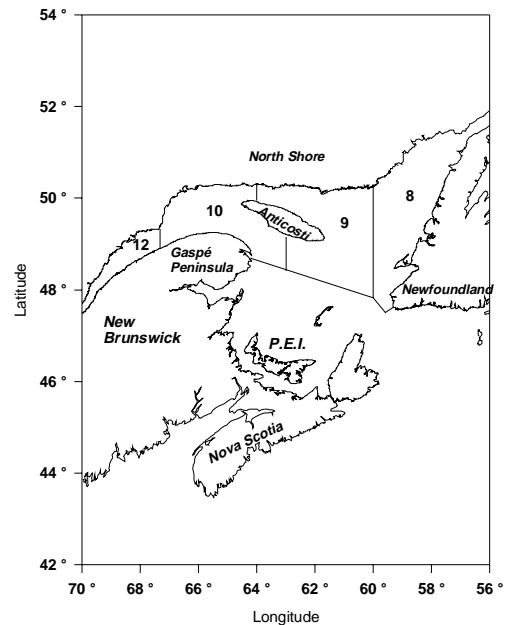


Shrimp of the Estuary and the Gulf of St. Lawrence

Abstract

The shrimp fishery in the Gulf of St. Lawrence began in 1965. Shrimp are exploited from spring to fall in four management units by three provincial fleets. Stock assessments are carried out each year in order to determine whether significant changes have occurred in the status of the stock that would warrant adjustments in the conservation strategy and management plan. In 1996, TACs were increased by 10% in three of the four management units. Landings in 1996 were the highest ever observed for the fishery and TACs were reached in all fishing areas.

The abundance of shrimp in the Gulf and Estuary has fluctuated since the end of the 1980s. The latest stock assessment, though, indicates that the status of the shrimp population was good at the end of the 1996 fishing season. Fluctuations in abundance may be explained by the strength of the year classes supporting the fishery. Thus, high abundance indices in 1994, 1995 and 1996 are due to the increasing contribution of the year classes produced at the beginning of the 1990s. The 1993 year class, which is expected to change sex in 1997 and reach the size that is fully retained in trawls, appears to be as strong as those of 1992 and 1991. Together with the 1992 year class, it should maintain catch rates at a high level in 1997.



Biological characteristics

Peculiarities in the biology of the northern shrimp (*Pandalus borealis*) have had a direct impact on the type of fishing that has developed in the Gulf since the 1960s. Fishers have learned to take these peculiarities into account in order to optimize their performance and minimize their operating costs. Shrimp are found throughout the northern Gulf at depths varying from 150 to 300 m (80 to 160 fathoms); concentrations are found where the water temperature remains between 4 and 6°C.

Life cycle

Commercial shrimp catches are made up of variable proportions of males and females. Females caught at the beginning and at the end of the fishing season bear eggs under their abdomen. This is because shrimp reproduce in fall, and the females carry their eggs under their abdomen all winter, from October to May. The eggs hatch and the larvae

are released in spring, from April to mid-May. The larvae are pelagic and settle on the bottom in late summer, three or four months later. Their form and behavior are then adult. They reach sexual maturity 30 months later, when they reproduce for the first time as males. A shrimp is both male and female during its life-cycle, spending about the first four years of its life as a male, then changing sex and reproducing as a female for at least two more years. Egg-bearing shrimp are therefore the largest in commercial catches; male shrimp are smaller than female shrimp because they are younger. Towards the end of the summer, sexually mature females that will reproduce in the fall are easily distinguished from males by examining their reproductive organs in the cephalothorax; the mature reproductive organs can be seen through the carapace. Females are then said to have a green head.

Migrations

Shrimp follow migratory patterns that are well known to commercial fishers. Each year, they carry out migration related to their reproduction. In late fall and early winter, the egg-bearing females begin to migrate to shallower areas (80 to 100 fathoms) in their distribution range. In spring, they gather at sites suitable for releasing the larvae, while the males are still scattered throughout the distribution range. Fishers take full advantage of this spring gathering of egg-bearing females to obtain high yields. Once the larvae have been released, the females molt and then disperse to deeper areas (120 to 150 fathoms). Shrimp also migrate vertically. They leave the bottom at night to rise in the water column, probably to feed on plankton, then return to the bottom during the day. The scale of vertical migrations may vary depending on the stage of development of the shrimp and local conditions. For example, small male shrimp appear to leave the

bottom earlier and rise higher in the water column than do female shrimp. Fishers usually fish only during the day, when shrimp are concentrated in the first few meters above the seabed. Yields are low at night and it may not be worthwhile fishing.

Geographical distribution

In general, shrimp are distributed differently throughout the area according to their age and size. Young male shrimp are often found in shallower areas (100 to 120 fathoms), often at the heads of channels, while older shrimp, the females, are often found in deeper areas (120 to 150 fathoms). However, while all stages of sexual development can be found at all depths suitable for shrimp, it can be seen that for a given stage or age, shrimp in deeper water have better growth and are larger than those in shallower water. In addition, concentrations of small shrimp in shallower water are often more dense than those of large shrimp in deeper water. Fishers search for spots where yields are highest, while at the same time exploring the entire area looking for large shrimp in an effort to optimize both their yield and the proportion of large shrimp in their catches.

In the last three years changes in the geographic distribution of shrimp have been observed. Some shrimp aggregations have been found in sectors where few shrimp had been observed before. Geostatistic analyses were performed on data collected during research surveys from 1990 to 1996 in order to map the annual distribution of shrimp in the St. Lawrence Gulf and Estuary. The resulting maps clearly show changes in the geographic distribution of shrimp since 1990 (Figure 1). The distribution of shrimp in the Sept-Îles and Anticosti areas, where high densities are observed, has progressively spread

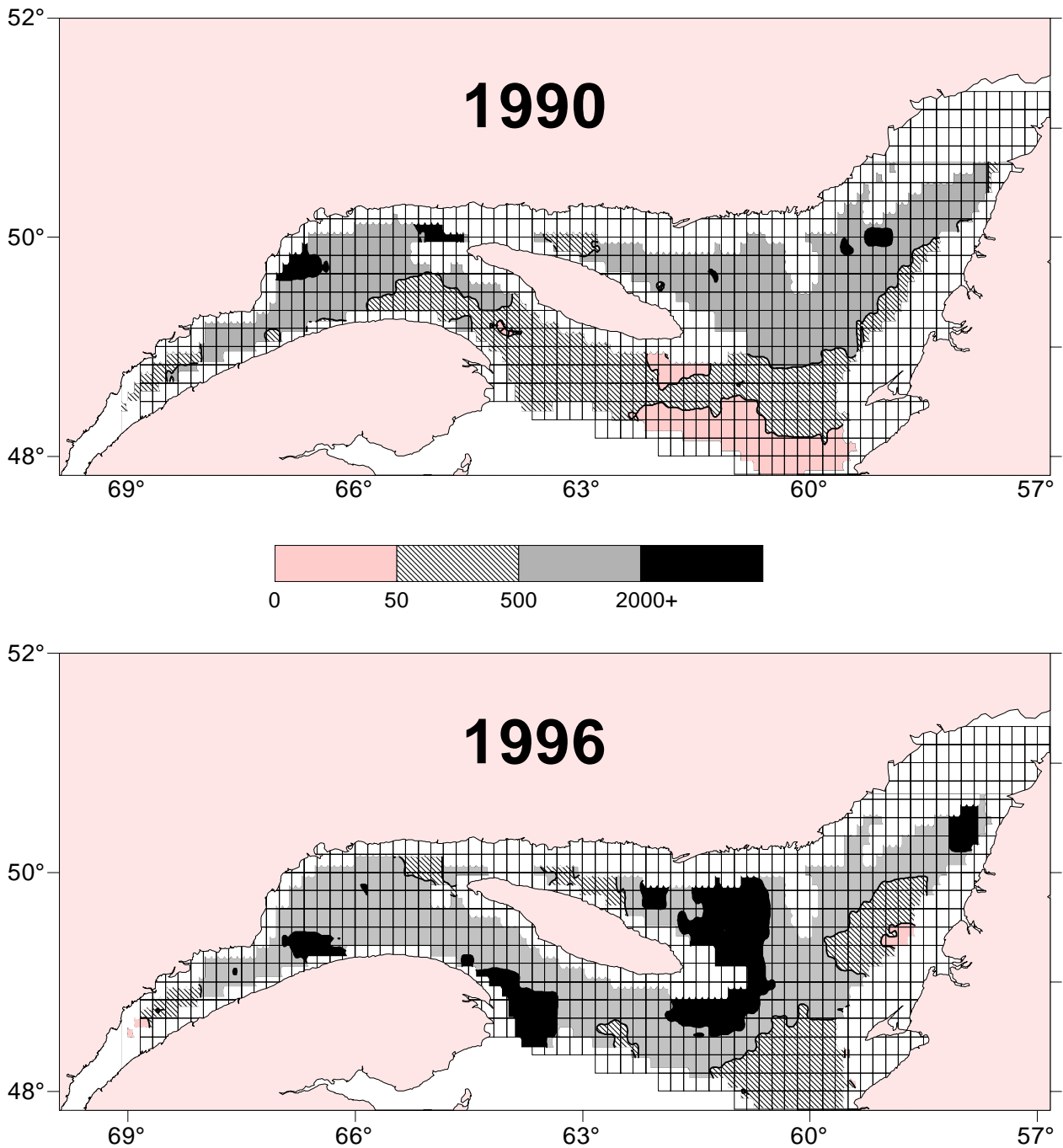


Figure 1. Geographic distribution of shrimp in the St. Lawrence Estuary and Gulf in 1990 and 1996. The shades of gray represent the different shrimp densities in kg/km².

southward. In 1990, shrimp were present mainly in the northern part of these management units, but since 1994 the center of the distribution has shifted toward the Laurentian Channel in the southern part of the units.

In 1996, shrimp were distributed throughout the Gulf, including the Laurentian Channel.

The shrimp may have reacted to environmental changes affecting their own geographic distribution or that of their food. The

oceanographic conditions of the Gulf have changed in the last seven years in response to, among other things, extreme weather conditions. The water masses of the Gulf in general have become colder. These changes have been rather gradual and cannot entirely explain the more recent changes in stock distribution that have occurred during the last three years. On the other hand, it is well known that for marine fish or invertebrates species, when the abundance of a population increases, individuals tend to extend their geographic distribution and are found in areas where they were less frequent before. The fact that predators have recently become scarce in the Gulf is surely an important factor in the increase in abundance and the subsequent extended distribution of shrimp. The abundance levels of cod and redfish have been at their lowest since the beginning of the shrimp fishery in the Gulf in the middle of 1960s. Natural mortality of shrimp by predation has probably decreased appreciably and thus survival, in locations traditionally exploited and in new locations, must have increased substantially.

Conservation approach

The development of the fishery has varied with the sector and the fishing fleet. The Québec fleet harvests mainly the western Gulf, while the Newfoundland fleet concentrates its operations in the Esquiman channel. The New Brunswick fleet divides its operations between the eastern and western Gulf. To more accurately reflect the fishing pattern and the geographic distribution of shrimp, a reorganization of the management units was proposed in 1992. The five management units in place since the beginning of the 1980s were reduced to four in 1993: Sept-Îles (Area 10) which now includes the previous South Anticosti unit, Anticosti (Area 9)

previously named North Anticosti, Esquiman (Area 8), and Estuary (Area 12) (Figure 2).

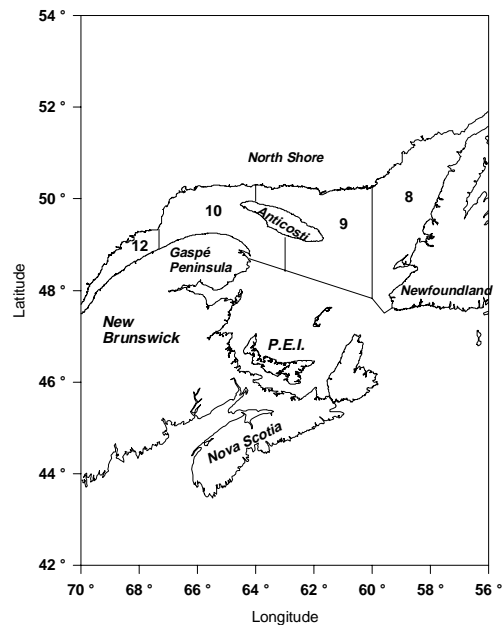


Figure 2. The management units for the shrimp fishery of the St. Lawrence Estuary and Gulf: Sept-Îles (Area 10), Anticosti (Area 9), Esquiman (Area 8) and Estuary (Area 12).

Management of the shrimp fishery of the northern Gulf consists of a range of measures, including control of catches by means of Total Allowable Catches (TACs) for the four management units. Québec and New Brunswick license holders have had individual quotas since 1991, and those from the Lower North Shore and the west coast of Newfoundland only since 1996. The number of licenses in 1996 in the Gulf was 125. Other management measures include the setting of a minimum mesh size (40 mm) and, since 1993, the requirement to use the Nordmore grate to reduce the groundfish by-catch significantly.

TAC management is a way of limiting exploitation of shrimp and protecting the re-

productive potential of the population. Catches are limited so that a certain proportion of the shrimp are not fished and remain in the population for reproduction. The aim is to maintain a sufficient spawning biomass to ensure recruitment. The TAC can be adjusted in accordance to the stock status. However, the analytical tools necessary for calculating increases and decreases in TAC in response to changes in stock status are unavailable for shrimp. Changes in TAC are thus made on an empirical or experimental basis.

The increase in the TACs of the Sept-Îles management unit in the 1980s was intended as a cautious attempt at experimental management. In gradually increasing the TACs, the intention was to raise the exploitation rate so as to assess the impact on the resource and ultimately to determine the optimal exploitation rate. The TACs of three management units (Sept-Îles, Anticosti, Esquiman) was then increased at the beginning of the 1990s in response to increases in abundance that came about during the second half of the 1980s. The TAC remained unchanged until 1995 even though the abundance of shrimp fluctuated between 1990 and 1995. In 1996, the TAC was increased by 10% for three of the four management units (Sept-Îles, Anticosti, Esquiman) in response to the recent increases in abundance observed between 1992 and 1995. This latest increase in abundance was substantial and the short-term prospects regarding shrimp availability were excellent. The TAC of the Estuary management unit has not been increased since 1982 because of uncertainty in the assessment of the stock in that fishing area. No negative effect has ever been detected of exploitation on the populations of shrimp in the Estuary and Gulf.

The fishery

Landings of northern shrimp in the St. Lawrence Estuary and Gulf of have grown steadily since the shrimp fishery began in the mid-1960s, increasing from approximately 1,000 t to 7,500 t during the 1970s and reaching over 15,000 t in the late 1980s (Figure 3, Annex 1). Data on the 1992 fishing season show that Gulf landings decreased by 22% between 1991 and 1992, while data for the 1993 season reveal that landings rose by 21% between 1992 and 1993. Data of 1994 and 1995 also point to an increase of 8 and 10 % over 1993. The 1996 landings indicate an increase of 9% over 1995 and last year's catch was in fact the highest ever recorded for the fishery. Each fishing area at-

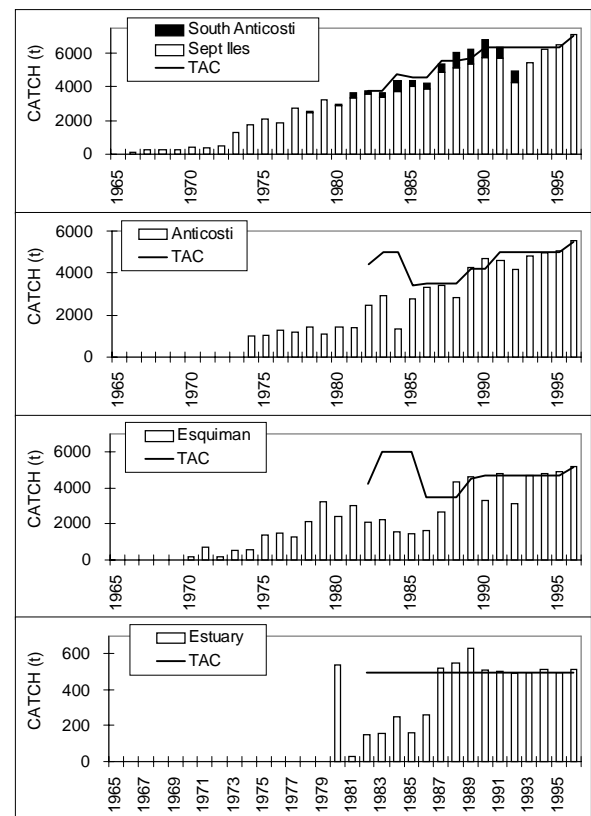


Figure 3. Landings and Total Allowable Catch (TAC) for northern shrimp in the management units of the St. Lawrence Estuary and Gulf since 1965.

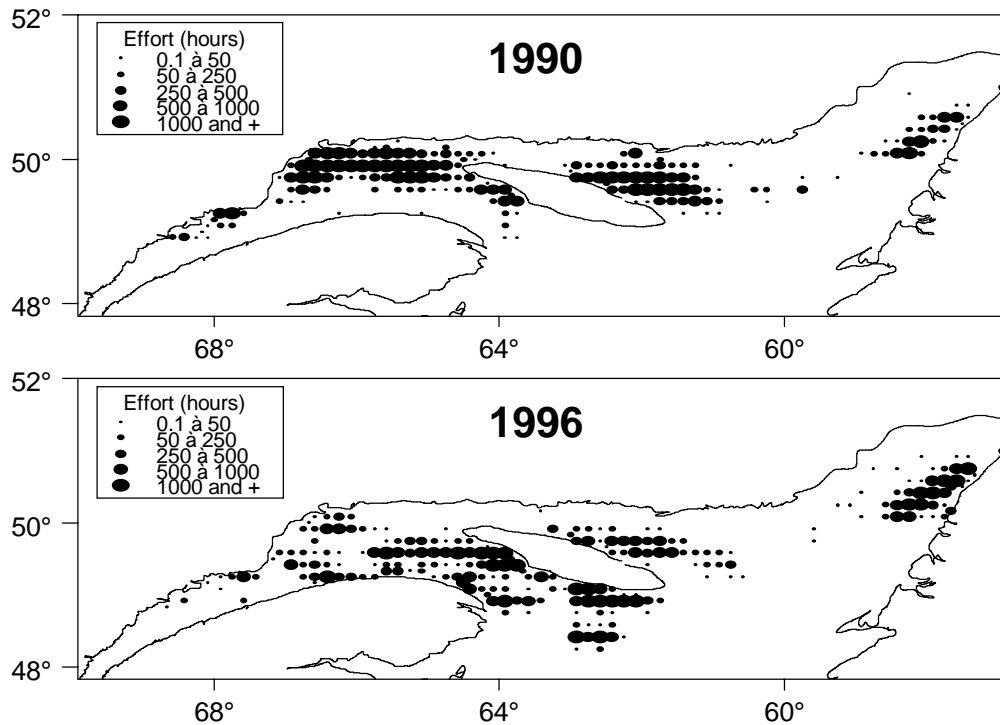


Figure 4. Geographic distribution of fishing effort in the shrimp fishery of the St. Lawrence Estuary and Gulf in 1990 and 1996.

tained their TAC in 1994, 1995 and 1996.

The geographic distribution of fishing effort has changed since 1990. In 1990, 1991 and 1992, the fishing effort was concentrated at the heads of the channels in the Anticosti and Esquiman Channel areas and off the northwest side of Anticosti Island in Sept-Îles area (Figure 4). In 1993, fishers began to exploit more southern locations while decreasing the effort in northern locations (at the heads of the channels). In 1994 and 1995, most of the effort was concentrated off the Gaspé Peninsula, off southeast coast of Anticosti Island, and in the Laurentian Channel in the Sept-Îles and Anticosti areas. The pattern was similar in 1996 with a good portion of the effort distributed along the north and south sides of the Laurentian Channel. These

changes in the geographic fishing pattern are probably due to two factors. Firstly, the constraints or borders which restrained the spread of the effort to more southern locations were eliminated in 1993 when the management units were reorganized; the South Anticosti management area was dismantled and the southern border of Sept-Îles area corresponding to the NAFO Division 4T line was eliminated. Secondly, shrimp concentrations have increased in southern locations, in the Laurentian Channel in particular, where they have been less abundant before.

Abundance indices

Commercial fishery statistics (shrimper catch and effort data) are used to calculate annual

catch rates or catch per unit of effort (CPUE) i.e. the quantity of shrimp caught in one hour of fishing. The data are standardized to account for the evolution of fishing fleets (changes in fishing power brought about by changes in fishing boats and renewal of the fleets) and the seasonal fishing pattern; statistics from the three fleets have been included in the analyses since 1982. The statistics from years prior to the reorganization of the management units in 1993 were reanalyzed to correspond with the present management units.

Catches per unit of effort for Anticosti and Esquiman Channel areas increased from the middle of the 1980s to the beginning of 1990s (Figure 5). Catches per unit of effort increased later in the Sept-Îles and Estuary areas; they were relatively stable up to 1989, then increased in 1990 and 1991. The catch per unit of effort in all four areas decreased in 1992. Sept-Îles catch per unit of effort was relatively stable in 1992, 1993 and 1994 then increased in 1995 and 1996 while that of the Estuary area increased from 1992 to 1996. Anticosti and Esquiman Channel catches per unit of effort remained at lower levels in 1992 and 1993 than in 1989, 1990 and 1991, then rose in 1994; it increased again in 1995 and remained stable in 1996 in the Anticosti area, while it decreased in 1995 and increased again in 1996 in the Esquiman Channel area.

Since 1990, research surveys have been conducted in the St. Lawrence Estuary and Gulf in August-September of each year. They are carried out on a vessel of the Department, the *C.S.S. Alfred Needler*, using a shrimp trawl and following a stratified random sampling scheme. Results are presented as mean catch per tow i.e. the mean quantity of shrimp caught by a standard tow of one hour.

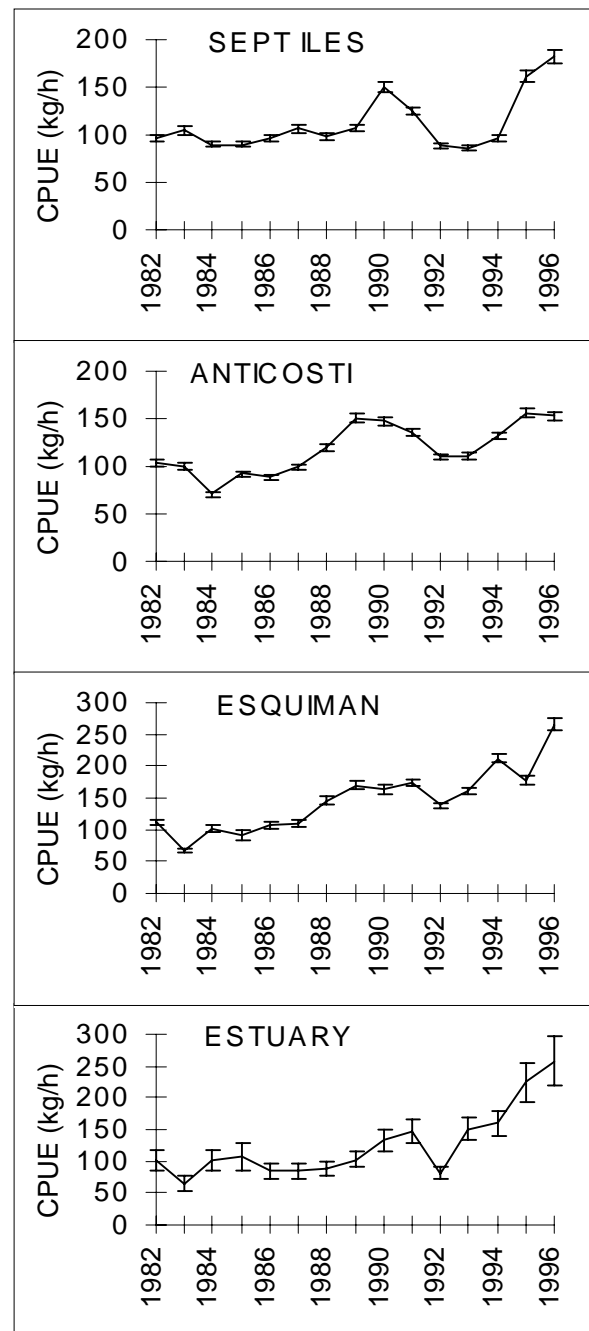


Figure 5. Standardized catch per unit effort (CPUE) for commercial shrimpers in the four management units of the St. Lawrence Estuary and Gulf since 1982.

In general, the catch per tow decreased between 1990 and 1993 then increased in 1995 and 1996 in the Sept-Îles, Anticosti and Esquiman Channel areas (Figure 6). However, the catch per tow decrease or increase pat-

tern is slightly different between the management units. The index decreased between

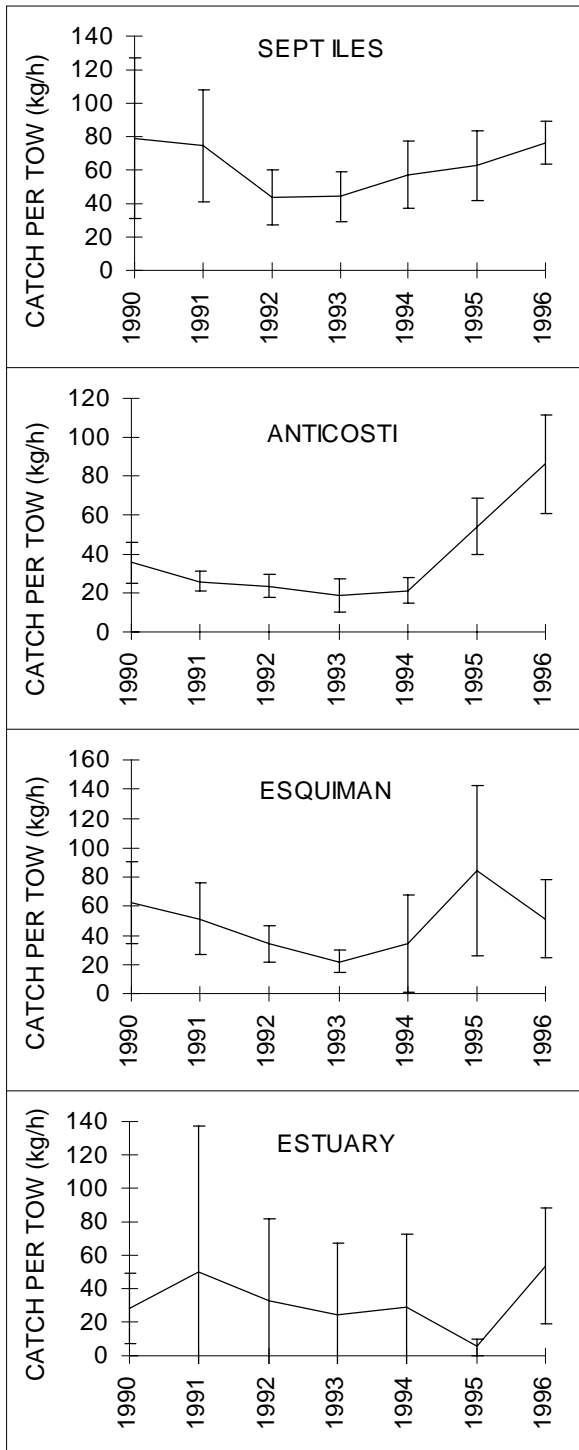


Figure 6. Standardized catch per tow of shrimp obtained during research surveys conducted in the St. Lawrence Estuary and Gulf since 1990.

1990-91 and 1992-93 in the Sept-Îles area then gradually increased up to 1996. In the Anticosti and Esquiman Channel areas, the index gradually decreased between 1990 and 1994, then rose in 1995. The index increased again in the Anticosti area in 1996 but decreased slightly in the Esquiman area. In the Estuary area, the index decreased gradually from 1991 to 1995 followed by a substantial increase in 1996.

The vertical bar associated with the mean catch per tow represents the confidence interval of the estimate. By looking at the range of the confidence intervals, it can be seen that the variability of the data can be relatively high. Therefore, the survey indices should be examined in their whole to draw out the general trend in the time series. The indices are relative, depending on the year, and do not correspond to the absolute abundance of shrimp present in the population. It is generally agreed that surveys in the Gulf follow the general trends in shrimp populations quite well (for example, changes in distribution and population structures, direction of changes in abundance) and that commercial catch per unit effort gives a good indication of fishing activity, but the difference between two data points does not necessarily correspond to the absolute difference between the shrimp biomass of two years.

Generally speaking, both indices (commercial catches per unit of effort and survey mean catches per tow) are consistent and vary in the same direction even though commercial catch rates represent the abundance of shrimp on fishing grounds that do not necessarily correspond to the overall distribution of shrimp. For the Sept-Îles area, for example, the commercial catch rate increase in 1995 was relatively higher than the survey index increase because fishers had changed their geographic fishing pattern over the last two years. They exploited more southern

locations where the greatest increase in the survey was observed. The fact that CPUE is higher when research indices are high indicates that there exist some degree of synchronization between important events that occur in the Gulf as a whole: the values were at their lowest in 1992-93, while the highest values were observed in 1990-91 and 1995-96.

Population structure

Length frequency distributions are calculated from commercial catch and survey samples. Commercial catch length frequency distributions have been obtained since 1982 and from research samples since 1990, but are presented here from 1993 to 1996 only.

Cohorts or year classes can be identified by examining the length frequency distributions. A cohort is made up of individuals born the same year. Since these individuals grow at essentially the same rate, it is possible to identify modes or groups composed of individuals of approximately the same size and presumably the same age. The first year-class, with a modal size of approximately 11 mm, would be a year and a half old, meaning that the individuals in that year-class would have been born in the spring of the preceding year. The subsequent modes represent the preceding year-classes while the last mode represents an accumulation of female shrimp of one or more year-classes. It is therefore possible to follow the progress of the cohorts over several consecutive years and thus assess their relative abundance.

Using bottom trawls with 40-mm mesh, shrimp are first caught when they are two or three years old; they then measure approximately 14 mm in length (cephalothorax length) and are male. They are fully recruited to the fishery i.e. 100% vulnerable to capture by trawls at about 22 mm, when they are four or five years old and are mostly female.

The representation of young cohorts in the first sizes to be selected by the trawls will depend not only on their abundance but also on their growth. A cohort with faster growth will appear earlier in the catches, sometimes giving the impression of being highly abundant. Moreover, because the shrimp, as they grow, are increasingly retained by trawls, the numbers of individuals in the cohorts rise in the catches from year to year while in the population, their abundance declines owing to natural mortality and fishing.

Fishers particularly target large shrimp, with the result that their catch rates depend on the abundance of shrimp having a cephalothorax length greater than 22 mm. Fluctuations in the abundance of shrimp having a cephalothorax length greater than 22 mm may be explained by the strength of the cohorts. A very strong cohort may support the fishery for a year or two when the shrimp reach the size at which they change sex. The successive arrival of several strong cohorts may thus maintain the biomass and catch rates at a high level for several years.

The increase in the abundance indices in the late 1980s and early 1990s was due to the very high abundance of some cohorts produced in the mid-1980s (the 1984, 1985, 1986 and 1987 year-classes) that reached the size retained by fishing gear and that were targeted by the fishers at the end of the 1980s and the beginning of the 1990s (Figure 7). The decline in catch rates and survey indices observed in 1992 and 1993

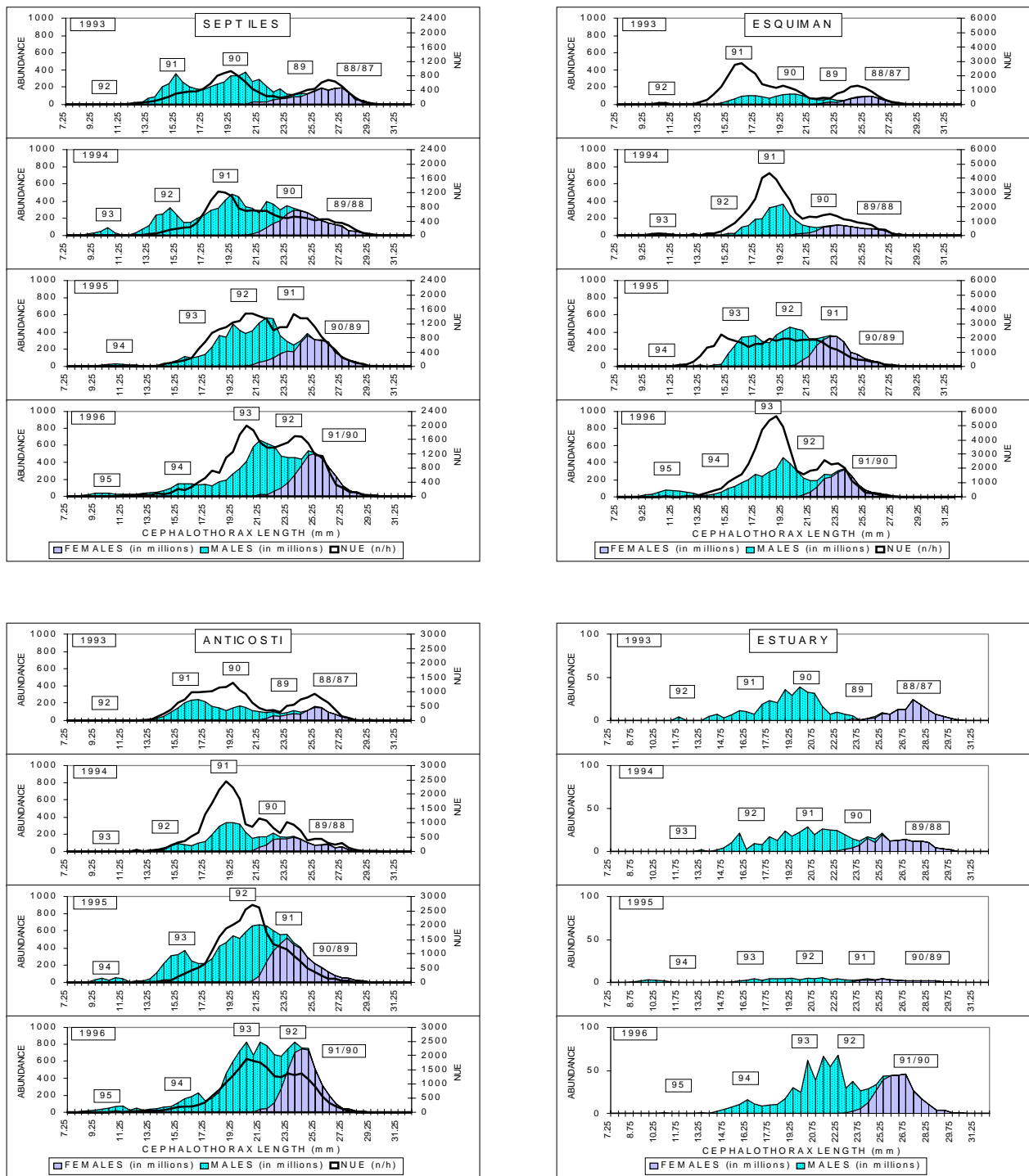


Figure 7. Size frequency distribution of shrimp in the four management units: shrimp abundance obtained from research surveys is in the grayed areas, and number per unit effort obtained from commercial catch samples is in the ungrayed areas.

was due to the fact that the cohorts produced in the late 1980s, which sustained the fishery in 1992 and 1993 (the 1988 and 1989 year-classes), were much less abundant. The 1990 year-class seems to have an abundance equal to or lower than the mean; its impact was to maintain the catch rates and survey indices without making them rise. Catch rates and survey indices rose in 1994, 1995 and 1996 thanks to the growing contribution of the 1991, 1992 and 1993 year-classes; these cohorts seem more abundant than the preceding ones. The 1992 year-class changed sex in 1996 and should still sustain the fishery in 1997 along with the 1993 year-class that should then change sex itself.

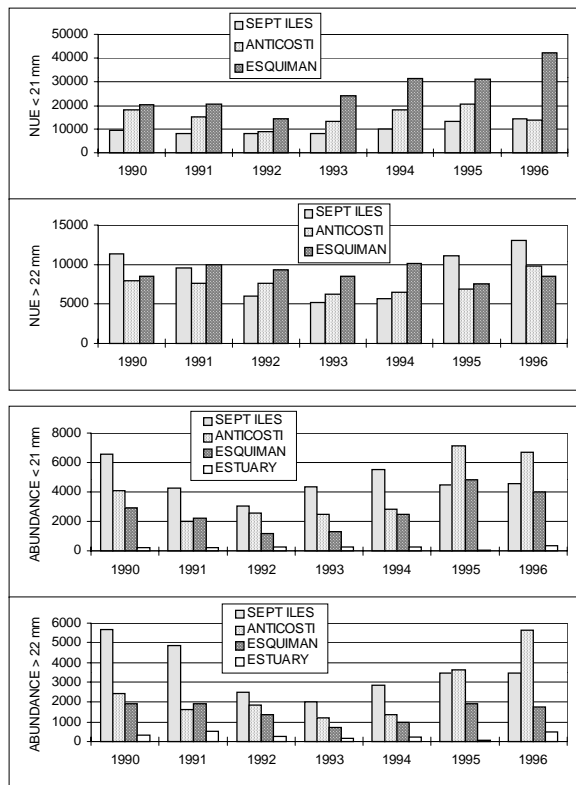


Figure 8. Numbers of shrimp smaller the 21 mm cephalothorax length (mostly males) and those larger than 22 mm (mostly females) in commercial catches (number per unit effort) and in research survey samples (abundance) in the four management units from 1990 to 1996.

The abundance of females (shrimp greater than 22 mm of cephalothorax length) did not steadily decrease between over the years (Figure 8). As for the commercial fishery and research survey indices, the abundance of females varied and depends on the strength of cohorts going through the fishery. Male shrimp, smaller than 21 mm of cephalothorax length, decreased gradually in abundance between 1990 and 1993, as the 1988, 1989 and 1990 year-classes recruited to the fishery. Female shrimp, greater than 22 mm, decreased subsequently and reached their lowest level in 1993 and 1994. Male shrimp increased in abundance in 1993, 1994 and 1995 with the contribution of the 1991, 1992 and 1993 year-classes. The abundance of females then began to increase in 1994 and 1995. The abundance level of male shrimp in 1996 was similar to that of 1995.

Status of the resource and future prospects

The abundance indices (commercial fisher catch rates and research survey indices) are higher in 1995 and 1996 than in 1992 and 1993. Generally speaking for the entire Gulf, the shrimp abundance increased between the first half of the 1980s and the end of the decade, remained high in the early 1990s, and then decreased in 1992. It remained stable in 1993 and increased again in 1994 and 1995. It was still high in 1996. This increase resulted in higher catches in 1994 and 1995, and the TACs, which had remained the same since 1991, were reached in all fishing areas in 1994 and 1995. TAC was increased by 10% in the Sept-Îles, Anticosti and Esquiman areas in 1996 and were all reached. The uncertainty mentioned in 1995 regarding the shrimp in the Estuary was largely due to low values obtained during the 1995 research survey. The 1996 results, however, indicate that the status of that fishing area is very

much like that of the Gulf fishing areas. **The results of the assessment indicate that the status of the shrimp populations of the Estuary and the Gulf was good at the end of the 1996 fishing season.**

Assessment data (abundance indices and population structure) for shrimp in the Estuary and Gulf have been discussed with the fishers involved in the fishery. In general, indices from both the commercial fishery and research samples conform very well with the fishers' view of the abundance of the resource.

The high abundance indices observed in 1994, 1995 and 1996 are probably due to the growing contribution of the cohorts produced at the beginning of the 1990s. In the next few years, the fishery will depend on the cohorts produced during the first half of the 1990s. **The 1993 year-class, that should change sex in 1997 and reach the sizes fully retained by the gears and targeted by the fishers, seems as abundant as the 1991 and 1992 year-classes. It should contribute to maintaining the catch rates at a high level, similar to those of 1996 or at least higher than those of 1992 and 1993.** The 1994 year-class, that should be fully recruited to the fishery in 1998, is not yet well represented in fisher or survey catches because shrimp are too small. It is therefore difficult to forecast its global contribution to the fishery success in the Gulf before it grows and approaches the size at sex change. In general, the abundance of shrimp smaller than 21 mm of cephalothorax length, which will support the fishery in the next years, was similar in 1995 and 1996.

Experience has shown that the abundance of shrimp aggregations can change quite rapidly. In light of this, discussions on catch levels should take into account the abundance indices observed over a few years so that the chosen levels would be sustainable at all re-

source abundance levels. Although the abundance indices follow quite well the overall pattern of fluctuations in the populations, they are greatly affected by the fishing pattern of the fishers and by the availability of shrimp at the time of surveys, and thus do not necessarily correspond to the absolute biomass of shrimp on the grounds. The analytical tools needed to calculate or adjust the TACs in relation to the fluctuations in the resource are unavailable.

A cautious approach to the determination of long term TACs seems most appropriate since the predator-prey relationship must be taken into consideration. Shrimp productivity in the Gulf is probably higher now than what it was when the predators were present. The return of the predators would probably cause an increase in predation mortality and it is likely that the shrimp aggregations would not be able to sustain an exploitation rate as high as it was when the predators were absent.

Annex 1 A. Catches (t) of northern shrimp per management unit since 1965 (SI: Sept-Îles; ANT: Anticosti; ESQ: Esquiman; EST: Estuary).

CATCH					
Year	SI	ANT	ESQ	EST	Gulf
1965	11				11
1966	95				95
1967	278				278
1968	271				271
1969	273				273
1970	413		159		572
1971	393		691		1084
1972	481		184		665
1973	1273		520		1793
1974	1743	980	594		3317
1975	2135	1025	1368		4528
1976	1841	1310	1494		4645
1977	2746	1185	1249		5180
1978	2526	1460	2166		6152
1979	3207	1108	3226		7541
1980	2978	1454	2441	539	7412
1981	3680	1385	3014	27	8106
1982	3774	2464	2111	152	8501
1983	3647	2925	2242	158	8972
1984	4383	1336	1578	248	7545
1985	4399	2786	1421	164	8770
1986	4216	3340	1592	262	9410
1987	5411	3422	2685	523	12041
1988	6047	2844	4335	551	13777
1989	6254	4253	4614	629	15750
1990	6839	4723	3303	507	15372
1991	6411	4590	4773	505	16279
1992	4957	4162	3149	489	12757
1993	5485	4791	4683	496	15455
1994	6288	4951	4783	512	16534
1995	6513	5061	4896	496	16966
1996	7152	5574	5233	515	18474

Annex 1 B. Total Allowable Catch (TAC, t) of northern shrimp per management unit since 1982 (SI: Sept-Îles; ANT: Anticosti; ESQ: Esquiman; EST: Estuary).

TAC					
Year	SI	ANT	ESQ	EST	Gulf
1982	3800	4400	4200	500	12900
1983	3800	5000	6000	500	15300
1984	4800	5000	6000	500	16300
1985	4600	3400	6000	500	14500
1986	4600	3500	3500	500	12100
1987	5600	3500	3500	500	13100
1988	5600	3500	3500	500	13100
1989	5700	4200	4500	500	14900
1990	6400	4200	4700	500	15800
1991	6400	5000	4700	500	16600
1992	6400	5000	4700	500	16600
1993	6400	5000	4700	500	16600
1994	6400	5000	4700	500	16600
1995	6400	5000	4700	500	16600
1996	7040	5500	5170	500	18210

For more information:

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Published by

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P. O. Box. 1000, Mont-Joli,
Quebec, Canada
G5H 3Z4

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