustaceans that have a hard outer shell, which they must periodically shed (molt) in order to grow. Females generally produce eggs once a year (not more) in the late summer-fall and carry them, attached to their abdomen until the spring, when they hatch. Consequently, shrimp bear eggs, (i.e., are "ovigerous") for about 8 months of the year. Newly hatched shrimp spend 3 to 4 months as pelagic larvae, feeding near the surface. At the end of this period they move to the bottom and take up the life style of the adults. On the Scotian Shelf, the northern shrimp first matures as a male at 2 years of age, and at Age 4 it changes sex, to spend another 1 to 2 years as a female. They live on average 6 to 8 years, depending on current environmental conditions and population dynamics. Shrimp concentrate in deep "holes" (>100 fathoms) on the eastern Scotian Shelf (Figure 1), but nearshore concentrations along the coastline were discovered in 1995 by the DFO-Industry survey. In general, northern shrimp prefer temperatures of 2-6ºC, and a soft, muddy bottom with a high organic content.

The Fishery

The fishery currently consists of 28 (17 active vessels) inshore licenses mostly <65’ length overall (LOA) and 14 (7 active vessels) mid-shore licenses 65-100’ LOA. All mobile licenses have been under Individual Transferable Quotas (ITQs) since 1998. A competitive trap fishery with 14 licenses (1 currently active) restricted to Chedabucto Bay has been almost inactive recently due to current economics. The fishery operates under a 5-year “evergreen” management plan (last ratified for 2009-2014), which documents sharing agreements between fleet sectors.

Catches have been close to the Total Allowable Catch (TAC) since individual SFA quotas were combined into a single TAC in 1994, with minor shortfalls associated with re-allocations of uncaught trap quotas to the mobile fleet late in the season (Table 1; Figure 2). More substantial shortfalls occurred in 2005-2008 unrelated to resource availability. The gap between TAC and catch has narrowed steadily since 2005 as problems associated with market conditions and quota reallocations were resolved. Trap fishing effort and catches have decreased to negligible amounts (1mt in 2010) since 2005 due to low prices. The mobile fleet continues to prefer open access to all areas (i.e., no individual SFA quotas) because of the flexibility this offers in obtaining favourable combinations of good catch rates and counts (shrimp sizes).

Table 1. Recent shrimp TACs and landings ('000's mt)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010[1]
TAC	5.5	5.0	3.0	3.0	3.5	5.0	5.0	5.0	5.0	3.5	5.0
Landings	5.4	4.8	2.9	2.8	3.3	3.6	4.0	4.6	4.3	3.5	5.0

[1]Landings projected to December 31, 2010.

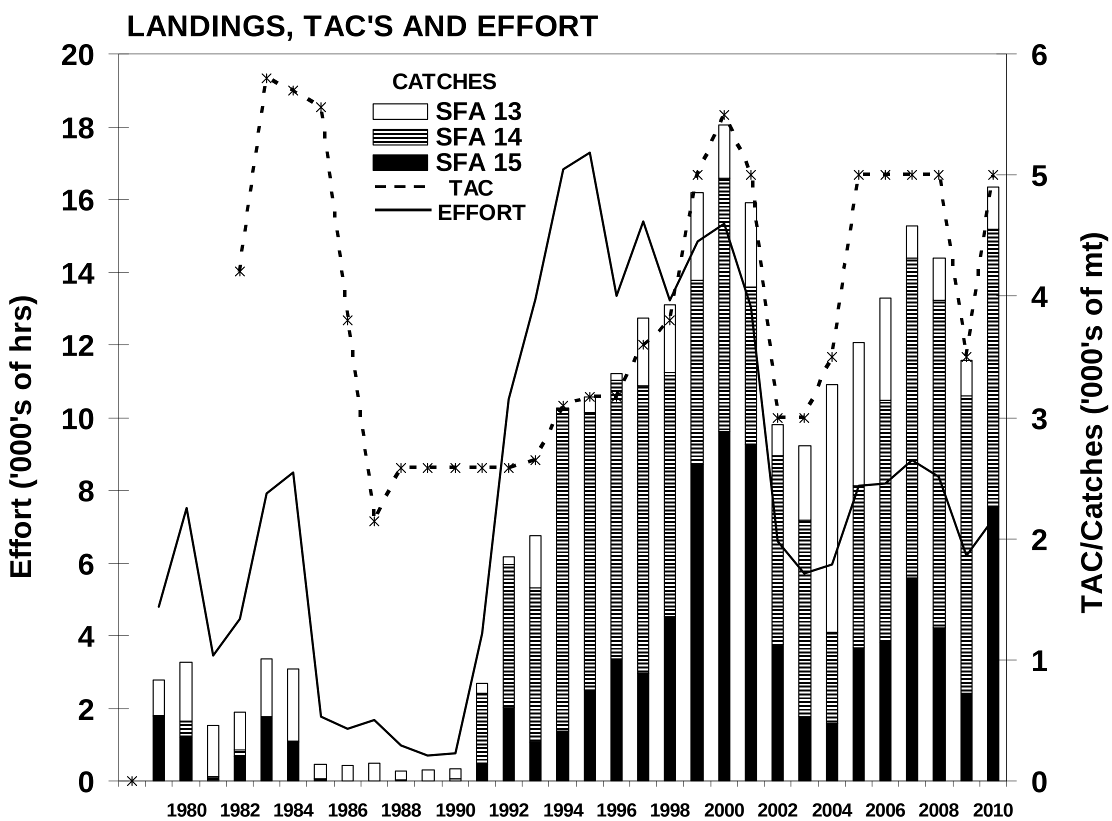

Figure 2. Landings, TACs, and Effort.

Relative to previous years, a greater percentage of the catch was taken in February-April in 2010 (Figure 3, left). Although most shrimp are caught during April-June, less of the catch was taken during this period in 2010 than in recent years. In 2010 there was a temporal (earlier) and spatial (into areas traditionally reserved for shrimp-fishing) shift in snow crab fishing effort to minimize crab fishing during the molting season. Some shrimp fishers reported gear conflicts with snow crab fishing gear in areas traditionally reserved for shrimp fishing during the spring and early summer. If the remainder of the TAC is caught this fall (likely), the amount of **fishing**

during the ovigerous period (August-April) will be the highest on record. Fishing during the ovigerous period can contribute to reduced egg production. Other factors that could decrease egg production include decreasing size at sex change, female sizes, and spawning stock biomass.

The **spatial pattern** of the fishery has changed significantly over the years (Figure 2), reflecting changing distributions of biomass and size frequencies. Prior to 1999, most of the effort and catch was in the SFA 14. In 1998, fishing began along-shore near the Bad Neighbour Shoal, with 44% of the catch taken in this area during 1999. This decreased to between 4-12% from 2003-2005 and then increased to between 20-25% since 2006. In 2004, a large part of the TAC (57%) was taken in SFA 13, but this has declined since 2007 as effort shifted back to SFA 14 to take advantage of the large accumulated biomass there. A larger proportion of the catch was taken in SFA 15 in 2010. Exploitation indices increased in all areas in 2010 due to the decreased biomass and increased TAC. None of the areas were subjected to >20% exploitation in 2010.

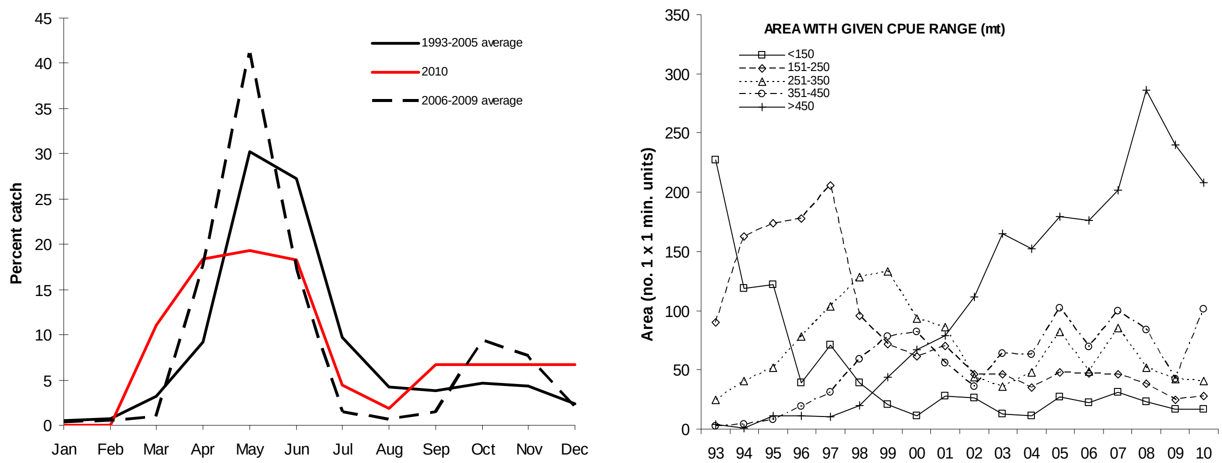

Figure 3. Temporal (left) and spatial (right) patterns in the Scotian Shelf shrimp fishery.

Indicators of shrimp size continue towards larger maximum, female and sex-transition sizes and lower counts. The **average sizes of females** in the catch decreased from 1997-2001 compared to the higher sizes of the early to mid 1990s (Figure 4, left). While fishery-removal of older and larger animals in the population likely accounts for some of this change, decreased growth rates of the strong 1993-1995 year classes were likely also a factor. This trend reversed after 2001, as the survivors of these year classes continued to grow and the weaker succeeding year classes achieved larger sizes. Female size decreased greatly in 2007-2008 as the slow growing 2001 year class changed sex, but increased in 2009 as these females died off and were replaced by late-maturing males that had additional years to grow before sex transition. The same likely contributed to the further increase in female size in 2010. The **proportion of females** (Figure 4, left) caught increased from 2000-2004 as males became less abundant and the 1993-1995 year classes dominated the population and catch as females. This trend reversed in 2005-2008 as the 1993-1995 year classes died off and males from the strong 2001 year class recruited to the fishery. This began to reverse in 2009, much as in the previous cycle, and continued to increase in 2010 as late-maturing males recruit to the female component of the stock. Commercial **count** estimates (numbers of shrimp per pound) mirror these changes, increasing significantly in 2005-2007 as males from the 2001 year class recruited to the fishing gear (Figure 4, right). They have decreased since as these shrimp changed sex and continued to grow as females, and as the abundant 4+ males recorded in 2009 are recruiting to the female portion of the population.

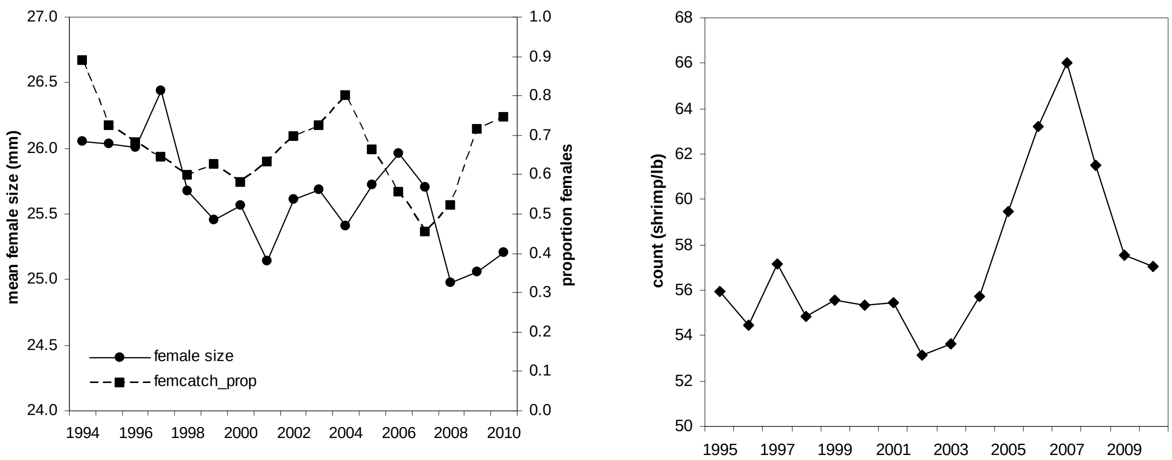

Figure 4. Mean female carapace length, proportion of females (left) and the count per pound (right) in the commercial shrimp trawl fishery.

ASSESSMENT

Stock Trends and Current Status

After a sustained long-term increase, commercial Catch per Unit Effort (**CPUE)** indices (Figure 5) leveled off and have been fluctuating at a high level since 2002. The DFO-industry trawl survey has shown two divergences from CPUE trends (Figure 5). The first, between 2000-2003, was attributed to changing spatial distribution patterns of the relatively large 1994-1995 year classes as these moved through the population and died off. However, the second divergence (2005-2008) was not consistent with a shrinking, more concentrated resource since the area of highest catch rates (>450kg/hr; Figure 3, right) had continued to increase, while the areas of lower catch rates have remained relatively small. The DFO-Industry survey index (Figures 5 and 6) increased significantly in all areas in 2009, with an overall increase of nearly 50% from the previous year. Some of this increase can be attributed to growth and increased availability to the survey trawl of the 2001 year class. A concurrent increase in the standardized CPUE index is also likely due to this; however, the CPUE increase was only 10% above the previous year, the difference presumably being due to survey-related factors. It is probable that a decrease in the attack angle of the Nordmøre grid in the survey trawl, discovered and repaired prior to the 2009 survey, was at least partly responsible for this second divergence. Moreover, since the survey index experienced its largest one-year increase in 2004, when the survey trawl was new, the possibility that the first divergence just prior to this was also at least partly due to decreased trawl efficiency cannot be ruled out. In 2010, there were consistent decreases in all three CPUE-based indices (Figures 5 and 6). A decrease in the area of highest catch-rates (>450 kg/hr, Figure 3, right) and an increase in the coefficient of variation of standardized survey catches provide evidence that shrimp are beginning to aggregate on the fishing grounds. This, coupled with decreases in all three CPUE based abundance indicators provides compelling evidence of a biomass downturn. This is consistent with the prediction that a lag between the end of the abundant 2001 year class and the recruitment of the next abundant year classes (2007-2008) to the adult population would take place (Figure 9).

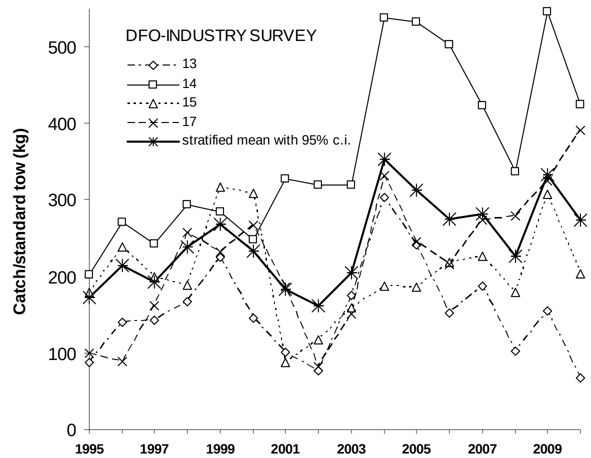

Figure 5. Commercial CPUE and survey abundance indices.

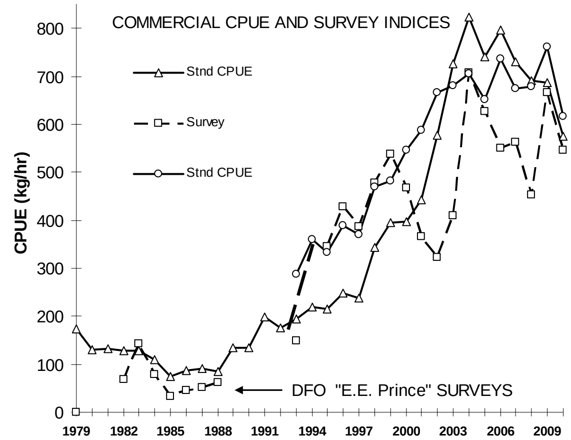

Figure 6. DFO-Industry survey abundance indices by area.

Based on the survey indices, the **total biomass** point estimate decreased to 37,212mt in 2010, slightly above the average of the 2000-2009 high-productivity period. Biomass estimates decreased in all areas except for stratum 17 (inshore). Although **spawning stock biomass** (SSB, females) decreased to 21,707mt this year, it remains at the third highest point estimate on record.

As a result of the decreased biomass and increased TAC in 2010, **total exploitation** increased to 13.2%. For the same reasons, **female exploitation** increased to 16.8%.

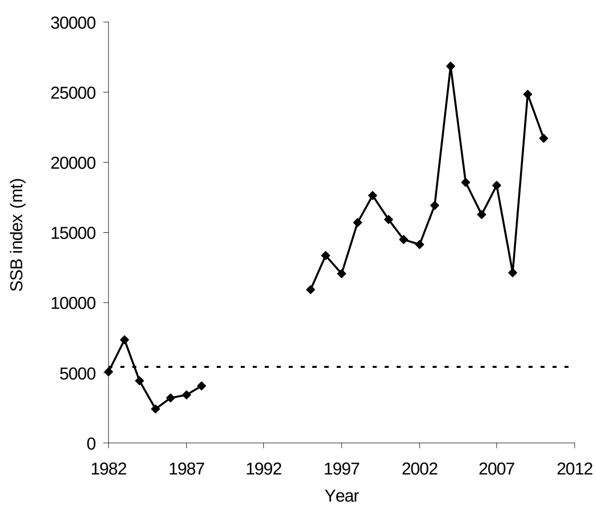

Figure 7. Changes in the spawning stock biomass index for the Eastern Scotian Shelf shrimp population. The dashed line shows the lower limit reference point at 30% of the mean value during the 2000-2010 high-productivity period.

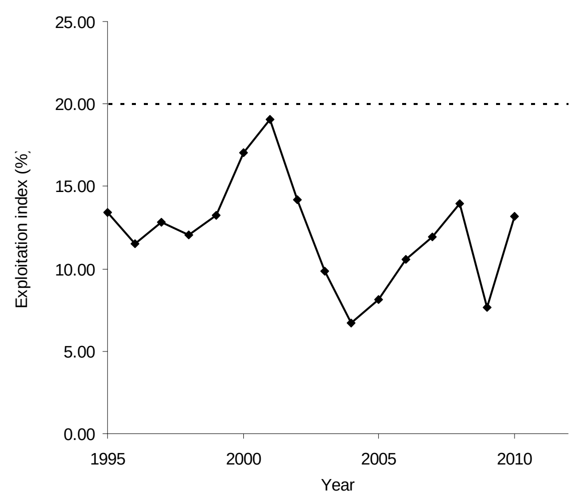

Figure 8. Changes in the exploitation index for the Eastern Scotian Shelf shrimp fishery. The dashed line shows the limit reference point of 20% for the exploitation index.

The interpretation of year class strength and longevity is complicated by a number of factors including: the low catchability of shrimp younger than Age 4; the strong influence of growth rate on the catchability of Age 4 shrimp; difficulty in distinguishing and assessing year classes after Age 3; and changing longevities and natural mortalities associated with environmental or density-dependant influences. Furthermore, the tendency of a single year class, especially large ones such as 2001, to change sex over a number of years, makes it difficult to distinguish them from adjacent year classes. Nonetheless, the recruitment pulses of 2001 and 2007-2008 coincide with the maturation of strong year classes, i.e. 1993-1995 and 2001, respectively. This is evidence that strong year classes have produced large spawning stock biomasses.

Good recruitment associated with the 2001 year class led to record high biomasses in 2004-2006. In 2008, at Age 7, this year class was near or at the end of its life span and its natural mortality was expected to increase sharply. Since this year class comprised up to 70% of the biomass at its peak and was followed by poorer recruitment, biomass was expected to decrease. This appeared to be confirmed by a decreasing survey index; however, this is now considered a false signal.

The abundance of **Age 2 shrimp**, increased to above average in 2009, apparently confirming the strength of the 2007 year class determined as 1 year old shrimp from belly-bag results in 2008. The strength of the 2008 year class as **Age 1 shrimp** in belly bag results were also above average. Belly-bag catches are not affected by changes to the Nordmøre grid and appear to corroborate the recruitment pulses shown in the main survey trawl results. The abundant 2006-2007 year classes continue to provide a detectable signal in the trawl survey (Figure 9) as they approach recruitment to the fishery, likely beginning in 2011-2012 and recruiting fully as 5 year olds in 2012-2013. However, the decline in the abundance of Age 1 and Age 2 shrimp in 2010 are inconsistent with expectations based on the record high SSB index and the high belly-bag index in 2009, respectively.

The abundance of **Age 4 male shrimp** increased in 2010. An abundance of Age 4+ males in 2009, probably representing late maturing males from the 2001 year class, provided females to the spawning population in 2010 and should continue to do so in 2011. Taken together, these indices suggest good recruitment to the spawning stock biomass in 2011.

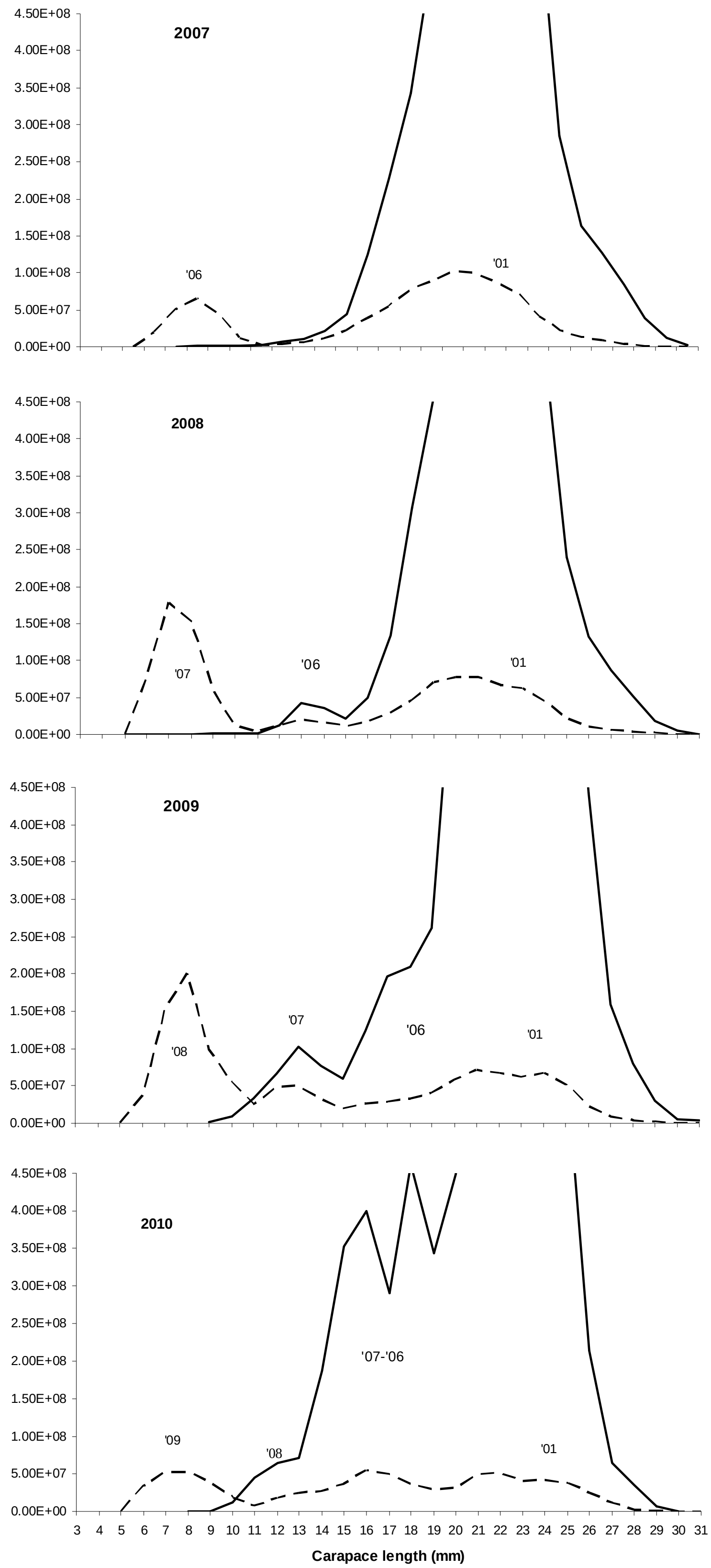

Figure 9. Population estimates from belly-bag and main trawl catches for the 2007-2010 survey.

Decreases in average **length at sex change** (L_t) in shrimp stocks can contribute to population downturns due to decreased female fecundity (smaller shrimp produce fewer eggs). On the

Scotian Shelf, length at sex change has shown a decreasing trend since the mid 1990s, when monitoring began, and approached the small sizes associated with the low population levels of the 1980s (Figure 10). Length at sex change increased during the last 4 years, probably due to late sex change of 2001 year class males, some of which had an additional year(s) to grow. **Maximum size** (L_{max}) has shown a similar decreasing trend, but has increased for the past two years, likely for the same reasons (Figure 10). The possibility that the observed long-term decreasing trend in both indicators is a cumulative fishing effect that may be having a negative impact on the population's reproductive capacity bears consideration.

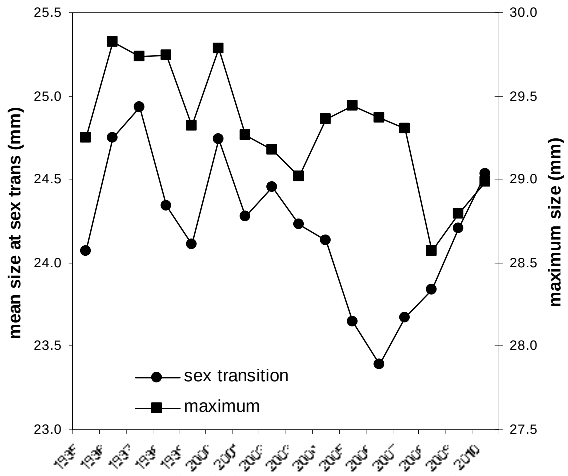

Figure 10. Changes in mean carapace size at sex transition and maximum carapace size.

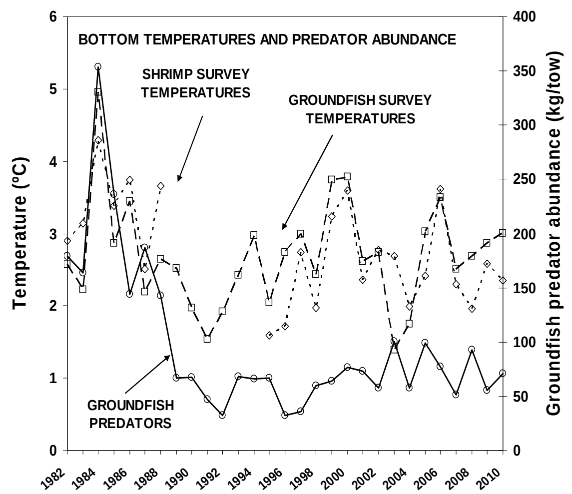

Figure 11. Bottom temperatures and predator abundance on the eastern Scotian Shelf shrimp grounds.

Predator feeding studies have shown that shrimp are important prey for many groundfish species, and significant negative correlations between shrimp and groundfish abundance have been demonstrated from the Gulf of Maine to Greenland. Many groundfish stocks remain at low levels on the eastern Scotian Shelf, and **natural mortality due to predation** is probably below the long-term average (Figure 11).

For some northern shrimp stocks near the southern limits of the species' range, abundance is negatively correlated with water temperatures. On the Scotian Shelf, the large population increase that occurred from the mid 1980s to the mid 1990s is associated with colder surface and bottom **water temperatures**. This is at least partly because colder temperatures increase the length of the egg incubation period, resulting in later egg hatchings that are closer to the spring phytoplankton bloom and warming of the surface layers where larvae feed and grow. Large fluctuations in bottom water temperatures (Figure 11) may also be associated with the cyclical recruitment pattern experienced since the early 1990s (i.e., 1993-1995, 2001 and 2007-2008 year-classes). **Spring surface temperatures** increased in 2010, which could have a negative effect on recruitment in 2011, and would be a concern for the shrimp stock if the trend continues. However, shrimp **survey bottom temperatures** decreased slightly in 2010. The abundance of cold water indicator species also provided equivocal signals (**capelin** increased while **Greenland halibut** continue to decrease).

The introduction of the Nordmøre grid in 1991 reduced **by-catch** and allowed the fishery to expand to its present size. By-catch information from observer coverage of 119 commercial sets from 2008 (2 commercial trips from Gulf-based vessels), 2009 (3 Nova Scotia vessel trips) and 2010 (1 Gulf and 3 Nova Scotia commercial trips) suggests that Gulf and Nova Scotia fleet trawl configurations including the use of the Nordmøre grate continue to ensure very low total by-catch (1.78%) by weight. It is noteworthy that this value is very likely over-estimated due to the minimum 1 kg weight recorded by the observers (e.g. a single sand lance would be recorded as 1 kg despite weighing only a few grams). There are currently no concerns with by-catch amount or species-composition.

Figure 12 provides a summary of 25 indicators related to the health of the eastern Scotian Shelf shrimp stock. Each indicator was assigned a color for every year there is data according to its percentile value in the series (i.e., >0.66 percentile = green or healthy, 0.66-0.33 percentile = yellow or cautious, and <0.33 percentile = red or critical). Indicators have been grouped into stock characteristics of abundance, production, fishing effects and ecosystem. Note that indicators are not weighted in terms of their importance, and the summary given at the top of the figure was determined as a simple average of individual indicators.

Although lower than the value for 2009, the summary indicator remained green in 2010, mainly due to the maintenance of positive values for CPUE-based (commercial and survey) indicators (survey biomass, SSB, Age 4 abundance, Gulf vessel and standardized commercial CPUE), coupled with improvements in indicators of shrimp size (size at sex-transition, maximum size, count), population evenness, capelin abundance and cod recruitment. Downturns were recorded for CPUE–based indicators, exploitation indicators (due to the former, coupled with the increased 2010 TAC), the belly-bag (Age 1) index, fishing during the ovigerous period, surface temperature and Greenland halibut recruitment.

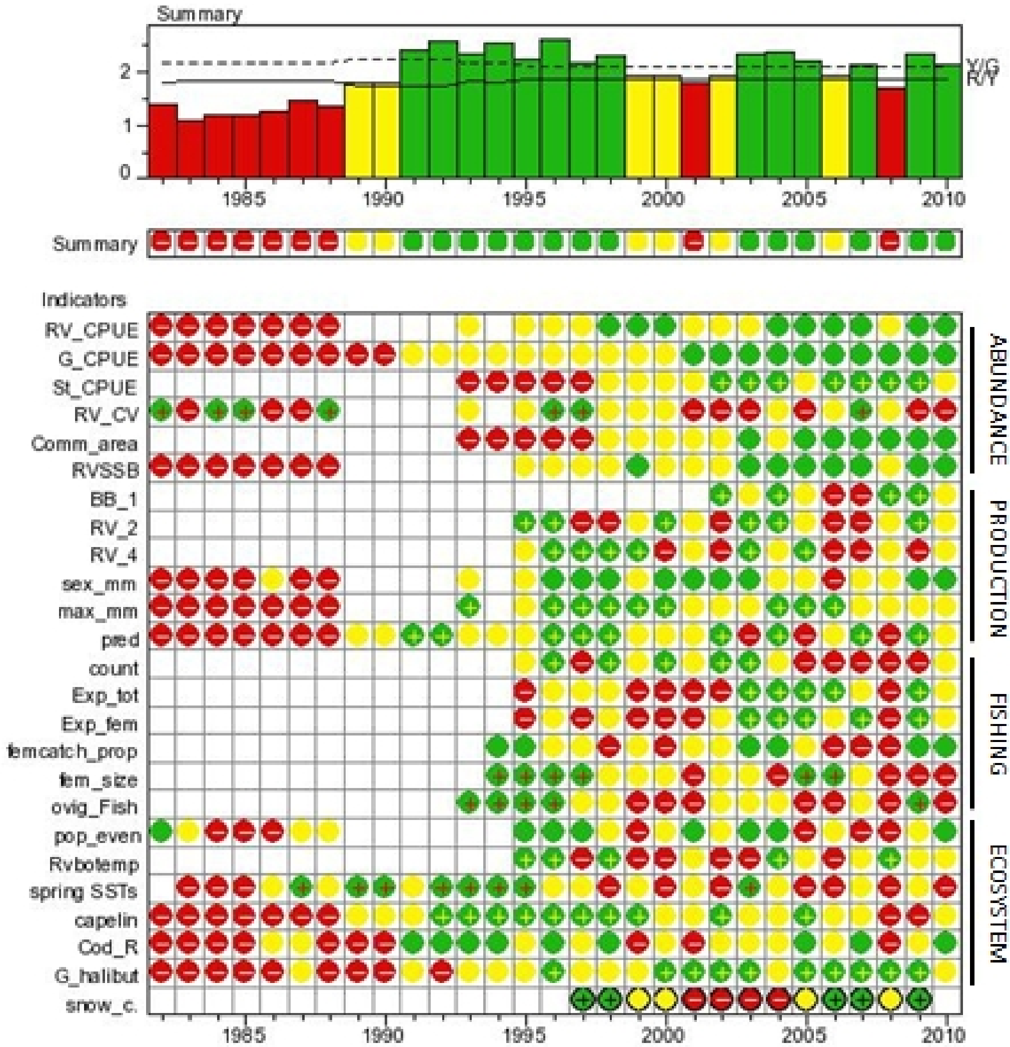

Figure 12. Traffic Light Analysis. Not all indicators in the Traffic Light table are discussed in the text. Please consult the current CSAS Research Document for a detailed description.

Sources of Uncertainty

DFO-Industry shrimp survey results are associated with high variances and biases associated with survey gear changes. Spatial and temporal variability in the distribution of shrimp is a source of uncertainty with regard to the accuracy of survey estimates; the survey is conducted consistently during the first ten days of June to try to mitigate this effect. In 2007-2008 problems with NETMIND distance sensors and data logging required use of historical average instead of actual wing spread data to calculate swept areas and abundance. The trend in commercial catch rate has not always been consistent with the trend in the shrimp survey index; the possible reasons for these divergences have been discussed previously. Given the inability to accurately age shrimp, modal groups are assigned to age classes, a process that is somewhat subjective, particularly for larger individuals. Growth rates can decrease dramatically due to density dependence, as happened with the strong 2001 year class. Consequently, recruitment to the fishery will be delayed and spread over a longer time period. Unforeseen changes in the ecosystem (e.g., predators), and the environment (e.g., temperature) together increase the difficulty of making long-term projections but are not expected to influence the advice for the 2011 fishery.

CONCLUSIONS AND ADVICE

The consistent downturns in all three CPUE-based indicators from commercial and survey data suggest that the overdue passage of the 2001 year class through the population is decreasing biomass. This biomass decrease was likely offset, in part, by the recruitment of abundant 4+ males (reported in 2009) to the fishery in 2010 (as females). The increased abundance of Age 4 shrimp in 2010 can be expected to further supplement fishable and spawning stock biomass in 2011. The degree to which these sources of recruitment to the spawning stock biomass will offset the expected downturn in the population until the relatively strong 2007 and 2008 year classes recruit to the fishery is uncertain. However, given that the latter are expected to begin to recruit to the fishery in 2011-2012, and currently high total and spawning stock biomass, it appears unlikely that the population lag will be very severe.

Considering the relatively high exploitation indices in 2010, further declines in biomass (assuming constant TAC) could raise the exploitation index in excess of the limit reference point for this stock, in which case TAC reductions would be required. This highlights the importance of having an accurate abundance index to monitoring response of the population to increased exploitation.

The continuation of a TAC of 5000 mt for 2011 is supported by the current assessment, with the proviso that a TAC reduction may be required for 2012 if exploitation indices approach or exceed 20% in 2011. A moderate decrease in the TAC would, of course, decrease the likelihood of over-running the exploitation limit reference point in 2011 should the biomass downturn continue.

SOURCES OF INFORMATION

This Science Advisory Report has resulted from a Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, Regional Advisory Meeting of December 17, 2011 on the Assessment of 4VW Shrimp. Additional publications from this process will be posted as they become available on the DFO Canadian Science Advisory Secretariat website at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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FOR MORE INFORMATION

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