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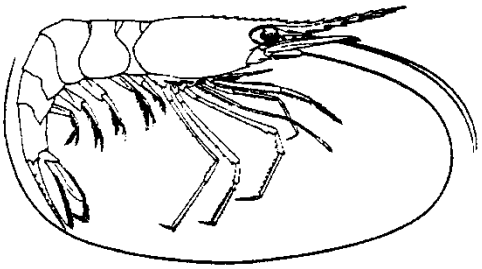
Canadian Science Advisory Secretariat
Quebec Region | Science Advisory Report 2018/015

ASSESSMENT OF NORTHERN SHRIMP STOCKS IN THE ESTUARY AND GULF OF ST. LAWRENCE IN 2017



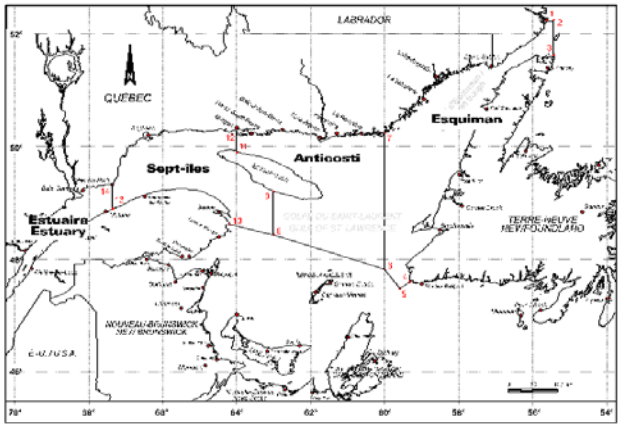


Figure 1. Shrimp fishing areas in the Estuary and Gulf of St. Lawrence.

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 each area. 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 23, 2018 meeting on Assessment of northern shrimp stocks in the Estuary and Gulf of St. Lawrence. Participants in the science review included representatives from DFO Science, DFO Fisheries Management, the fishing industry, provincial governments, university researchers, and Aboriginal organizations. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- In 2017, preliminary landings for all shrimp fishing areas were 22,431 t from a TAC of 26,732 t, a decrease of 26% since 2015. TACs were not reached in Sept-Iles and Anticosti areas.

- The standardized commercial fishery catch rate has been decreasing in the four fishing areas, reaching values in 2017 that are comparable to those observed at the beginning of the 2000s.
- The DFO research survey biomass index and abundance indices for males and females have been declining. Biomass and abundances in 2017 are close to the low values observed in the early 1990s.
- Juvenile abundance was low in 2016 and 2017 in all areas.
- Northern shrimp is still widely distributed in the northern Gulf of St. Lawrence, but since 2008 the DFO survey has shown a decline in the area of shrimp concentrations. This is also observed in the fishery, as some traditional fishing grounds have been abandoned because of the low abundance of shrimp.
- Warming water and increasing predation by redfish appear to be important factors in the decline of northern shrimp. These conditions are not expected to improve in the short term.
- In 2017, according to the precautionary approach for northern shrimp, the Estuary and Sept-Iles stocks were in the cautious zone whereas Anticosti and Esquiman stocks were still in the healthy zone but close to the cautious zone.
- Following the harvest guidelines established as part of to the precautionary approach, the projected harvest for 2018 is 239 t for Estuary, 4,267 t for Sept-Iles, 5,722 t for Anticosti and 5,508 t for Esquiman.
- The outlook for the status of northern shrimp stocks in the Estuary and Gulf of St. Lawrence is poor given the low recruitment, the warming water and the increasing predation by redfish. In the short term, the downward trend in these stocks is expected to continue.

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).

Species Distribution

Northern shrimp are present in the Northwest Atlantic, from Baffin Bay to the Gulf of Maine in the south. The species is generally associated with the deep water mass and found mainly at depths where sediments are fine and consolidated and where the temperature varies from 1 to 6 °C.

DFO research survey data indicate that the northern shrimp is widespread in the Estuary and in the northern Gulf of St. Lawrence (Figure 2). It is distributed over more than 98,000 km^2 at

depths from 150 to 350 m, with more than 80% of the biomass concentrated in channels between 192 and 331 m, at bottom temperatures ranging from 3.6 to 5.7 °C. While there is some stability in the area of occupancy, since 2000 there has been a decrease in shrimp concentration areas, where over 95% of the biomass is distributed, which have decreased from 54,000 km^2 to 33,000 km^2.

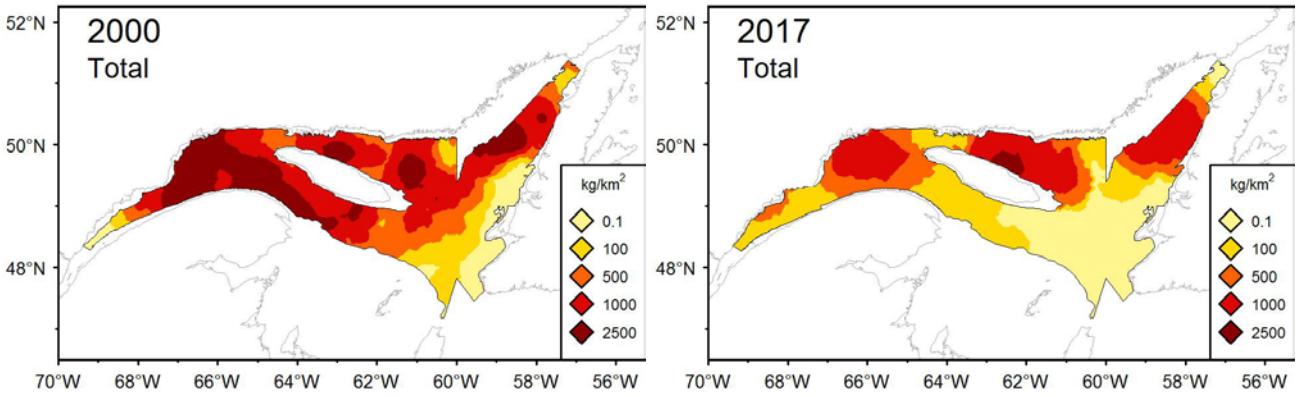


Figure 2. Northern shrimp catch rates (kg/km^2) distribution in the DFO survey in 2000 and 2017.

Environmental and Ecosystem Conditions

Temperature is a dominant ecological factor that influences the biology of ectothermic or cold-blooded organisms, such as the northern shrimp. These organisms have an optimal temperature window in which they function better. Moderate differences in the optimal temperature can affect productivity and reduce resistance to environmental challenges such as hypoxia and ocean acidification. The northern shrimp is a coldwater species. The Gulf of St. Lawrence is near the southern limit of the northern shrimp's distribution, and the species is present there in temperatures nearing the upper level of its thermal preference. In addition, larvae that emerge in the surface layer are exposed to a much wider range of temperatures, from about 0 °C to above 10 °C, which can affect their survival. The northern shrimp is therefore vulnerable to surface and deep-water warming.

Deep-water temperatures in the Gulf have been rising in the last 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 bottom of the Cabot Strait move upstream, mixing little with shallower waters. The seabed area covered by temperatures above 6 °C has increased in the Anticosti Channel, Esquiman Channel and Central Gulf, to the detriment of the bottom habitat immersed in waters within the temperature range of 5 to 6 °C (Figure 3). In 2017, male and female shrimp were found in bottom temperatures that were 1 °C warmer compared to the 1990 to 2015 average. In Sept-Iles, in the last five years, it has been observed that females mature later in the summer and bearing their eggs later in the fall. However, larval hatching in the spring does not seem to be affected by this phenomenon, with larval release still occurring near late April.

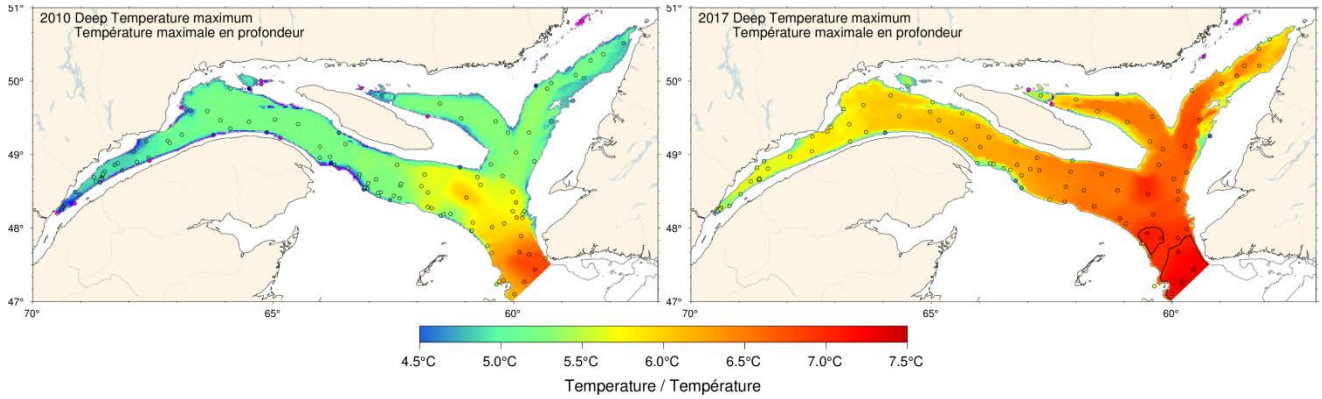


Figure 1. Maps of the maximum temperature at depths typically found between 200 and 300 m for 2010 and 2017.

The Estuary and Gulf of St. Lawrence ecosystem, dominated by groundfish until the late 1980s, has transitioned to an ecosystem dominated by forage species from the 1990s to 2010. Shrimp abundance increased after the abundance of large-sized groundfish species decreased. Since 2013, the situation has been reversing: the abundance and biomass of invertebrates sampled in the DFO survey in August is decreasing, while those of groundfish, mainly redfish, are increasing (Figure 4). Three strong cohorts (2011, 2012 and 2013) of Deepwater redfish (*Sebastes mentella*) have contributed to this increase since 2013 in the Estuary and northern Gulf. The 2011 cohort, which is the most abundant, now has a modal length of 20 cm, and these young redfish are distributed throughout the northern Gulf channels. The redfish diet varies according to the size of the fish. When small, up to about 20 cm, redfish mainly consume zooplankton. At intermediate sizes of 20 to 30 cm, redfish mainly consume shrimp, including the white shrimp (*Pasiphaea multidentata*) and the northern shrimp, while at about 30 cm, redfish consume a lot of fish. Estimated predation by redfish on northern shrimp has increased by a factor of six over the past two years.

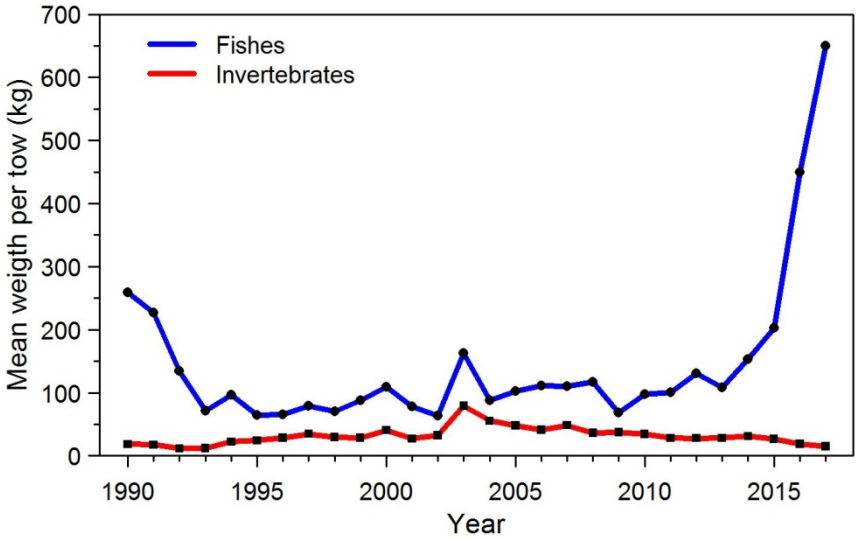


Figure 2. Biomass indices (kg per trawling tow) estimated during the DFO survey in the northern Gulf of St. Lawrence for invertebrates and fish.

These changes in environmental and ecosystem conditions observed in the Estuary and Gulf of St. Lawrence have an impact on northern shrimp population dynamic through their effects on

such factors as abundance, spatial distribution, growth, reproduction and trophic relationships. Warming water and increased predation by redfish appear to be important factors in the northern shrimp's decline. These conditions are not expected to improve in the short term.

Description of the fishery

The fishery has been managed by TAC since 1982, and the traditional fishers have had individual quotas since the mid-1990s. The number of active licences for northern shrimp fishing in the Estuary and Gulf was 111 in 2017. Operators are from five provinces and seven First Nations communities. 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 significantly reduces groundfish bycatches. A protocol to limit small fish bycatch is in place; thus, several fishing grids were temporarily closed during the 2014–2016 fishing seasons, due to large catches of small redfish. Shrimpers must also keep a log book, have their catches weighed at dockside, and agree to have an observer on board at the Department's request (5% coverage). Use of the Vessel Monitoring System (VMS) has been mandatory since 2012. The season begins on April 1 and ends on December 31.

Northern shrimp landings in the Estuary and Gulf of St. Lawrence have gradually increased since the fishery began. Landings have increased from about 1,000 t in the early 1970s to more than 35,000 t in 2004 and 2007–2010 (Figure 5). Landings decreased thereafter to 22,431 t in 2017. The preliminary statistics for 2017 indicate landings of 889 t in the Estuary, 7,236 t in Sept-Iles, 7,292 t in Anticosti, and 7,004 t in Esquiman (Figure 6). In 2017, the TAC decreased by 15% in the Estuary, Sept-Iles and Anticosti, and remained the same in Esquiman. As of January 9, 2018, the TAC has been reached at over 98% in the Estuary and at almost 100% in Esquiman. The TAC was not reached in Sept-Iles and Anticosti, where landings accounted for only 68% and 90% of the TAC, respectively.

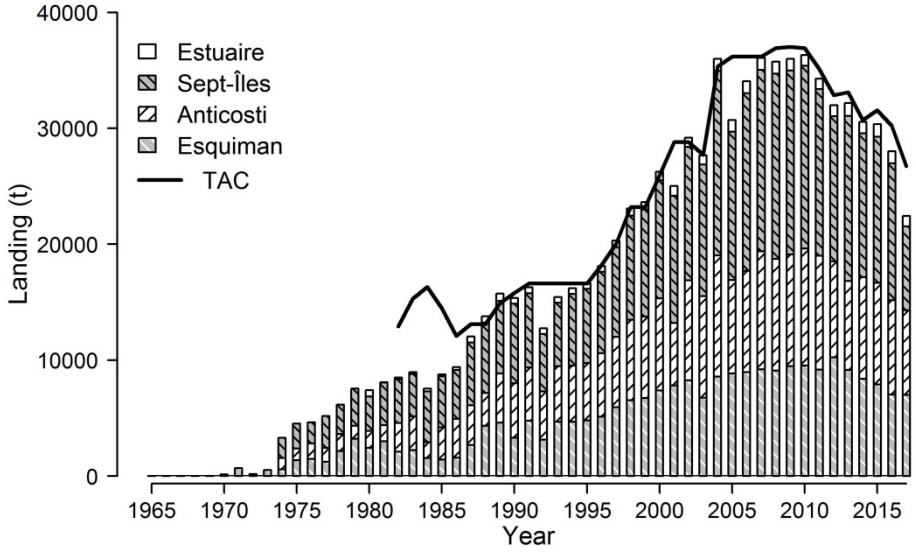


Figure 3. Landing and total allowable catches (TAC) by fishing area and by year. The 2017 data are preliminary.

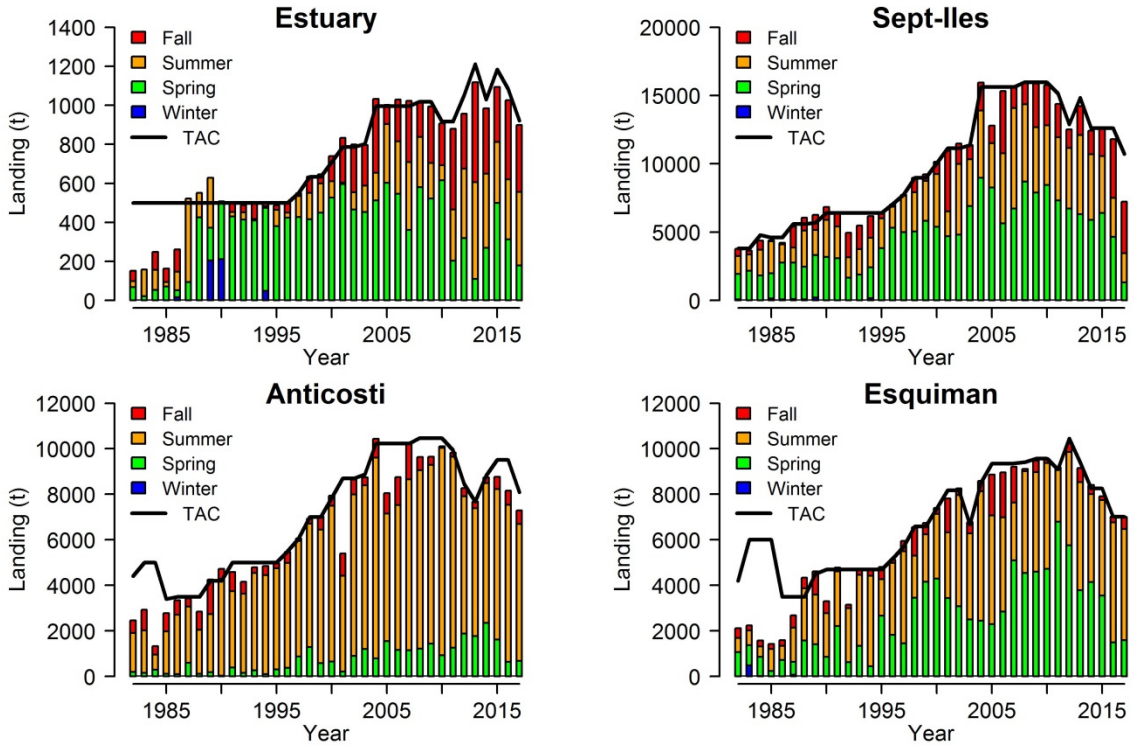


Figure 4. Seasonal landing and total allowable catches (TAC) by fishing area and by year. The 2017 data are preliminary.

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 correspond to the spots where high concentrations of shrimp are generally observed during the research survey (Figure 7). In recent years, certain traditional fishing grounds have been abandoned because of the low abundance of shrimp, for example, the area east of the Manicouagan Peninsula in the Estuary, the northeastern tip of the Gaspé Peninsula, the southeast of Anticosti Island, and the southwest of the Esquiman Channel.

Use of the Vessel Monitoring System (VMS) since 2012 has made it possible to pinpoint fishing grounds (Figure 7). Fishing effort increased in 2016 and 2017 and is comparable to the historical average (Figure 8). Since 2012, the total annual fishing effort has been about 100,000 hours and corresponds annually to a maximum footprint on the seabed of about 7,200 km^2, assuming no overlapping of tows. This effort is concentrated in an area of 13,800 km^2 where fishing intensity is variable. The fishing area where activity is most intense corresponds to an area of 2,250 km^2, where 54% of all fishing effort is deployed. The fishing footprint overlaps 14% of the shrimp's distribution range.

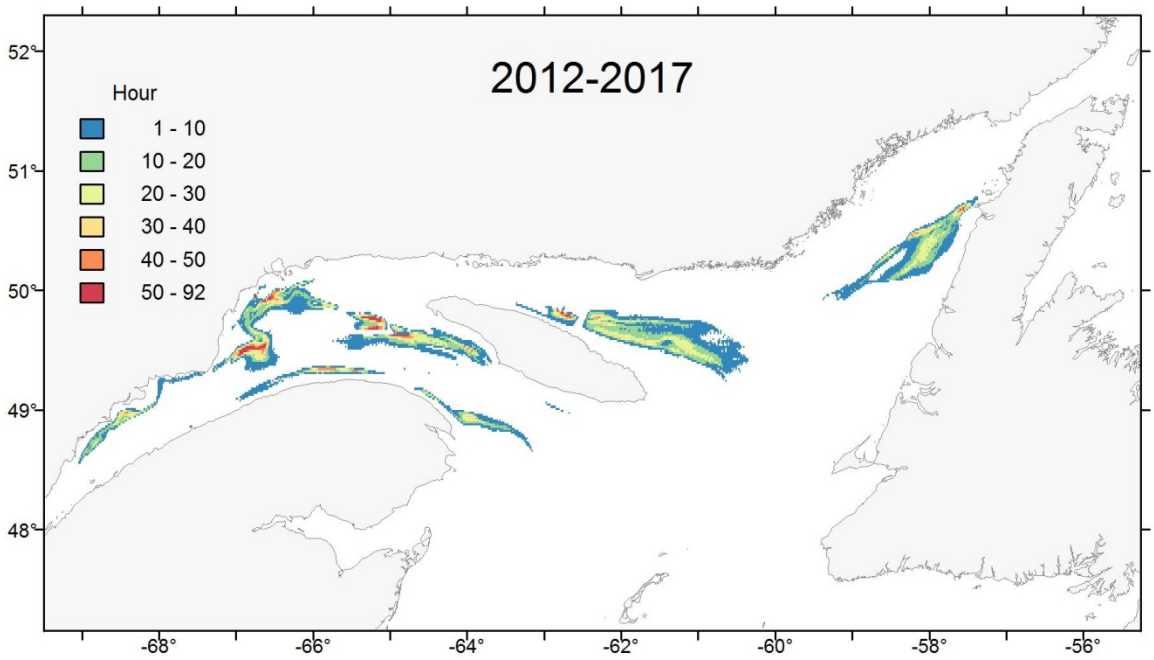


Figure 5. Distribution of the mean fishing effort from 2012 to 2017 according to data from the vessel monitoring system (VMS)

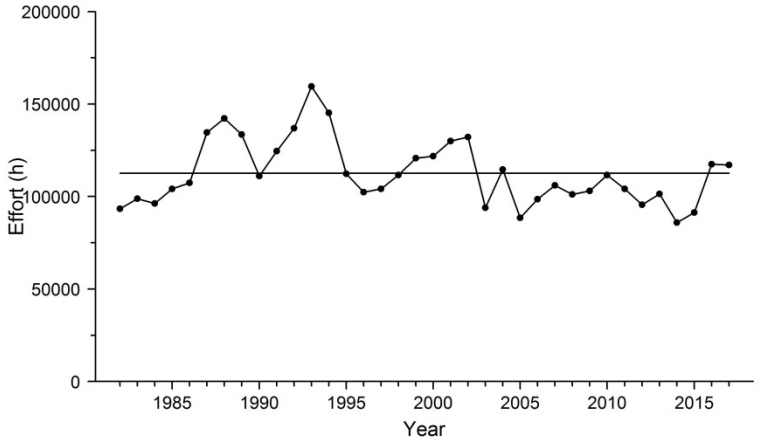


Figure 6. Total number of fishing hours per year for all management areas in the Estuary and the Gulf of St. Lawrence.

Annual catches per unit effort (CPUEs) are standardized to take into account changes in fishery capacity and in seasonal fishing patterns. CPUEs have varied widely over time and have followed similar trends since 1982 in all four areas. CPUEs were low from 1983 to 1995, increased from 1995 and peaked around 2005, and then remained high for a few years. Since 2014, CPUEs have been decreasing in the four areas and, in 2017, they reached values comparable to those observed in the early 2000s (Figure 9).

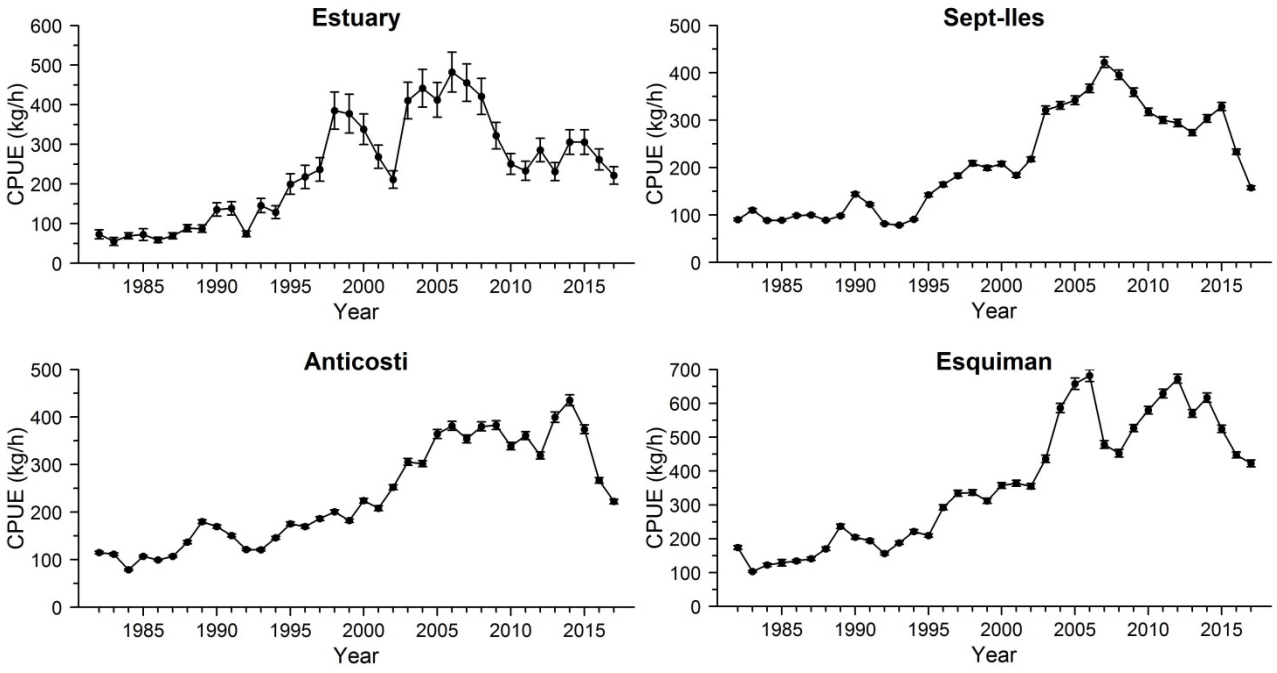


Figure 7. Standardized catch per unit effort (CPUE) from the fishery (confidence interval at 95%).

The DFO survey biomass index indicates a downward trend for several years in all areas. The biomasses observed in 2017 are close to the values of the early 1990s (Figure 10).

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 the index to target exploitation rates. However, the method does make it possible to track relative changes over the years. The exploitation rate index has increased and is above the series average (1990–2016) in each area except Anticosti, where it decreased in 2017 and is close to the average (Figure 11). If the Sept-Iles and Anticosti TACs had been reached in 2017, the exploitation rate index values would have been higher than those observed.

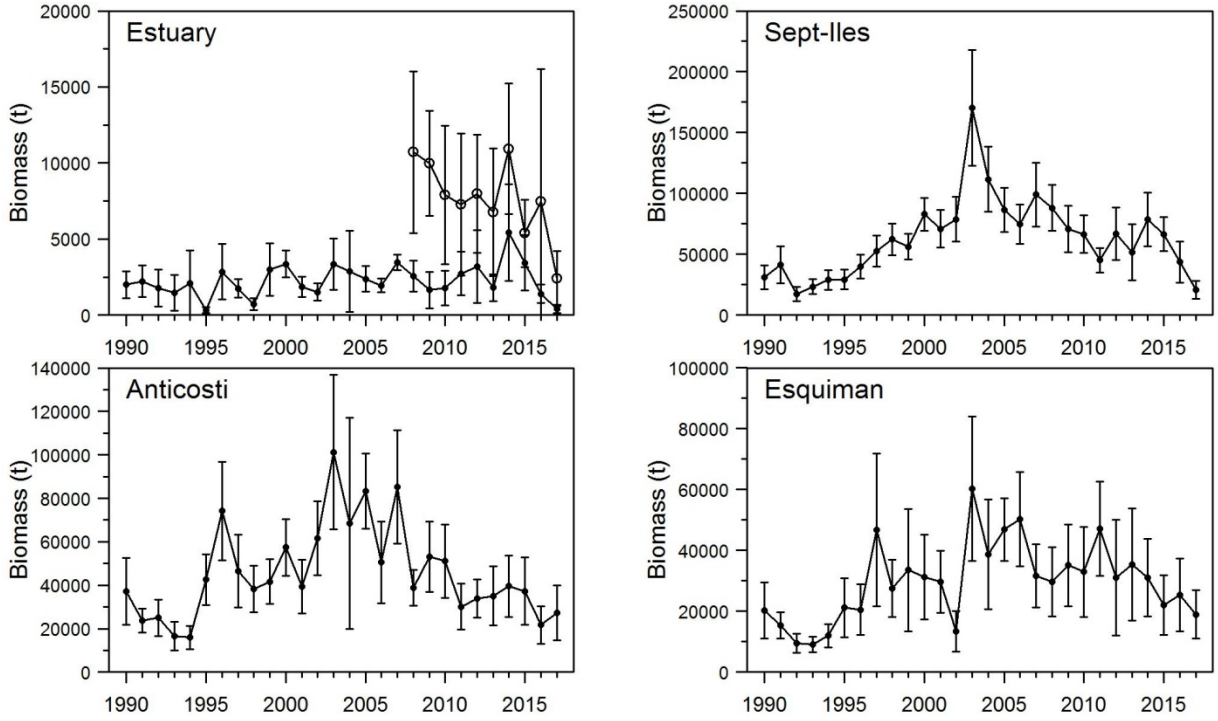


Figure 8. Biomass index from the research survey (confidence interval 95%). For Estuary, the open circles represent results obtained by integrating strata from the shallow portion that were added in 2008.

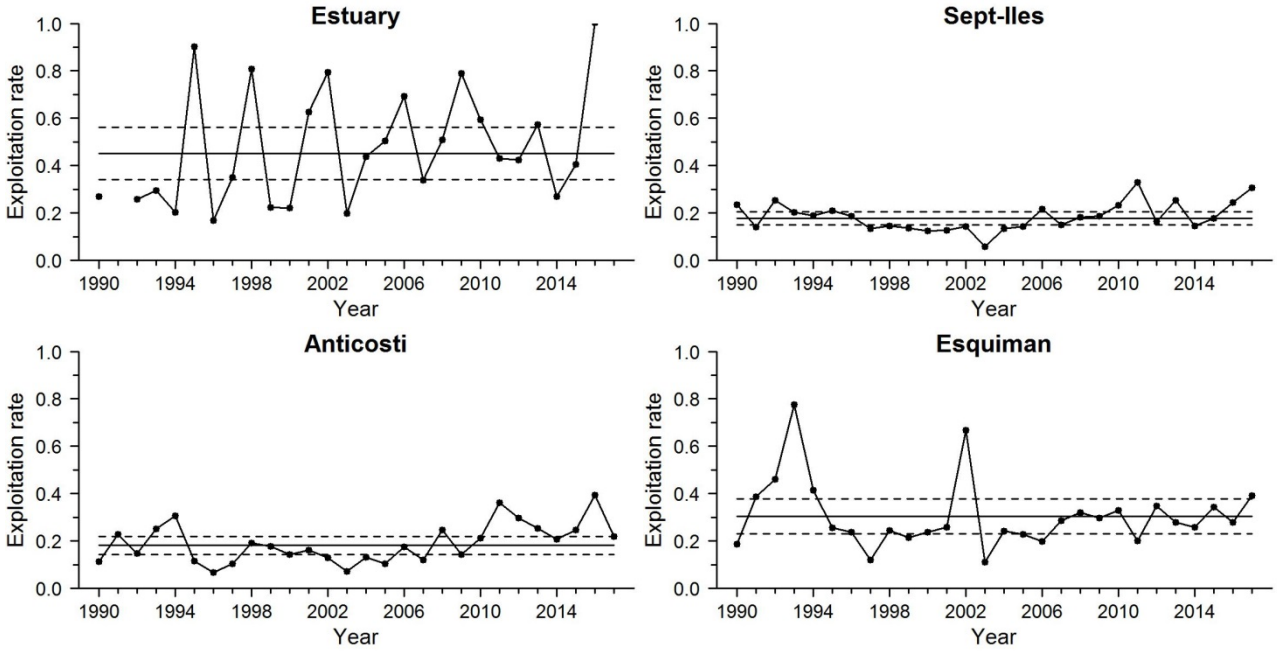


Figure 9. Index of the exploitation rate by fishing area and by year. The solid horizontal line represents the 1990-2015 mean ± 0.5 standard deviation.

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 the research survey (abundance in August). In order to combine them, each index is first standardized in relation to a reference period. The main indicator of stock status represents the mean of the four indices. For the Estuary, survey indices are based on the original sampling area.

Standardized abundance indices of males and females in the fishery and the research survey show a downward trend in recent years in the four fishing areas (Figure 12). The downward trend has been felt, on average, for longer in females than in males. Similarly, the trend has been noticeable for longer in the research survey compared to the commercial fishery, except in the Estuary area, where there are strong inter-annual variations in these indices. For the Sept-Iles, Anticosti and Esquiman areas, the downward trend has been observed for more than six years in the research survey and for four years in the commercial fishery.

The commercial fishery index has decreased by more than 34% for males and females since 2015 in the Estuary, Sept-Iles and Anticosti areas. In Esquiman, the decrease is 10% for males and 22% for females. In all cases, commercial fishery indices are decreasing and nearing the values observed in the early 2000s.

Since 2015, the decline in abundance in the research survey has been very marked in the Estuary and Sept-Iles, where decreases of more than 60% have been observed in two years. The Estuary and Sept-Iles indices are close to the values observed in the early 1990s. In Anticosti, the abundance decreased by 25% in two years, while in Esquiman, the decrease was 29% for males and 8% for females. For these two areas, the indices are comparable to the values observed in the early 2000s.

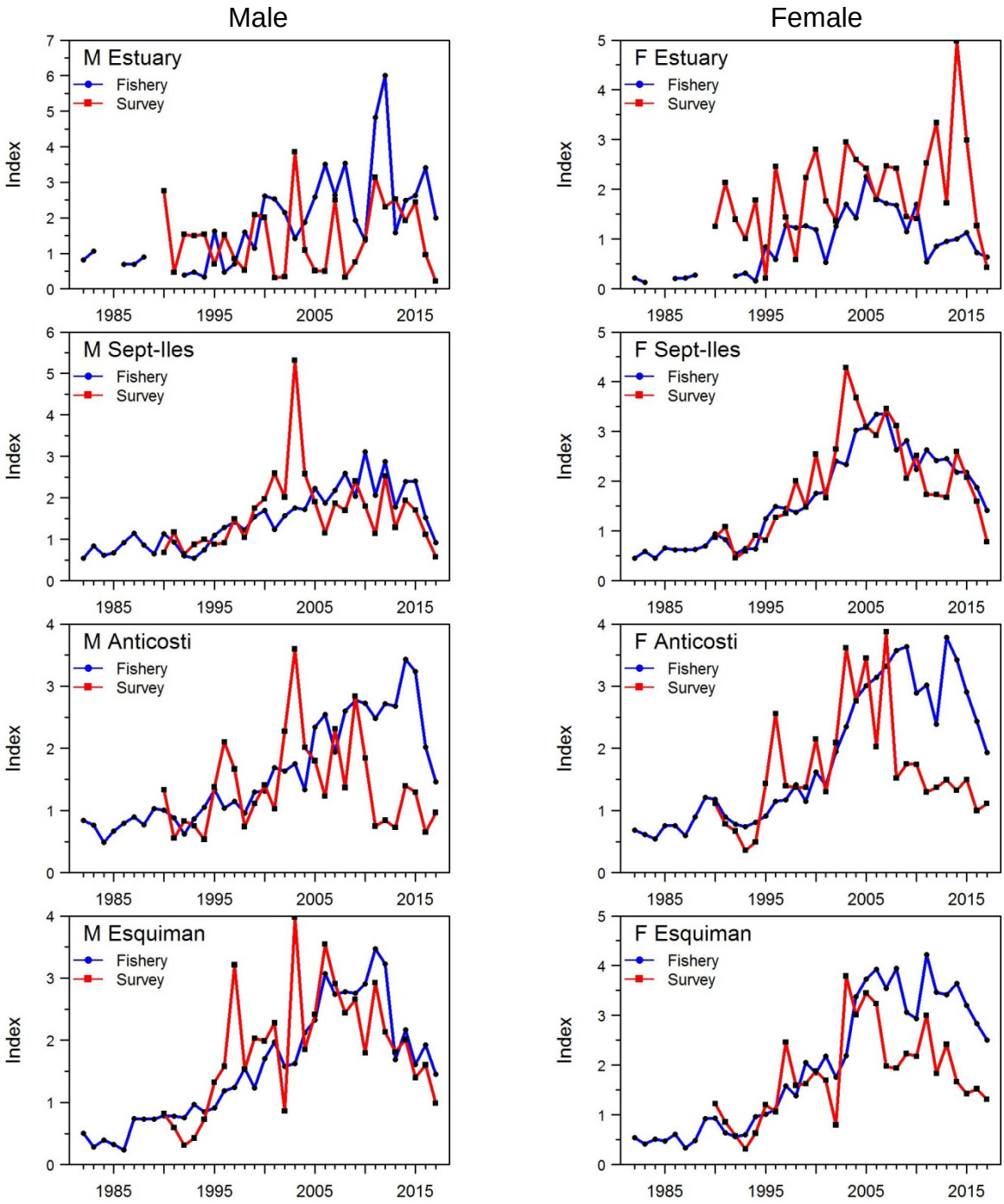


Figure 10. Standardized indices from the main indicator of stock status, which is the abundance of male and female shrimp from the DFO survey and the catch per unit effort of male and female shrimp in the summer commercial fishery.

The main indicator of stock status has been decreasing since 2014 for the four stocks and is comparable to the values observed in the mid-1990s (Figure 13). In 2017, the Estuary and Sept-Iles stocks were in the cautious zone, while the Anticosti and Esquiman stocks were still in the healthy zone, but close to the cautious zone.

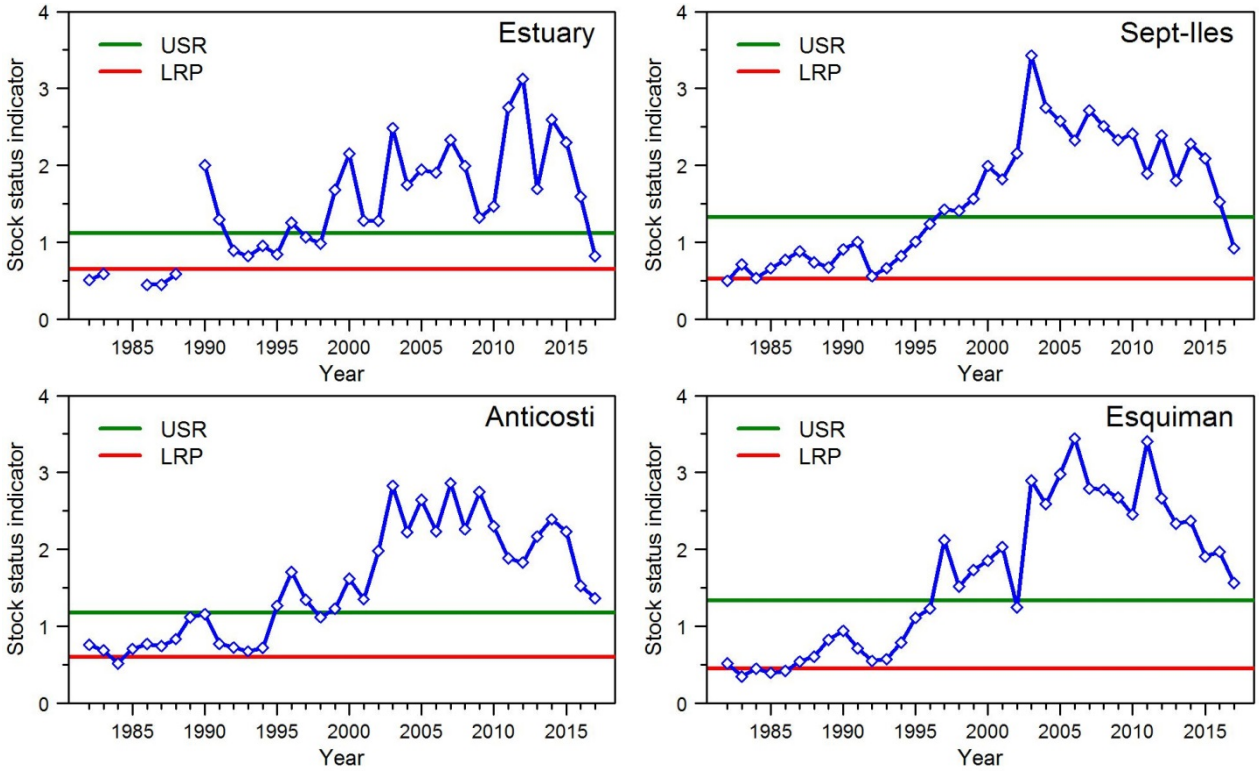


Figure 11. Main stock status indicator by year and limit (LRP) and upper (USR) stock reference points for each fishing area.

Outlook

It is possible to obtain an estimate of the relative abundance of age classes by examining their contribution to the research survey catches (Figure 14). The abundances for the Estuary area correspond to those estimated for the area that was extended in 2008 (see Sources of Uncertainty section).

The demographic structures by area obtained in 2017 from the DFO survey show that male and female abundances are decreasing and are below the series average (1990–2016). In addition, juvenile abundance (carapace length between 8 and 12 mm) was low in 2016 and 2017. Therefore, in the short term, recruitment in the fishery should be low in all areas.

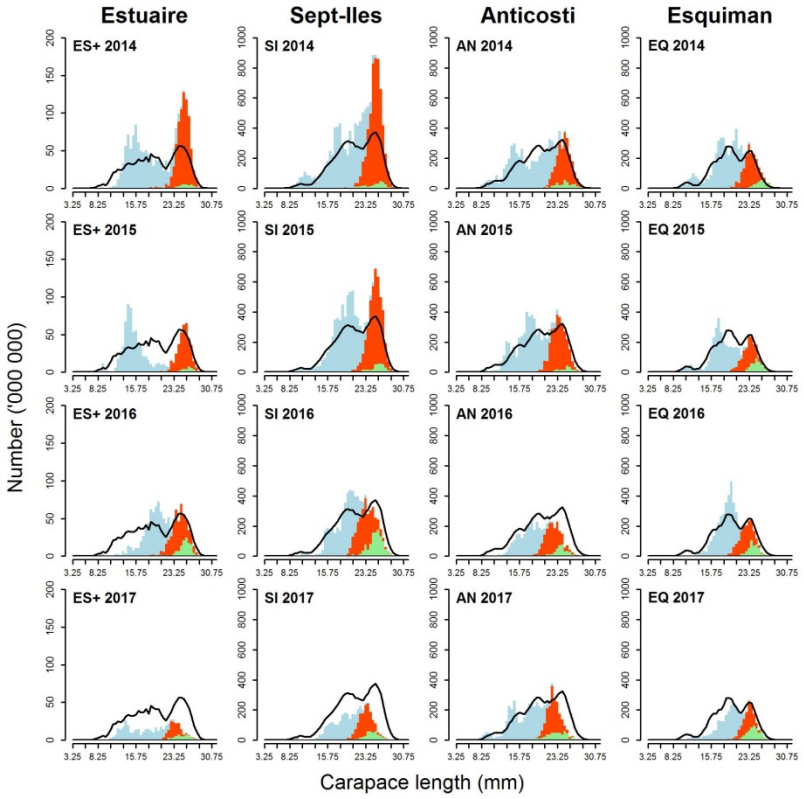


Figure 12. Shrimp abundance from the research survey (in number) by length class and by fishing area from 2014 to 2017. The histograms represent males (in blue), primiparous females (in red) and multiparous females (in green) and the solid line represents the mean of the years 1990-2015 (2008-2015 for 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. From 2010 to 2015, a discrepancy was observed between the abundance indices of the DFO survey and those of the commercial fishery for male and female shrimp in the Anticosti area and for female shrimp in the Esquiman area. This discrepancy can be explained by the fact that these two indices do not sample the same fraction of the population. Indeed, the research survey covers the entire shrimp distribution area in the Estuary and northern Gulf of St. Lawrence, whereas the fishery targets channel heads where shrimp abundance is higher. However, for the last two years, these commercial fishery and research survey indices show the same trends. Recent convergence of the indices may indicate that the attrition of shrimp biomass and areas of concentration is now such that it is no longer possible to maintain high catch rates in the commercial fishery.

The allocation of additional stations in the shallow area of the Estuary since 2008 has had a very significant impact on the number of males and females surveyed in the Estuary fishing area. After 10 surveys with this increased coverage, the inter-annual coherence between the shrimp abundance measured according to the original area and the extended survey area indicates that the biomass was largely underestimated and the exploitation rate index significantly overestimated for the Estuary area. In the short term, shallow strata should be integrated into estimates of the main indicator of stock status.

CONCLUSIONS AND ADVICE

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

The main indicator of stock status has been decreasing since 2014 for the four stocks and is comparable to the values observed in the mid-1990s. In 2017, the Estuary and Sept-Iles stocks were in the cautious zone, while the Anticosti and Esquiman stocks were still in the healthy zone, but close to the cautious zone.

Harvest guidelines were established according to the main indicator and its position relative to the stock status classification zones (healthy, cautious and critical) in compliance with the precautionary approach. According to the guidelines, the projected harvests for 2018 are 239 t for the Estuary, 4,267 t for Sept-Iles, 5,722 t for Anticosti, and 5,508 t for Esquiman (Figure 15). Decreases for the Estuary and Sept-Iles stocks are significant, at 74% and 60% respectively.

Fisheries Management will set the 2018 TACs based on these harvests by following the decision rules of the precautionary approach currently in effect.

The outlook for the status of northern shrimp stocks in the Estuary and Gulf of St. Lawrence is poor given the low recruitment, the warming water and the increasing predation by redfish. In the short term, the downward trend in these stocks is expected to continue.

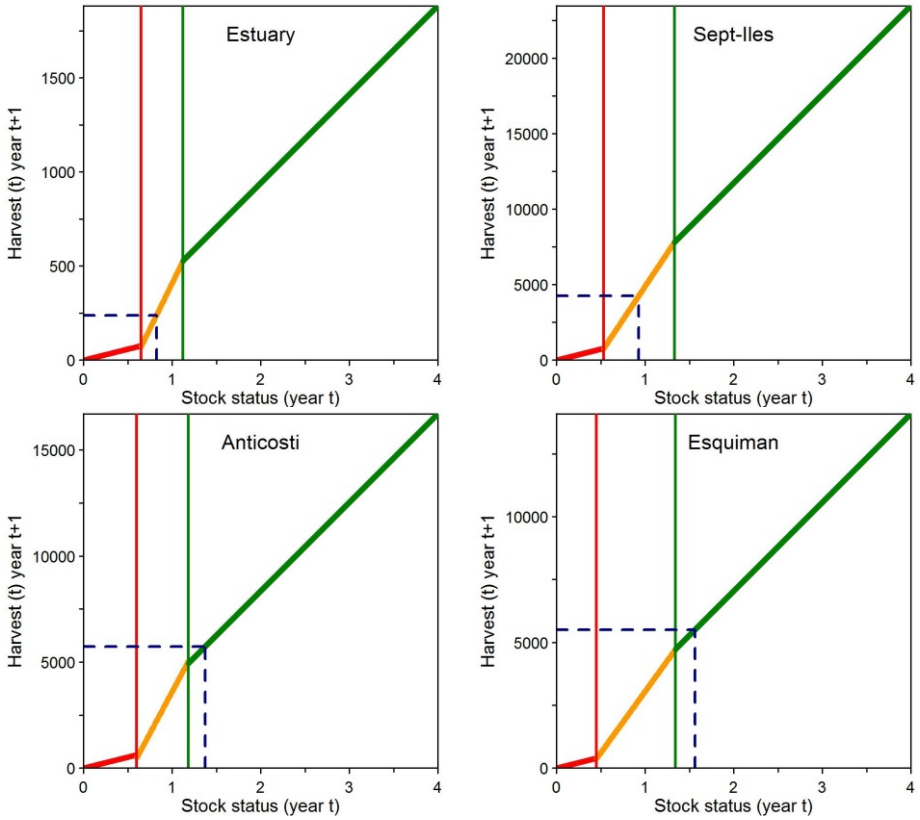


Figure 13. Harvest guidelines by fishing area. The projected harvest for 2018 is shown in view of the main stock indicator in 2017.

OTHER CONSIDERATIONS

Bycatches of small fish in the shrimp fishery between 2000 and 2017 were examined using at-sea observer data. 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 historic peak of over 1,500 t in 2016. From 2000 to 2015, bycatches averaged 1.8% of the weight of the northern shrimp catch; in 2016 and 2017, they averaged 5% (Figure 16). This increase is mainly due to a strong increase in catches of small redfish and a decrease in northern shrimp catches. The main species in the 2017 catches were, in order of importance, redfish, herring, Greenland halibut, capelin, white shrimp, witch flounder, white barracudina, and American plaice. Total catches estimated per species in these bycatches nonetheless represent less than 1% of the estimate of their respective biomass in the DFO survey.

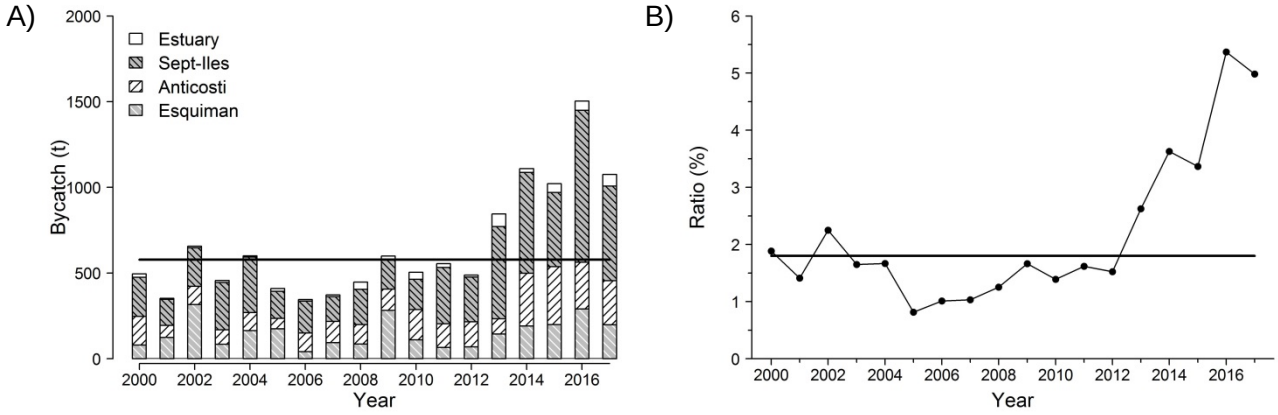


Figure 14. A) Bycatches for all species for each year and shrimp fishing area during fishing activities directed at northern shrimp and in the presence of an at-sea observer. B) Ratio (%) of bycatches to total northern shrimp catches. Solid lines indicate the average for the years 2000 to 2015.

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*). From 2000 to 2017, the share of *P. multidentata and P. montagui* in the total shrimp catch is estimated at 0.8% and 0.2%, respectively, according to the samples collected during landings.

The trawls used for the shrimp fishery come into contact with the floor. The erect and rather rigid biogenic structures of the benthic ecosystem, essentially corals and sponges, are generally considered to be the most potentially affected by the disturbances that fishing activities cause. Information on coral and sponge bycatches in shrimp fishing gear suggest 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. The overlap of the shrimp fishery footprint on the major benthic areas of corals and sponges in the Gulf of St. Lawrence is low. The overlapping is 12.7% for coral areas and 8.4% for sponge areas.

Assessment Schedule

The Estuary and Gulf of St. Lawrence northern shrimp stocks are assessed every two years. The precautionary approach adopted for this fishery requires an annual update of the main stock status indicator. This main indicator of stock status is calculated from the commercial fishery indices in the summer and the DFO research survey. This update was therefore

prepared in early winter of the intermediary year to provide Fisheries Management with information about the projected harvests for the upcoming season, for the four shrimp fishing areas, according to the guidelines of the precautionary approach. Thus, Fisheries Management can adjust the TAC annually according to the decision rules of the precautionary approach.

SOURCES OF INFORMATION

This Science Advisory Report is from the January 23, 2018 meeting on Assessment of northern shrimp stocks in the Estuary and Gulf of St. Lawrence. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Bourdages, H., Brassard, C., Desgagnés, M., Galbraith, P., Gauthier, J., Légaré, B., Nozères, C. and Parent, E. 2017. Preliminary results from the groundfish and shrimp multidisciplinary survey in August 2016 in the Estuary and northern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/002. v + 87 p.

Devine, L., Scarratt, M., Plourde, S., Galbraith, P.S., Michaud, S., and Lehoux, C. 2017. Chemical and Biological Oceanographic Conditions in the Estuary and Gulf of St. Lawrence during 2015. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/034. v + 48 pp.

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