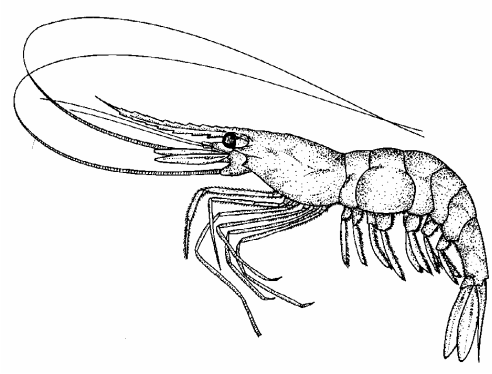
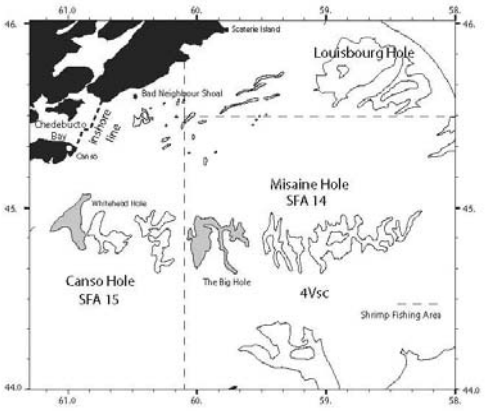
Fisheries and Oceans Canada | Pêches et Océans Canada
Science | Sciences
Maritimes Region
Canadian Science Advisory Secretariat
Science Advisory Report 2005/060

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





Context

The northern or pink shrimp, Pandalus borealis, is the only shrimp species of commercial importance in the Maritimes Region. Shrimp are crustaceans, and have a hard outer shell which they must periodically shed (molt) in order to grow. The females produce eggs once a year in the late summer-fall and carry them, attached to their abdomen, through the winter until the spring, when they hatch. Consequently, shrimp bear eggs, or 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. Shrimp live 5 to 8 years, depending on conditions.

Shrimp concentrate in deep "holes" on the eastern Scotian Shelf, but nearshore concentrations along coastlines closest to the offshore populations were discovered by 1998. They prefer temperatures of 2 to 6 ºC, and a soft, muddy bottom with a high organic content.

The trawl fishery on the Scotian Shelf occurs during summer in the deep offshore shrimp "holes", and on an inshore area near the Bad Neighbor 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 grate, and a Total Allowable Catch (TAC). This fleet (about 20 active trawlers) is divided into two sectors, a midshore sector consisting of 7 vessels 65-100' Length Over all (LOA) based in New Brunswick on the Gulf of St. Lawrence side, and an inshore sector consisting of vessels mainly <65' LOA based on the Atlantic coast of Nova Scotia. A trap fishery, consisting of 6 active vessels, is conducted mainly in Chedabucto Bay. All licenses except traps operate under ITQs.

SUMMARY

- The DFO-industry survey abundance index decreased from last year to the second highest on record. Most of the biomass continues to concentrate in the Misaine area (SFA 14).
- The SSB (spawning stock biomass of females) also decreased but was still the second highest on record.
- Commercial catch rates (CPUEs) have decreased slightly since 2003 but remain high.
- The strong 2001 year-class, first identified as such in 2002, continues to hold up in all areas. Normally, it should begin to recruit to the 2006 fishery as females, however, due to density dependence its growth rate is below average, which could delay sex change up to several years.
- Fishers experienced greater difficulty in avoiding lower-value, small shrimp in 2005. This is expected to continue in 2006, with the severity dependant on growth rate and timing of sex change of the 2001 year-class.
- Total exploitation and female exploitation indices remain below average.
- The 2005 fishery shifted its effort from SFA 13 to other areas, however, the large accumulated biomass in SFA 14 continues to be lightly exploited.
- Low groundfish predator abundance implies low shrimp natural mortality.
- Biomass is expected to remain high as the 2001 year-class recruits to the female population over several years. Uncertainties associated with the growth of the 2001 year-class and the probability of large catches of small shrimp indicates that the 2006 TAC should not exceed the 2005 level.
- The 2002-2004 year-classes are weaker than the 2001 year-class, consequently biomass is expected to decrease when this year-class has moved through the population.

DESCRIPTION OF THE ISSUE

Rationale for Assessment

Advice on the status of the eastern Scotian Shelf shrimp stock is requested by DFO Fisheries Management and industry to help in determining a TAC which is consistent with the management plan. Annual assessments are required because of the cyclical nature of recruitment to the population and the fishery, as well as fluctuations of the sizes 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 collapse, which has occurred in the adjacent Gulf of Maine stock.

The Fishery

Landings (000s t)

Year	1998	1999	2000	2001	2002	2003	2004	2005[1]
TAC	3.8	5.0	5.5	5.0	3.0	3.0	3.5	5.0
Landings	3.9	4.9	5.4	4.8	2.9	2.8	3.3	3.6

[1]Landings projected to December 31, 2005.

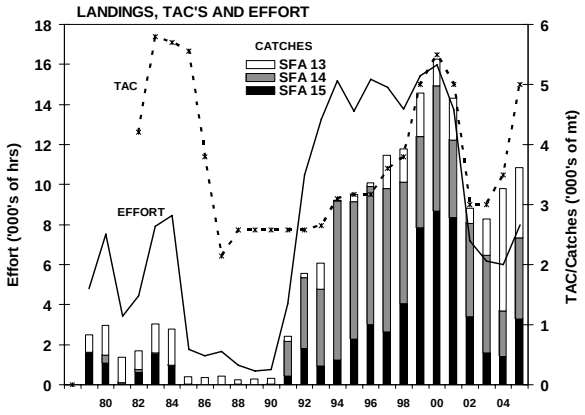


Figure 1. Landings, TACs and Effort.

The introduction of the Nordmøre grate in 1991 reduced groundfish bycatches to low levels (2-4%) and allowed the shrimp fishery to expand. It currently consists of 28 inshore licenses mostly <65' LOA and 7 midshore licenses 65-100' LOA. In 1996, the inshore component of the trawler fleet moved from individual quotas (IQs) to individual transferable quotas (ITQs), while the midshore moved from a competitive fishery to IQs. All vessels have been under ITQs since 1998. Temporary mobile licenses were introduced in 1998 as part of a co-management agreement (1998-2002) to take advantage of increasing stock biomass and TACs, while facilitating effort reduction in the event of the rapid downturn often seen in shrimp fisheries. With the TAC decreased, temporary access was removed in 2002-2003. Disagreement on temporary access prevented the successful negotiation of a new co-management agreement and the 2003-2005 fishery operated under the provisions of the 1998-2002 agreement. All 6 temporary licenses were made permanent for the 2005 fishery, albeit without a full share of the TAC. A new multi-year co-management plan is under review.

The TAC has been caught most years since individual SFA quotas were combined into a single TAC in 1994, although there have been minor shortfalls (Figure 1). The fishery continues to prefer open access to all areas (i.e. no individual SFA quotas) because of the flexibility this offers in obtaining favorable combinations of good catch rates and counts. A more substantial shortfall in catch relative to the TAC occurred in 2005 due to a combination of poor market conditions, bad weather, difficulties in avoiding small shrimp, and other logistic problems. Science recommended against a requested season extension due to the lower than projected biomass and large number of small shrimp in the catch.

The **temporal pattern** of the fishery has changed over the years. Catches during the August-April ovigerous (egg-bearing) period tend to increase when TACs increase as fishers take longer to catch higher quotas and curtail fishing during the summer months to avoid "soft" (molting) shrimp. This was the case in 2005 when the percentage of the catch taken during the ovigerous period rose to 36%. This is not currently considered to be a problem due to the large SSB, but it could potentially contribute to other factors decreasing population fecundity, including decreasing size at sex change.

The **spatial pattern** of the fishery has changed significantly over the years. Prior to 1999, most of the effort and catch was in the Misaine Hole (SFA 14). In 1998, the Nova Scotia trawler fleet (vessels <65' LOA) began to fish alongshore off the Bad Neighbor Shoal, with 44% of the catch taken in this area during 1999. This has since decreased and only amounted to about 11% of the catch in 2005. After taking a large part of the 2004 TAC in SFA 13, in 2005 the catch was more evenly distributed throughout the stock area. Although catches increased in SFA 14 the large accumulated biomass in this area remains lightly exploited relative to other areas. These changes in the distribution of fishing effort, as well as changes in the distribution/densities of strong year-classes shown by spatial analysis, indicate that catch per unit effort is not representative of overall abundance. For example, commercial catch rates continued to increase during a recent period of survey biomass decreases because a group of strong year-classes concentrated into dense shoals.

Smaller **average sizes of females** in recent years compared to the mid 1990s is interpreted to be due in part to the removal of accumulated older and larger animals in the population by the fishery, but decreased growth due to increased densities may also be involved. An increasing trend in the **proportion of females** caught since 2000 occurred as males became less abundant and the strong 1993-1995 year-classes dominated the population and catch as females. This indicator decreased in 2005 due to large number of males from the 2001 year class. **Counts** (numbers of shrimp per pound) data provided by vessel captains increased significantly in 2005 for the same reason. This indicates that many fishers had difficulty avoiding small shrimp from this year-class and maintaining counts below buyer limits to obtain the best prices. Some fishermen voluntarily switched to larger codend mesh sizes in 2004-2005 to avoid

small shrimp, but this apparently was less effective in 2005 as the 2001 year-class grew. Experienced captains had significantly lower counts in 2005, indicating that fishing skill is an important factor. High counts and low prices continue to concern the fishery, however exploitation rates of the smaller sizes are below average, consequently, this not a conservation concern. The catch at length for 1995-2005 is shown in Figure 2.

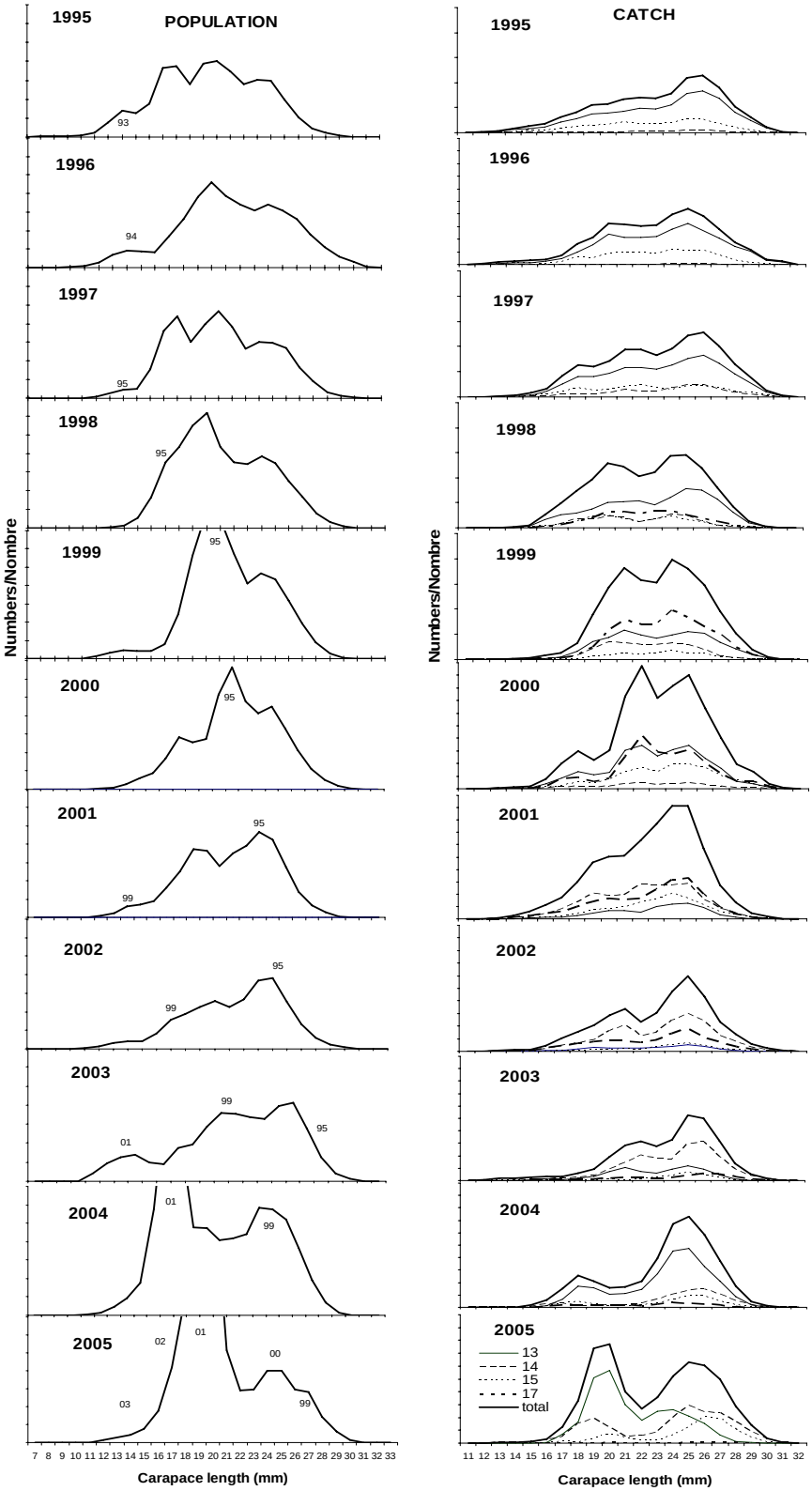


*Figure 2. Survey population (left) and catch (right) at length estimates 1995-2005. The maximum value of each panel is 7*108 and 10*107 shrimp for the population and catch figures, respectively. Selected year-classes are identified in the population estimates. The catch at length is also shown by fishing area.*

The trap fishery off Canso (SFA 15) did not take place during 2005 due to poor market conditions.

RESOURCE ASSESSMENT

Stock Trends and Current Status

After a sustained long-term increase commercial **CPUE** indices (Figure 3) leveled off and even decreased slightly in the last 2 years, but they remain high. As indicated above, these indices probably do not reflect overall abundance changes in the short term due to changes in the spatial distribution of the resource and fishing effort.

The DFO-industry **survey index** (Figures 3, 4) decreased in 2005, but was still the second highest of the 11 year series. Much of the biomass (45%) remains concentrated in Stratum 14 (Misaine). The **spawning stock biomass** (female) also decreased in 2005 but was still the second highest on record.

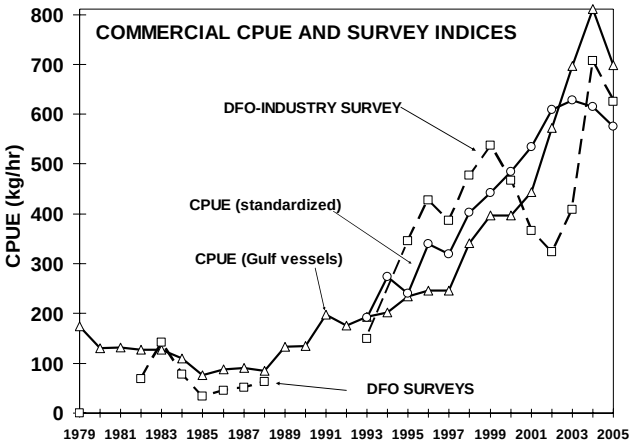


Figure 3. Commercial CPUE and survey abundance indices.

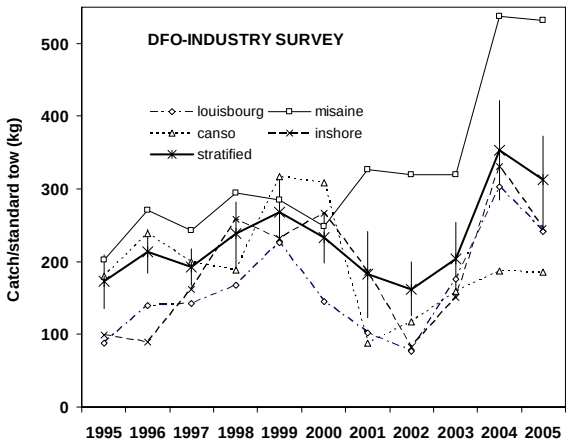


Figure 4. DFO-industry survey abundance indices by strata.

During the late 1990s the fishery was supported by a strong group of year-classes (1993-1995), which reached the end of their life cycle in the early 2000s. Lower levels of recruitment in the mid 1990s led to a biomass decrease from 2000-2002. Good recruitment in the late 1990s and early 2000s has led to the high biomass of 2004 and 2005. The **abundance of age 4 shrimp** in 2005 (i.e. 2001 year-class shrimp that should begin entering the fishery as females in 2006) was at a record high in the 2005 survey. Consequently, it is expected that biomass will increase as individuals from this year-class grow. However, growth rates have been slower than average due to density dependence. Some, perhaps all, age 4 males may delay sex change for a year, a phenomenon often observed with good shrimp year-classes. The **abundance of age 2 shrimp** (2003 year-class) was below average in the 2005 survey trawl. Survey trawl and belly bag catches indicate that the 2002-2004 year-classes are considerably weaker than the 2001 year-class. The survey population at length is shown in Figure 2.

Total exploitation (8.1%) and **female exploitation** (12.0%) increased slightly in 2005 but remained below the long term average. Exploitation was more evenly distributed throughout the stock area than in 2004 when much of the catch was taken in SFA 13.

Decreases in average **length at sex change** (L_t) (Figure 5) may be associated with decreased growth rates, and population downturns due to decreased population fecundity (smaller shrimp produce fewer eggs). Length at sex change has shown a slight decreasing trend during the 1990s, and a significant decrease in the last two years, but remains substantially larger than the period of low abundance in the 1980s. **Maximum size** (L_{max}) (Figure 6) usually shows a concurrent decrease with L_t when growth rates decrease but this has not yet occurred with regard to the decrease in L_t since 2003. Current L_t estimates may be biased downward because of the large number of older males from the 2001 year-class.

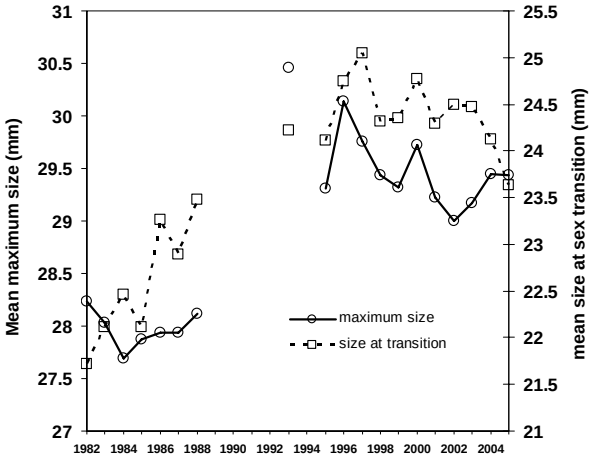


Figure 5. Changes in mean size at sex transition and maximum size.

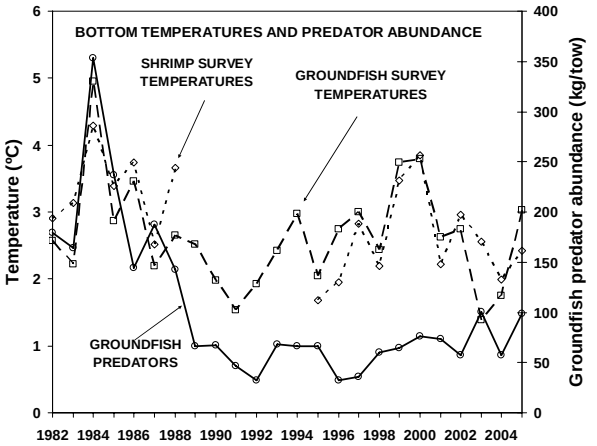


Figure 6. Bottom temperatures and predator abundance on the eastern Scotian Shelf shrimp grounds.

Regarding **ecosystem considerations**, 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 (Figure 6) on the eastern Scotian Shelf and **natural mortality** due to predation is probably below the long-term average.

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 population increase since the late 1980s may be associated with colder surface and bottom **water temperatures**. Warmer temperatures in the mid-to-late 1990s may have contributed to decreased shrimp recruitment. Bottom temperatures have cooled on the shrimp grounds since 2000 and may be related to recent improved recruitment (Figure 6). The continued abundance of most cold water indicator species including shrimp, capelin and Greenland halibut suggests that the regime shift which led to their success is enduring. However, snow crab recruitment has been decreasing for a number of years. The different response of this species cannot be explained at this time. Surface and bottom water temperatures were warmer in 2005, but a warming trend is not evident.

Figure 7 provides a summary of 23 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 good, 0.66-0.33 = yellow ○ or intermediate and <0.33 = red ⊖ or bad. It should be noted that these boundaries, although consistent across indicators, may not be appropriate for some and need to be refined. Indicators have been grouped into stock characteristics of abundance, production, fishing

effects and ecosystem. Note that the summary given at the top of the figure was determined as a simple average of equally weighted individual indicators.

There was relatively little change in the traffic light table from last year and the summary continues to be favorable (green). Two of the four characteristics have been green and two yellow for the last two years indicating a balanced distribution of favorable indicators among the suite examined. The fishing impact characteristic remained yellow largely because of the high counts associated with the strong 2001 year-class and increased fishing during the ovigerous period because of the higher TAC. The ecosystem characteristic remained yellow because of increased temperatures, despite improvements in three indicator species. There are no strong signals that could suggest a regime shift to one less favorable to shrimp.

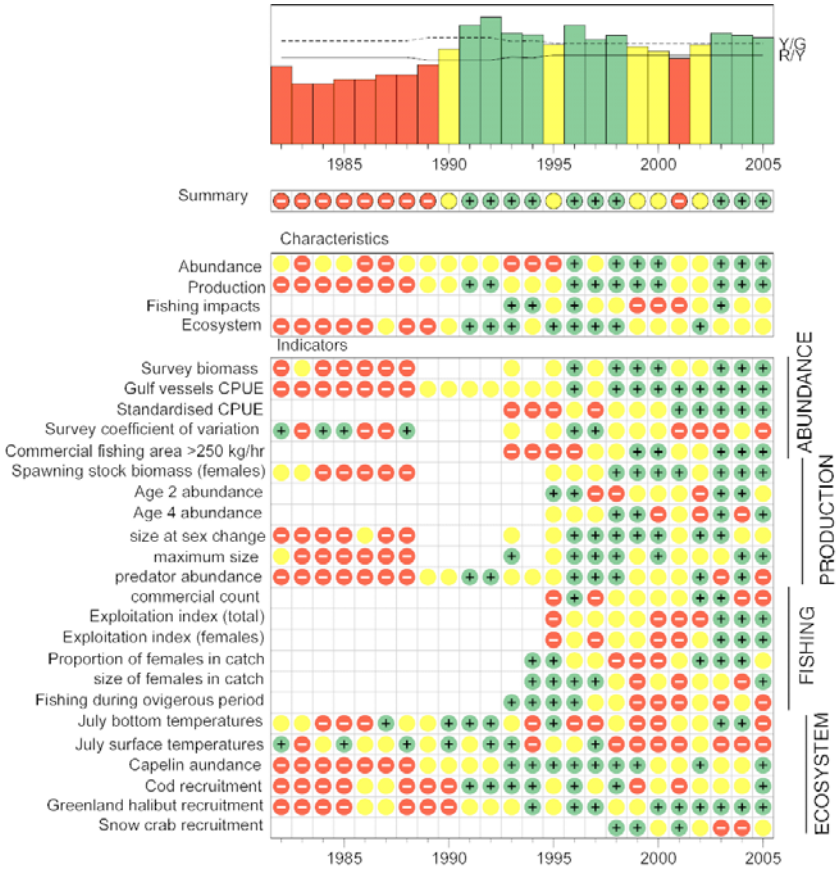


Figure 7. Traffic Light Analysis. Not all indicators in the Traffic Light table are discussed in the text. Please consult CSAS Research Document 2006/001 for a detailed description.

ADDITIONAL STAKEHOLDER PERSPECTIVES

Industry is generally in agreement with the results of the assessment, which were presented at several meetings, including RAP. In particular, they note the problems experienced with small shrimp, which would be from the 2001 year-class (Figure 2), and low prices.

CONCLUSIONS AND ADVICE

Outlook

Increases since 2002 have resulted in record biomass estimates during the last two years. Normally, the strong 2001 year-class should begin to recruit to the fishery as females in 2006 but due to its slower growth rate this will probably occur over several years, and it may be delayed entirely for a year. If completely delayed spawning stock biomass will decrease in 2007 but total biomass should remain high for several years as this year-class grows. The 2002-2004 year-classes appear to be below average at this time, consequently biomass is expected to decrease after the 2001 year-class dies off. This pattern of high followed by lower recruitment was previously seen in this stock. The stable population evenly distributed across year-classes at the beginning of this fishery appears to have been replaced by a cyclical recruitment pattern often seen in developed shrimp fisheries. This may be an unavoidable consequence of exploitation, resulting in a less stable population more vulnerable to collapse, as well as economic instability. A continued precautionary approach, including annual assessments and a conservative harvest strategy, is indicated.

Shrimp from the 2001 year-class will probably be smaller than average in the 2006 fishery and will not reach their maximum size for another 2-3 years. Consequently, the difficulties in avoiding small shrimp in 2005 are expected to continue into 2006.

A substantial increase in the TAC was effected for the 2005 fishery to take advantage of the accumulated and growing biomass and the observation that fishers were able to avoid small shrimp from large year-classes in the past. However, the projected biomass was overestimated, and fishers were unable to avoid small shrimp. Only about 80% of the 2005 TAC was caught. This is not due to decreased abundance or catch rates and is attributed to logistical problems experienced by some fishers. A requested season extension was not recommended due to the lower than projected biomass and slow growth of the 2001 year-class. With biomass expected to remain high as the 2001 year-class grows current catch levels should be sustainable for the next two years. Further increases in the TAC are not advisable at this time because of uncertainties with growth rates and the resulting impact on biomass. In addition, large catches of small shrimp may not be welcomed by industry due to low prices.

OTHER CONSIDERATIONS

Sources of Uncertainty

DFO-industry shrimp survey results are associated with high variances. The accuracy of estimates can also be biased by temporal changes in availability during the survey period. Spatial analyses indicate that catch rates do not always represent overall abundance trends. There is considerable subjectivity associated with assigning modal groups to year-classes in the MIX analyses, consequently estimates of year-class strength, population numbers-at-age and projections using these analyses must be interpreted cautiously. Growth rates can decrease dramatically due to density dependence as appears to be happening with the strong 2001 year-class. Consequently, recruitment to the fishery will be delayed and spread over a longer time period. Uncertainties associated with the growth rate and sex change of this year-class preclude quantitative projections at this time. Unforeseen changes in the ecosystem e.g. predators, and the environment, e.g. temperature, together may lead to major regime shifts requiring radically different management strategies.

SOURCES OF INFORMATION

Koeller, P. 2000. Relative Importance of Environmental and Ecological Factors to the Management of the Northern Shrimp (*Pandalus borealis*) Fishery on the Scotian Shelf. J. Northwest Atl. Fish. Sci. 27: 21-33.

Koeller, P., M. Covey, and M. King. 2005. An Assessment of the Eastern Scotian Shelf Shrimp Stock and Fishery for 2004 and Outlook for 2005. DFO Can. Sci. Adv. Sec. Res. Doc. 2005/001.

Koeller, P., M. Covey, and M. King. 2003. Is Size at Sex Transition an Indicator of Growth or Abundance in Pandalid Shrimp? Fish. Res. 65: 217-230

Koeller, P., L. Savard, D. Parsons, and C. Fu. 2000. A Precautionary Approach to Assessment and Management of Shrimp Stocks in the Northwest Atlantic. J. Northw. Atl. Fish. Sci. 27:235-247.

FOR MORE INFORMATION

Contact: Peter Koeller
Bedford Institute of Oceanography
Department of Fisheries and Oceans
Science Branch, Population Ecology Division
P. O. Box 1006, Dartmouth, N.S. Canada, B2Y 4A2

Tel: (902) 426-5379
Fax: (902) 426-1862
E-Mail: koellerp@mar.dfo-mpo.gc.ca

This report is available from the:

Maritimes Provinces
Regional Advisory Process
Department of Fisheries and Oceans
P.O. Box 1006, Stn. B203
Dartmouth, Nova Scotia
Canada B2Y 4A2

Phone number: 902-426-7070
Fax: 902-426-5435
e-mail address: XMARMRAP@mar.dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas

ISSN 1480-4913 (Printed)
© Her Majesty the Queen in Right of Canada, 2005

La version française est disponible à l'adresse ci-dessus.

CORRECT CITATION FOR THIS PUBLICATION

DFO, 2005. Northern Shrimp on the Eastern Scotian Shelf (SFA 13-15). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2005/060.