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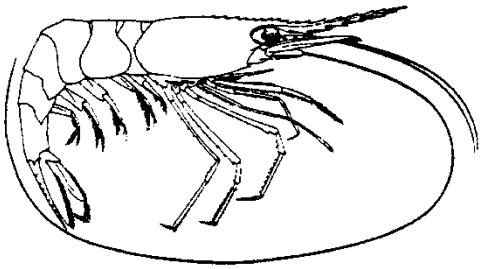
Canadian Science Advisory Secretariat
Quebec Region | **Science Advisory Report 2016/012**

ASSESSMENT OF NORTHERN SHRIMP STOCKS IN THE ESTUARY AND GULF OF ST. LAWRENCE IN 2015



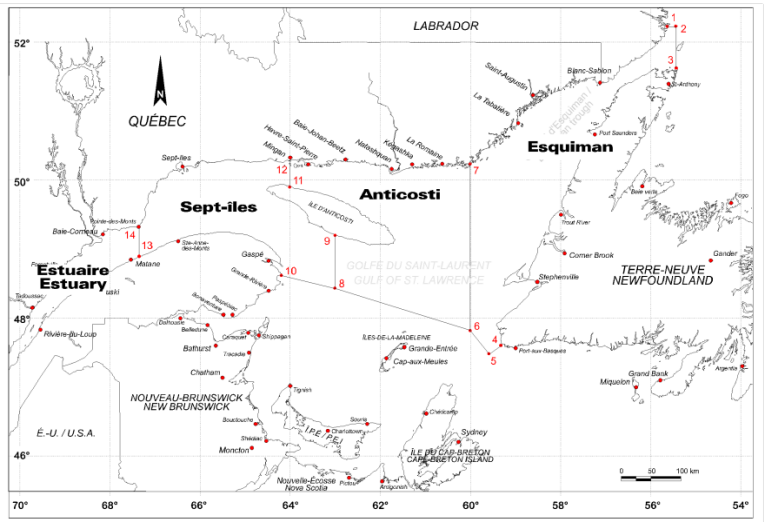


Figure 1. Shrimp fishing areas in the Estuary and Gulf of St. Lawrence.

Context

The Northern Shrimp (Pandalus borealis) fishery began in the Gulf of St. Lawrence in 1965. The exploitation is conducted by trawlers in four shrimp fishing areas (SFA): Estuary (SFA 12), Sept-Iles (SFA 10), Anticosti (SFA 9) and Esquiman (SFA 8) (Figure 1).

Shrimp fishing is regulated by a number of management measures, including the setting of total allowable catches (TAC) in the four areas. TAC-based management limits fishing to protect the reproductive potential of the population. The essential elements for the establishment of a precautionary approach were adopted in 2012. Reference points were determined and harvest guidelines were established based on the main indicator and its position in relation to the stock status classification zones (healthy, cautious and critical). These guidelines are consistent with a precautionary approach. Once the harvest is projected, decision rules are applied to determine the TAC.

This Science Advisory Report is from the January 21, 2016 meeting on Assessment of Estuary and Gulf of St. Lawrence Shrimp Stocks. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- In 2015, preliminary landings were 30,367 t on a TAC of 31,549 t.
- Total fishing effort has been stable for 10 years and corresponds annually to a maximum footprint on the seabed of approximately 6,400 km^2. The same areas are fished by shrimp harvesters from one year to the next.
- The fishery's standardized catch rate in the four areas was high compared to the historical average. Over the past four years, the catch rate was stable in Estuary, rising in Sept-Iles and Anticosti, and decreasing in Esquiman.
- The biomass index from the DFO survey in Estuary decreased in 2015. In Sept-Iles and Anticosti, the index declined between 2007 and 2011 and has remained stable thereafter. In Esquiman, the biomass index has decreased since 2011.
- The demographic structures observed by area in 2015 during the DFO survey revealed that male abundance was similar or slightly higher than the historical average, except in Estuary where it was lower. Thus, in the short term, the recruitment of females to the fishery could be equivalent to the average in most areas.
- The exploitation rate was comparable to the historical average in each area except for Anticosti where it was higher, but with a trend to be closer to the average since 2011.
- Changes in environmental and ecosystem conditions were observed in the Gulf of St. Lawrence, with increases seen for bottom temperature, and in abundance of Redfish and other groundfish. These changes could lead to impacts on shrimp population dynamics and productivity, such as effects on spatial distribution, growth, reproduction and trophic relationships.
- Bycatches in the shrimp fishery have increased due to the significant increase in catches of small Redfish. From 2013 to 2015, bycatch represented for 2.6%, 3.6% and 3.3%, respectively, by weight of Northern Shrimp catches. However, the estimated total catch for each species contributing to bycatches represents less than 1% of the estimated biomass by the DFO survey.
- The main indicator of stock status is calculated from the indices obtained from the summer fishery and the research survey. The main indicator shows that the stocks were in the healthy zone in 2015. Over the past five years, the main indicator was relatively stable in Estuary, Sept-Iles and Anticosti, while a downward trend was observed in Esquiman.
- Harvest guidelines were established according to the main indicator and its position relative relation to the stock status classification zones (healthy, cautious and critical) in compliance with the precautionary approach. According to the guidelines, the projected harvest for 2016 is 1,084 t for Estuary, 12,282 t for Sept-Iles, 9,310 t for Anticosti and 6,609 t for Esquiman.
- TACs are set annually by fisheries management from the projected harvests following the decision rules of the current precautionary approach.

INTRODUCTION

Species Biology

The biology of Northern Shrimp has several particularities, which in turn influence the exploitation strategy, fishery management and resource conservation.

Northern Shrimp change sex over the course of their life cycle, achieving male sexual maturity at about two and a half, then becoming female between four and five years old. The females, which carry their eggs beneath the abdomen, are thus among the largest specimens in commercial catches; the males are smaller because they are younger. Mating takes place in the fall and the females carry their eggs for eight months, from September until April. The larvae are pelagic when they hatch in the spring and metamorphose and settle to the bottom at the end of the summer. Northern Shrimp migrations are associated with breeding (the egg-bearing females migrate to shallower water in winter) and feeding (at night, they leave the ocean floor to feed on small planktonic organisms).

The data from the research survey indicate that Northern Shrimp is widely distributed in the Estuary and the Northern Gulf of St. Lawrence (Figure 2) at depths of 150 to 350 m (Figure 2) with more than 80% of the cumulative Northern Shrimp biomass found between 192 and 331 m in areas with a bottom temperature of 3.6°C to 5.7°C (Figure 3). The median depth for Northern Shrimp distribution is 260 m and the median temperature is 5.2°C. Northern Shrimp is generally associated with the deep water mass and the species is mainly found in channels at depths where sediment is fine and consolidated.

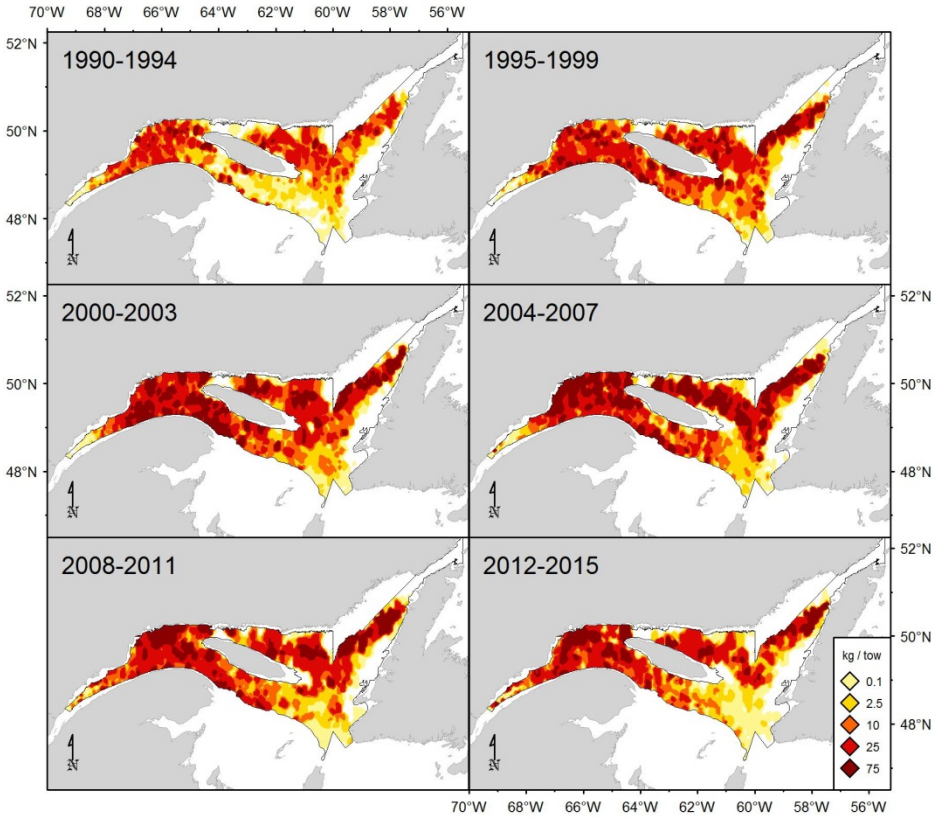


Figure 2. Northern Shrimp catch rates (kg/15 minutes tow) distribution in the DFO survey.

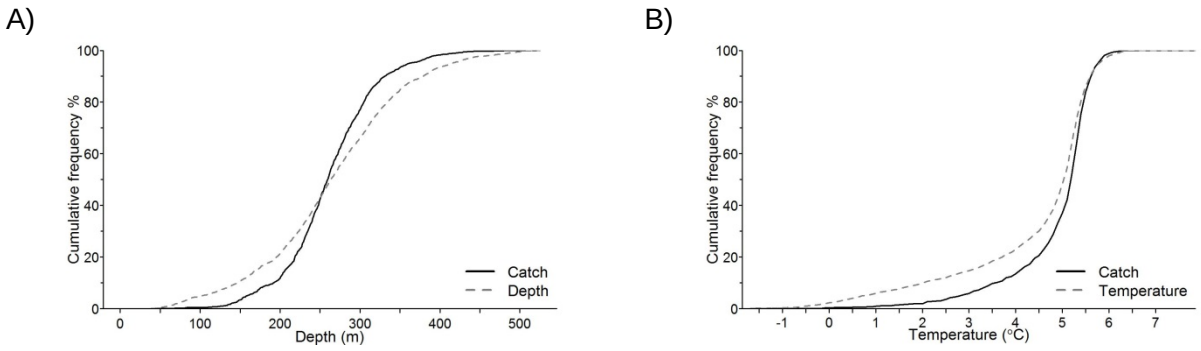


Figure 3. Cumulative frequency of catches (in weight) and of the number of tows sampled based on depth and temperature in the DFO survey, 1990–2015.

Description of the fishery

The number of active licences in the Estuary and Gulf Northern Shrimp fishery in 2015 was 115. The harvesters come from five provinces and seven First Nations. The fishery management measures include the imposition of a minimum mesh size (40 mm) and, since 1993, the compulsory use of the Nordmore grate, which reduces groundfish by-catches. Shrimpers must also keep a log book, have their catches weighted by a dockside monitoring program and agree to have an observer on board at the DFO's request (5% coverage). Use of a vessel monitoring system (VMS) has been mandatory since 2012. The fishery opens on April 1 and closes on December 31. The fishery has been managed by TAC since 1982 and the traditional fishers have had individual quotas since the mid-1990s.

Landings of Northern Shrimp in the Estuary and Gulf of St. Lawrence have risen gradually since the fishery began. Landings rose from approximately 1,000 tons in the early 1970s to more than 35,000 tons in the late 2010s (Figure 2). Landings decreased thereafter to reach 30,367 tons in 2015 (preliminary). Preliminary statistics indicate landings in 2015 of 1,093 tons in Estuary, 12,601 tons in Sept-Iles, 8,762 tons in Anticosti and 7,911 tons in Esquiman. In 2015, the TAC was increased by 15% in Estuary and 7.75% in Anticosti Sept-Iles while it remained stable in areas Sept-Iles and Esquiman. The TAC was reached in Sept-Îles, over 96% reached in Esquiman and over 92% reached in Estuary and Anticosti on January 18, 2016 (Figure 5). The proportion of fishing effort between spring, summer and fall seems to have been consistent over the years.

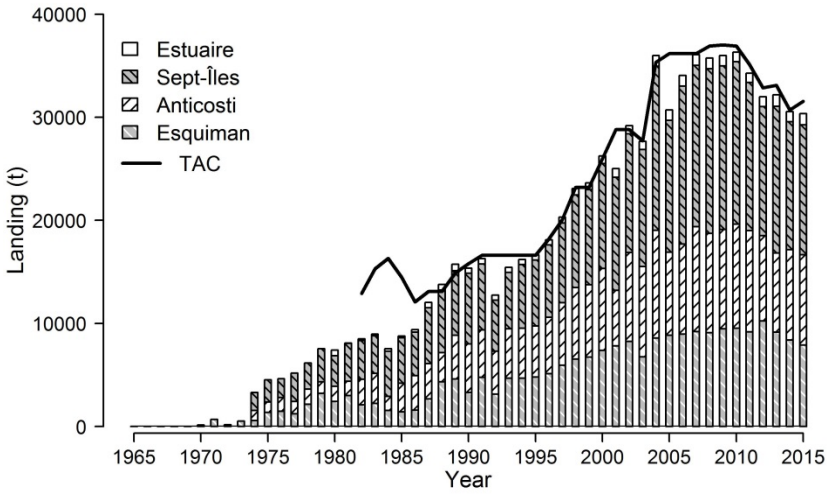


Figure 4. Landing and total allowable catches (TAC) by fishing area and by year. The 2013 data are preliminary.

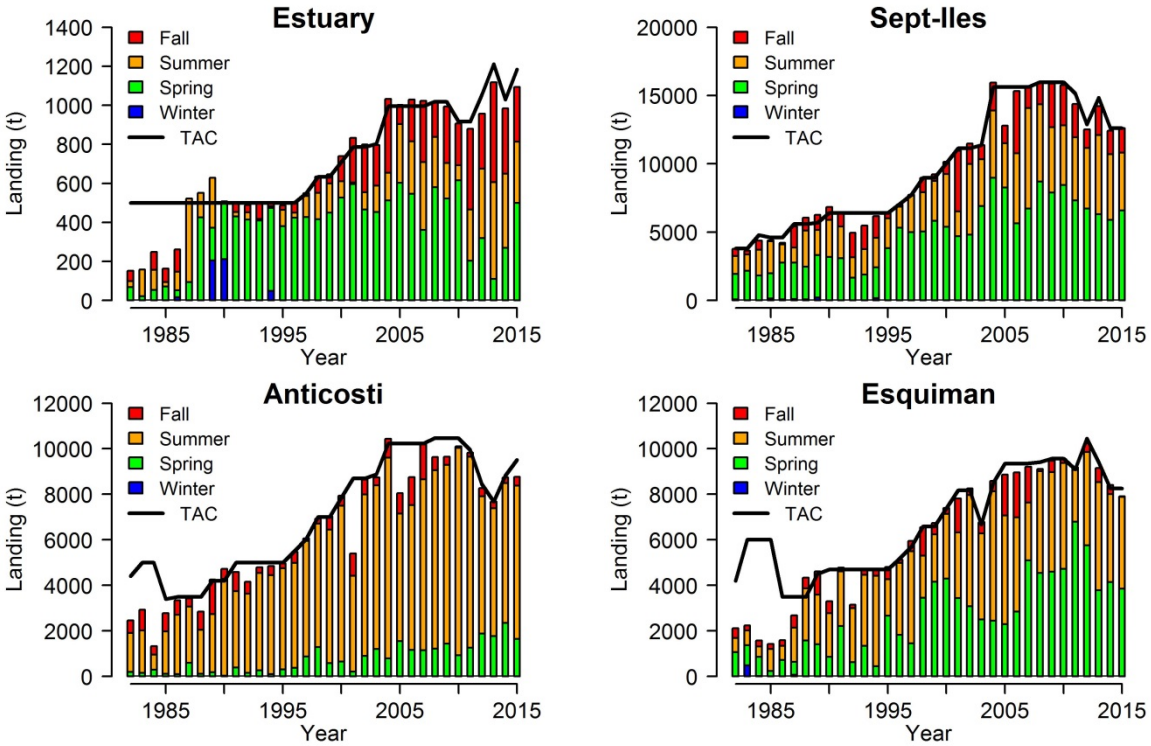


Figure 5. Seasonal landing and total allowable catches (TAC) by fishing area and by year. The 2015 data are preliminary.

ASSESSMENT

Programs were implemented in the 1980s and 1990s to monitor the fishery and the status of Northern Shrimp populations in the Estuary and Gulf of St. Lawrence on an annual basis. Commercial fishery statistics (shrimper catch and effort) are used to estimate the fishing effort and calculate catch rates. The commercial catch samples allow the estimation of the number of shrimp harvested by size classes and by sexual maturity stage. A research survey is conducted every year in the Estuary and Gulf of St. Lawrence in August from a DFO vessel. Biomass indices are calculated using a geostatistical method. Survey catch samples provide abundance estimates of shrimp by size classes and by stage of sexual maturity.

The sectors that sustain fishing in the four areas have not changed in recent years and correspond to the spots where high concentrations of shrimp were observed during the survey (Figure 4). The distribution of the biomass from the research survey shows that high concentrations of Shrimp were found in all fishing areas in 2015. However, as before, the southern sector of Anticosti and Esquiman areas sustained very few Shrimp.

Northern Shrimp is distributed over more than 95 000 km2 in the Estuary and the northern Gulf of St. Lawrence and 95% of the biomass is distributed over a minimum area of 45 000 km2. Since 2003, the total annual fishing effort was about 100 000 hours, a value slightly below the historical average (Figure 7) and corresponding annually to a maximum underwater footprint of about 6 400 km2 assuming no overlapping of tows. This effort is concentrated in an area of 13 500 km2 where fishing intensity is variable. The fishing zone where activity is most intense corresponds to an area of 1 850 km^2 where 47% of the fishing effort is deployed. The area where the fishery is practised overlaps 14% of the shrimp distribution area.

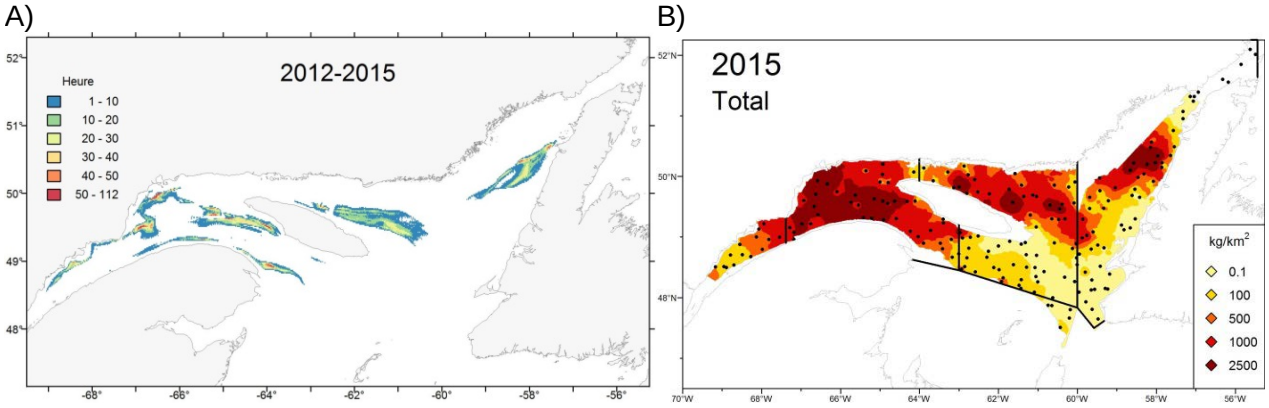


Figure 6. A) Distribution of the mean fishing effort from 2012 to 2015 according to data from the vessel monitoring system (VMS). B) Spatial distribution of the biomass (kg/km²) of shrimp estimated by kriging during the 2015 research survey.

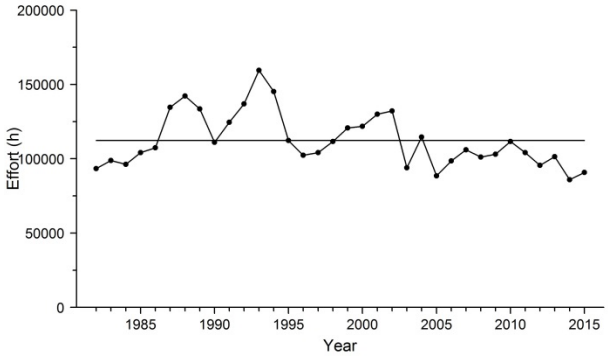


Figure 7. Total number of fishing hours per year for all management areas in the Estuary and the Gulf of St. Lawrence.

Catches per unit effort (CPUE) are standardized to take into account changes in fishery capacity and seasonal fishing patterns. CPUE in the four areas is high compared to the historical average. Over the past four years, the catch rate has been stable in Estuary, up in Sept-Iles and Anticosti and down in Esquiman. The CPUE decreased in Estuary between 2007 and 2010 and remained at an average level thereafter (Figure 8). The CPUE decreased from 2007 to 2013 in Sept-Iles and increased thereafter to above the historical average. The CPUE has been stable and high in Anticosti since 2005. Lastly, the CPUE in Esquiman is very high, but has been decreasing since 2013.

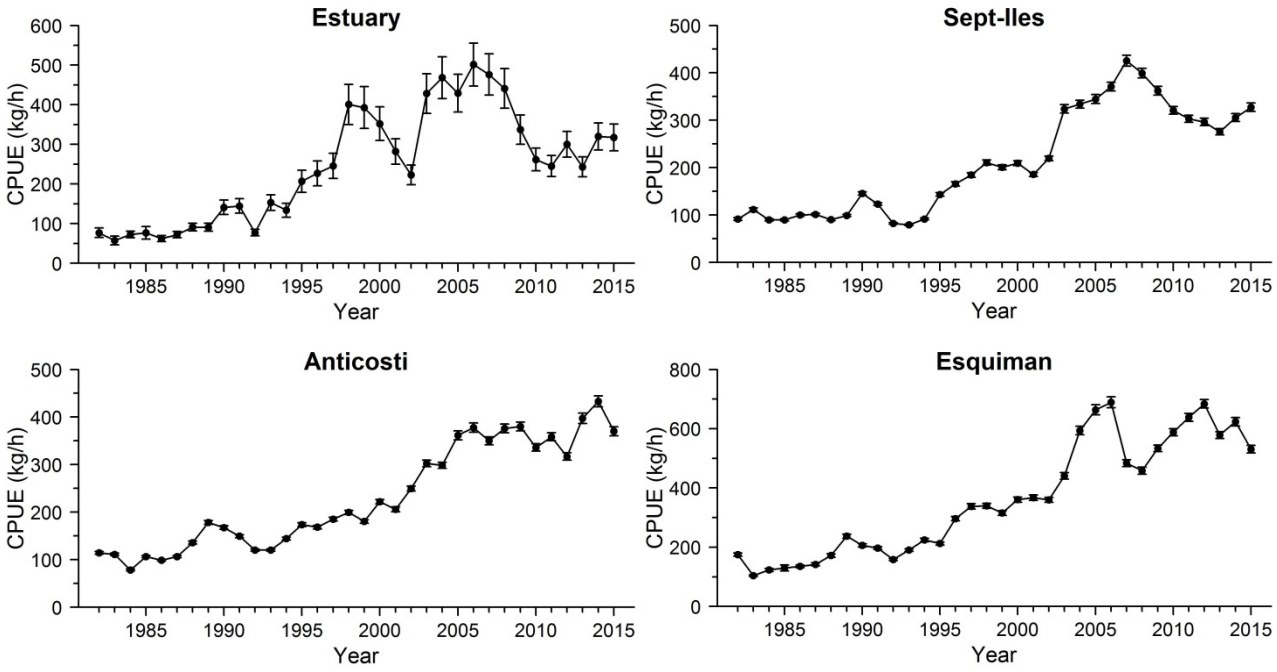


Figure 8. Standardized catch per unit effort (CPUE) from the fishery ± confidence interval (95%).

The biomass index from the DFO survey in Estuary decreased in 2015, but is still high. In Sept-Iles and Anticosti, the indices decreased between 2007 and 2011 and remained stable thereafter. In Esquiman, the index has been decreasing since 2011 (Figure 9).

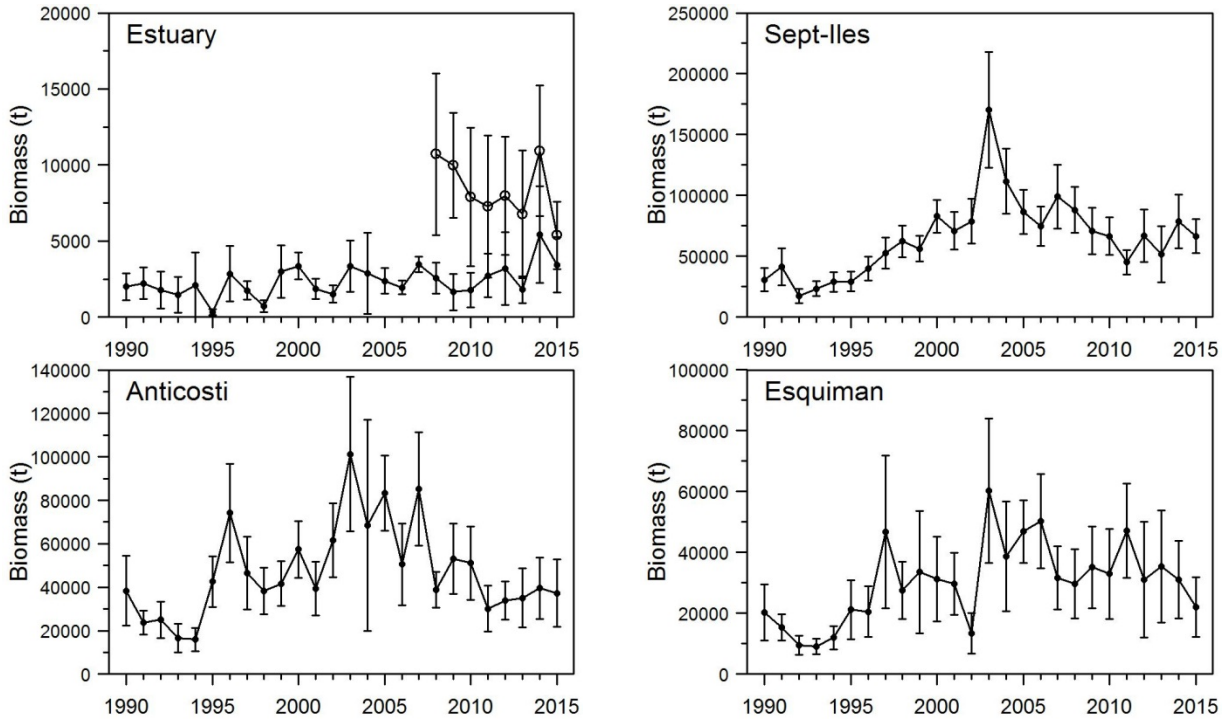


Figure 9. Biomass index from the research survey ± confidence interval (95%). For Estuary, the open circles represent results obtained by integrating strata from the shallow portion that were added in 2008.

An index of the exploitation rate is obtained by dividing the commercial catches in number by the abundance estimated from the research survey. This method cannot be used to estimate the absolute exploitation rate or to relate it to target exploitation rates. However, the method does make it possible to track relative changes in the exploitation rate over the years. In 2015, the exploitation rate index increased in Estuary, Anticosti and Esquiman and remained stable in Sept-Iles (Figure 10). The exploitation rates were near the historical average with the exception of Anticosti, where they were higher, but they have been trending downward toward the mean since 2011.

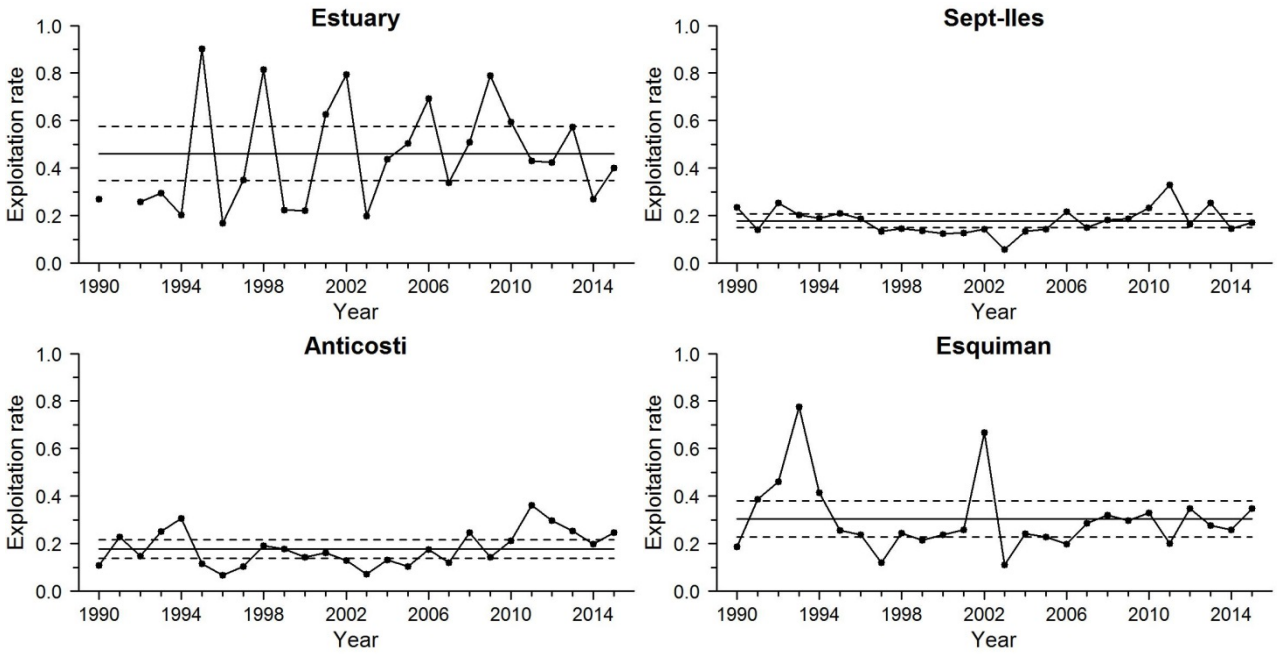


Figure 10. Index of the exploitation rate by fishing area and by year. The solid horizontal line represents the 1990-2013 mean ± 0.5 standard deviation.

Main Stock Status Indicator

The quantity of (primiparous) females recruited in a given year depends on the number of males that changed sex in the preceding winter. The abundance of reproductive females which will hatch the larvae in spring can be predicted from the reproductive stock estimated in summer and made up of primiparous females that have just changed sex and of multiparous females that survived larvae hatching.

The main indicator of stock status is calculated from the male and female indices obtained from the summer fishery (number per unit effort for June, July and August) and research survey (abundance in August). In order to combine the indices, each is standardized with respect to the reference period. The main stock status indicator represents the mean of the four indices.

The interannual variations of the indices in Estuary are large (Figure 11). The index for the male component in the fishery decreased significantly between 2012 and 2013 and remained stable thereafter whereas in the survey, male abundance has been stable for five years. The indices for the female component show a discrepancy; the survey shows very high abundances whereas the fishery shows an upward trend and the numbers per unit effort (NPUE) are near the historical average. The indices in Sept-Iles from the fishery and the survey show the same trends (i.e. stability in recent years). Indices for the male component in Anticosti increased in 2014 in the fishery and the survey. The NPUE for the fishery is at a historically high level whereas the abundance in the survey is near the average. The index of the female component from the fishery has been very high for a few years whereas in the survey, it is stable and near the average. In Esquiman, the indices for the male and female components in the fishery and the survey have decreased for four years.

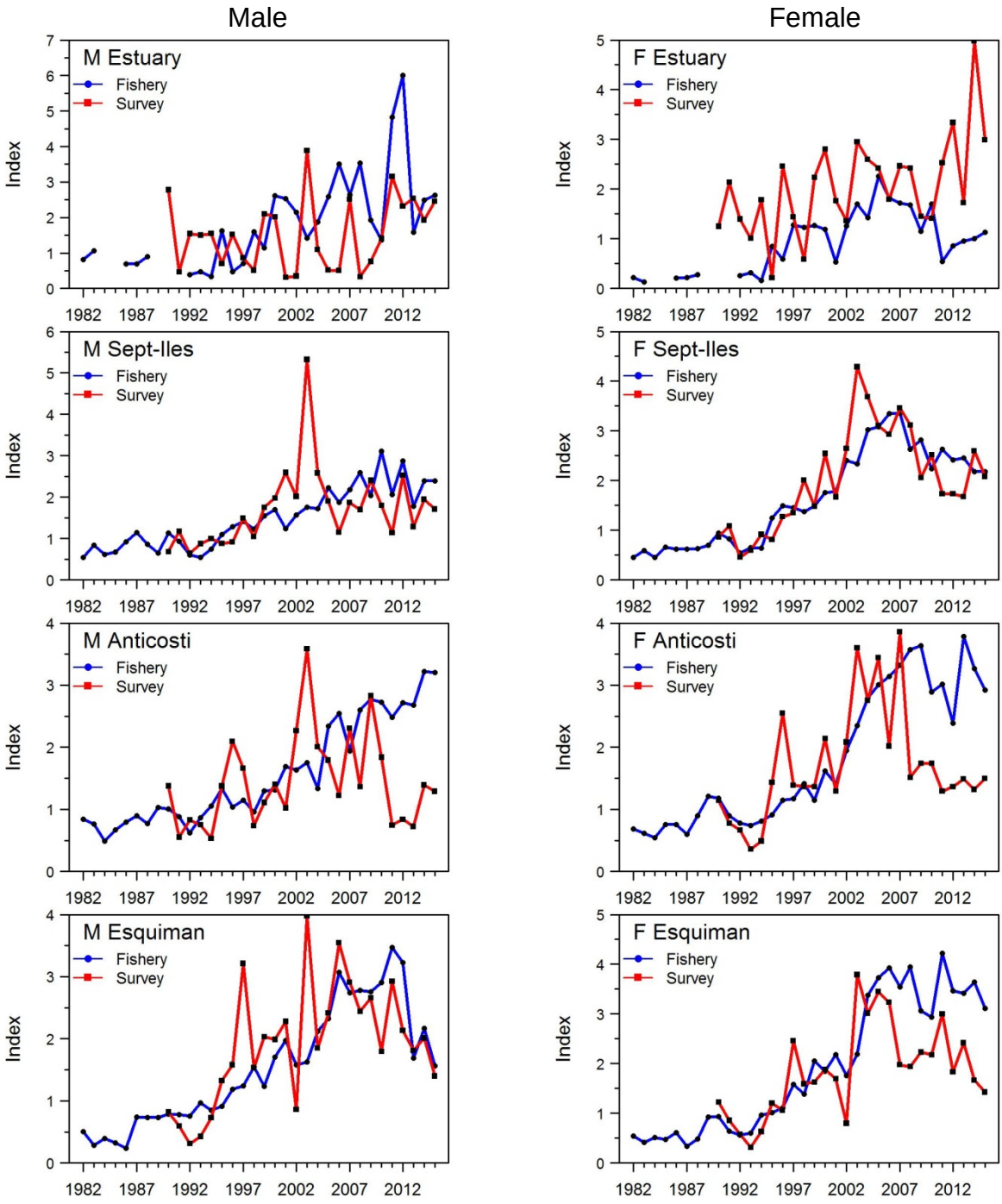


Figure 11. Standardized indices from the main indicator of stock status, which is the abundance of male and female shrimp from the DFO survey and the catch per unit effort of male and female shrimp in the summer commercial fishery).

The main indicator of stock status shows that the stocks were in the healthy zone in 2015 (Figure 12). However, compared to 2014, the indicator of stock status decreased in Estuary and Esquiman and is relatively stable in Sept-Iles and Anticosti. In the past five years, the indicator of stock status has been somewhat stable in Estuary, Sept-Iles and Anticosti whereas a downward trend has been observed in Esquiman.

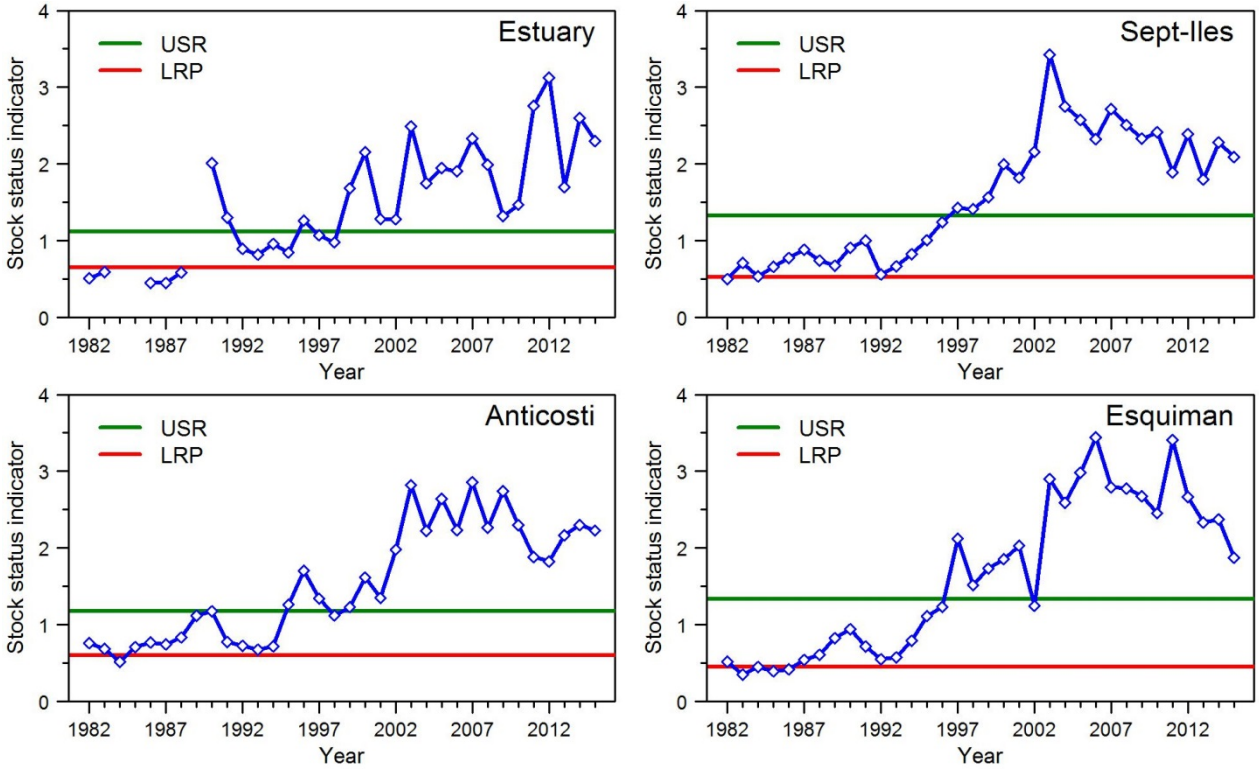


Figure 12. Main stock status indicator by year and limit (LRP) and upper (USR) stock reference points for each fishing area.

Outlook

It is possible to obtain an estimate of the relative abundance of the year classes by examining their contribution to the research survey catches (Figure 10). The abundances for the Estuary area correspond to those estimated for the area that was extended in 2008 (see Sources of Uncertainty).

Demographic structures show that abundance of males and females is near the historical average with the exception of the Estuary area, where it has been below the average observed since 2008. Males likely to change sex during the winter of 2016 were well represented in 2015 in Sept-Iles, Anticosti and Esquiman, but much less so in Estuary. The abundance of juveniles (carapace length between 8 and 12 mm) is near the historical average in the 2014 and 2015 surveys. Therefore, in the short term, recruitment to the fishery should equal the average in most areas.

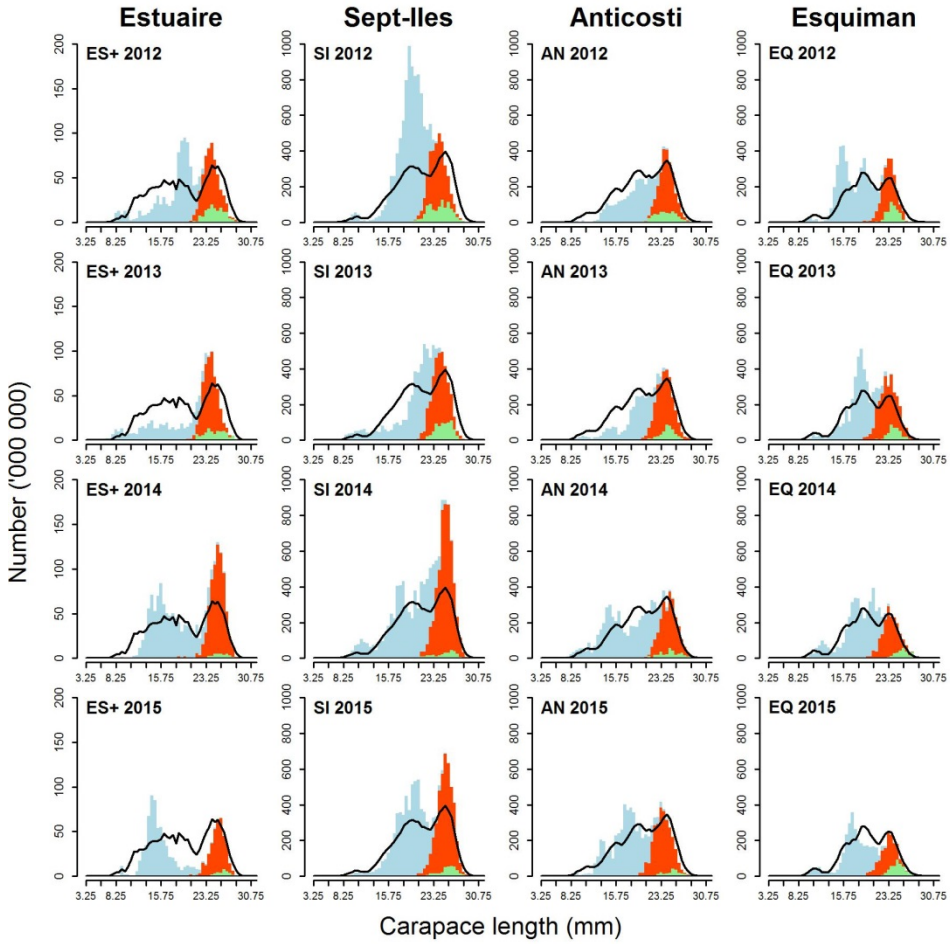


Figure 13. Shrimp abundance from the research survey (in number) by length class and by fishing area from 2012 to 2015. The histograms represent males (in blue), primiparous females (in red) and multiparous females (in green) and the solid line represents the mean of the years 1990-2013 (2008-2013 for the Estuary area).

Sources of Uncertainty

Generally, the commercial fishery catch rate and the abundance index in the research survey are consistent and considered to be good indicators of shrimp abundance. However, a recently noted discrepancy is still being observed between the abundance indices in the DFO survey and those in the commercial fishery for male and female shrimp in the Anticosti area and for female shrimp in Esquiman. These discrepancies can be explained by the fact that these two indices do not sample the same fraction of the population. The research survey covers the entire Estuary and northern Gulf of St. Lawrence whereas the fishery targets channel heads where shrimp abundance is higher.

The allocation of supplementary stations in the Estuary shallow waters since 2008 had a very significant impact on the catches of males and females in the Estuary fishing area. The results obtained after six surveys conducted on this extended area are consistent among the years and indicate that the abundance in the Estuary area is much greater than that previously estimated and that the exploitation rate index is much lower. In the short term, shallow strata should be integrated into estimates of the main indicator of stock status.

According to the industry, the distribution of fishing activities was affected by the closure of fishing grids in Sept-Iles and Anticosti in 2014 and 2015 because of excessively high bycatches and the increased presence of fixed gear in the traditional Esquiman fishing area in 2015. This movement of part of their activities to other areas may have an impact on the catch per unit effort. Changes in fishing effort distribution are observed occasionally, the reasons are to avoid bycatches and fixed gear or to focus activities on areas where shrimp is more abundant. However, spatial distribution of the fishing effort is not considered in the CPUE estimate.

CONCLUSIONS AND ADVICE

The purpose of the precautionary approach adopted in 2012 is to maintain a constant exploitation rate when the stock is in the healthy zone. TAC variations in the past two years were reflected through exploitation rate variations in the same directions, which maintained or came close to exploitation rates near historical averages.

Harvest guidelines were established according to the main indicator and its position in relation to the stock status classification zones (healthy, cautious and critical) in compliance with the precautionary approach. According to the guidelines, the projected harvest for 2016 is 1,084 t for Estuary, 12,282 t for Sept-Iles, 9,310 t for Anticosti and 6,609 t for Esquiman (Figure 14).

The 2016 TACs will be set by fisheries management based on these harvests and according to the decision rules in the precautionary approach currently in effect.

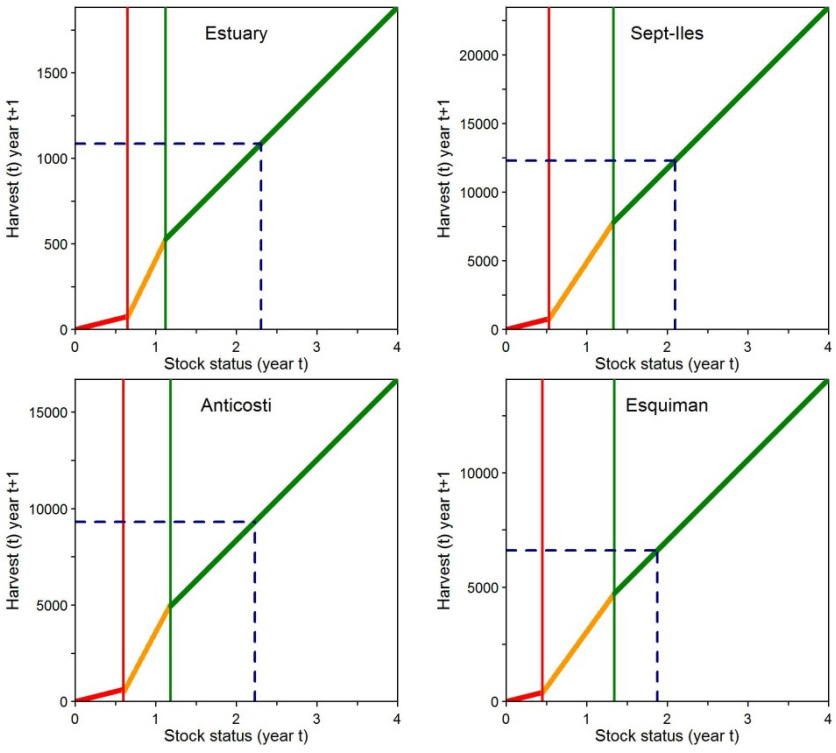


Figure 14. Harvest guidelines by fishing area. The projected harvest for 2016 is shown in view of the main stock indicator in 2015.

OTHER CONSIDERATIONS

Bycatches of small fish in the shrimp fishery between 2000 and 2015 were examined from the at-sea observer database. Fish bycatches were predominantly in the range of 1 kg or less per species and per sampled tow. Since 2013, bycatches in the shrimp fishery have risen well above the average, reaching a historical peak of over 1 100 tons in 2014; they represented 2.6%, 3.6% and 3.3% (in weight) of the Northern Shrimp catch (Figure 15). This increase is mainly due to a significant rise in small redfish catches. The main species in the catch in 2015 in order of importance are Redfish, Greenland Halibut, Capelin, White Barracudina, Herring and Witch Flounder. Estimated total catches for each species in these bycatches represent less than 1% of the biomass estimates in the DFO survey for each of them.

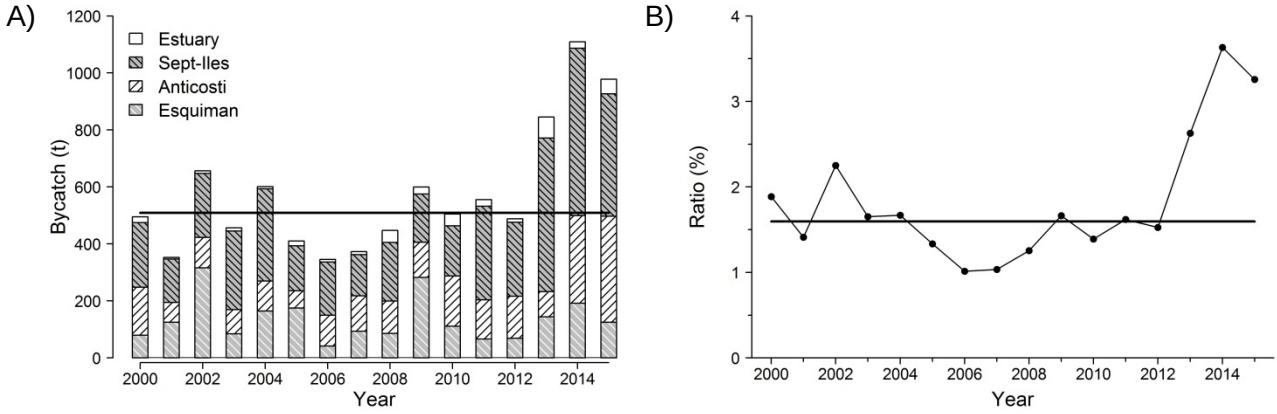


Figure 15. A) Bycatches for all species for each year and shrimp fishing area during fishing activities directed at Northern Shrimp and in the presence of an at-sea observer. B) Ratio (%) of bycatches to total Northern Shrimp catches. Solid lines indicate the average for the years 2000 to 2013.

Catches of other shrimp species during commercial fishing activities are very low compared to Northern Shrimp catches. Two shrimp species are common in catches: Pink Glass Shrimp (*Pasiphaea multidentata*) and Striped Shrimp (*Pandalus montagui*). For the period from 2000 to 2015, the percentage in the total *P. multidentata* catch observed at sea was 0.06% whereas it was 0.77% in landings; for *P. montagui*, the percentages observed were 0.0003% at sea and 0.21% in landings.

The trawls used for the shrimp fishery come into contact with the bottom. The hard structures of the benthic ecosystem, essentially corals and sponges, are generally considered as being the most potentially affected by the disturbances that fishing activities cause. Information on coral and sponge bycatches in fixed gear for shrimp fishing suggests that a relatively small proportion of trawling tows catch these species. Bycatches of sea pens (soft corals) are observed in 0.7% of tows and 0.3% of sponge tows. The overlap between the fishing footprint and the coral and sponge range varies depending on taxa. In general, overlap between the shrimp fishery and corals and sponges is minimal, with the exception of three taxa: *Pennatula aculeata*, *Pennatula grandis* and sponges in areas where fishing activities overlap 11.2%, 26.4% and 14.0% of the biomass estimated in the DFO survey.

Deep water temperatures in the Gulf have been rising for a few years. These waters, which come from outside the Gulf, are a mix of the cold Labrador current and the warm Gulf Stream waters. The ratio of these two water masses is currently richer in warm Gulf Stream water. Waters entering through the Cabot Strait move upstream, mixing little with shallower waters. Overall, the average temperature in the Gulf at depths of 150 to 300 m reached a record high in 2015, surpassing 6°C at 250 m and 300 m for the first time since 1915. The area of seafloor

with temperatures warmer than 6°C increased in the Anticosti and Esquiman channels and in the center of the Gulf, to the detriment of seafloor habitat in the 5 to 6°C temperature range. In 2015, male and female shrimp were found at bottom temperatures that were 1°C warmer compared to the 1990 to 2014 average. In Sept-Iles, it was observed that for five years females have matured later in the season and bearing their eggs later. However, larval extrusion in the spring does not seem to be affected by this phenomenon, with larval release remaining near the end of April from year to year.

The ecosystem dominated by groundfish in the early 1990s has progressed to an ecosystem dominated by forage species. Shrimp abundance increased at the same time as abundance of other large-sized groundfish species declined. For a few years now, an increase in the abundance of redfish and cod has been observed in the northern Gulf (Figure 16). Trophic changes may be observed in future years because shrimp are a major prey component for numerous species.

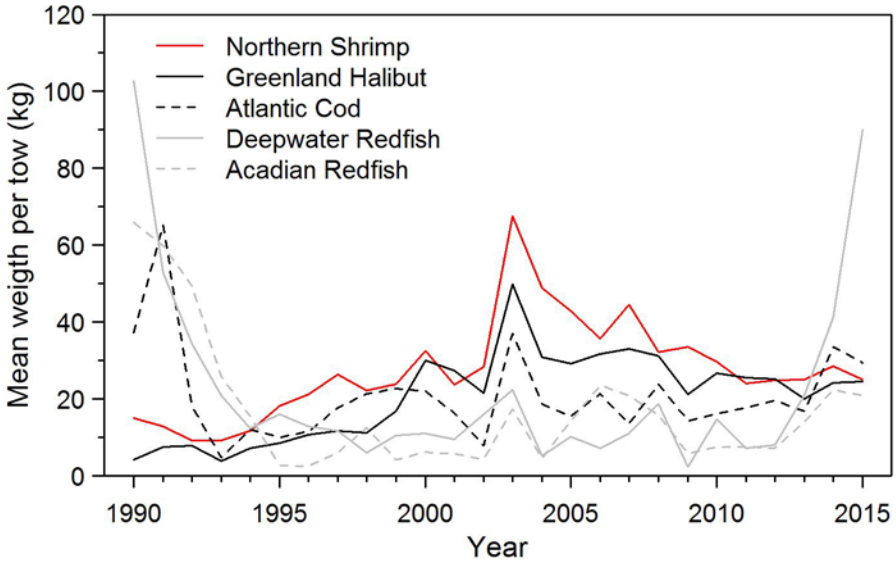


Figure 16. Biomass indices (kg per trawling tow) estimated during the DFO survey in the northern Gulf of St. Lawrence for main predators of Northern Shrimp

These changes in environmental and ecosystem conditions observed in the Gulf of St. Lawrence may have an impact on shrimp population dynamics through their effects on such factors as spatial distribution, growth, reproduction and trophic relationships.

SOURCES OF INFORMATION

This Science Advisory Report is from the January 21, 2016 meeting on Assessment of Estuary and Gulf of St. Lawrence Shrimp Stocks. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Devine, L., Plourde, S., Starr, M., St-Pierre, J.-F., St-Amand, L., Joly, P., and Galbraith, P.S. 2015. Chemical and biological Oceanographic Conditions in the Estuary and Gulf of St. Lawrence during 2014. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/071. v + 46 p.

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DFO. 2012. Assessment of the impact of northern shrimp trawling on benthic habitats communities in the Estuary and northern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/054.

DFO. 2013. Importance of bycatch in the northern shrimp fishery in the Estuary and northern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/066.

Galbraith, P.S., Chassé, J., Nicot, C., Caverhill, C., Gilbert, D., Pettigrew, B., Lefaivre, D., Brickman, D., Devine, L., and Lafleur, C., 2015. Physical Oceanographic Conditions in the Gulf of St. Lawrence in 2014. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/032. v + 82 p.

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