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Monitoring of the occurence of soft-shell crabs in commercial catches of snow crab (*Chionoecetes opilio*) in the southwestern Gulf of St. Lawrence (zone 12) in 1990 and 1991.

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1992

MONITORING OF THE OCCURRENCE OF SOFT-SHELL CRABS IN COMMERCIAL CATCHES OF SNOW CRAB (*Chionoecetes opilio*) IN THE SOUTHWESTERN GULF OF SAINT LAWRENCE (ZONE 12) IN 1990 AND 1991

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract

M. Hébert, C. Gallant, Y. Chiasson, P. Mallet, P. DeGrâce et M. Moriyasu 1992. Monitoring of the occurence of soft-shell crabs in commercial catches of snow crab (*Chionoecetes opilio*) in the southwestern Gulf of Saint-Lawrence (zone 12) in 1990 and 1991. Can. Tech. Rep. Fish. Aquat. Sci. 1886E:v+19 p.

After the drastic decrease of the snow crab catch in the southwestern Gulf of Saint Lawrence in 1989, the Department of Fisheries and Oceans (DFO) established a management plan for rebuilding the stock and long term stability for the industry. The important point in the management plan was the closure of the fishing season when the catch at sea of soft shell crab for two consecutive weeks was over 20 percent in number based on the carapace hardness. Since 1990, an intensive sampling program was conducted on board of snow crab boats to evaluate the weekly percentage of soft-shell crab in the capture. This report presents the general tendency of weekly and seasonnal catches of soft-shell crab and discusses the impact of the incidence of soft-shell crab during the fishery.

Résumé

M. Hébert, C. Gallant, Y. Chiasson, P. Mallet, P. DeGrâce et M. Moriyasu 1992. Le suivi du pourcentage de crabes mous dans les prises commerciales de crabe des neiges (*Chionoecetes opilio*) dans le sud-ouest du golfe du Saint-Laurent (zone 12) en 1990 et 1991. Rapp. tech. can. sci. halieut. aquat. 1886 E:v+19 p.

Après la chute drastique des prises du crabe des neiges dans le sud-ouest du golfe du Saint-Laurent en 1989, le Ministère des Pêches et des Océans (MPO) a établi un plan de pêche afin de reconstruire le stock tout en stabilisant à long terme l'industrie. Le point important du plan de pêche a été l'arrêt automatique de la pêcherie lorsque les captures en mer pour deux semaines consécutives atteignaient plus de 20 pourcent en nombre de crabes mous établie selon la dureté de la carapace. Depuis 1990, un programme intensif d'échantillonnage à bord des navires commerciaux a été établi afin d'évaluer hebdomadairement le pourcentage de crabes mous dans les captures. Ce rapport a pour but de démontrer une tendance générale de la capture hebdomadaire et saisonnière des crabes mous et de discuter des effets de l'incidence de ces crabes durant la pêcherie.

INTRODUCTION

The snow crab (*Chionoecetes opilio*) fishery in the southwestern Gulf of St. Lawrence began in 1966 and has grown steadily to become the economic mainstay of a number of regions on Canada's Atlantic coast (see Table 1). The story of that fishery may be divided into five distinct periods: exploration (1966-75), infra-structure development (1976-80), expansion (1981-86), drastic fall off in catches (1987-89) and finally a substantial recovery in catches (1990-91). This recovery is the result of a growth phase in the snow crab population coupled with conserva-tion-oriented advice from scientists, adequate management practices, and a con-structive response from the crab fishermen themselves (Chiasson *et al.* 1992, Mallet *et al.* 1992).

Since 1969, the southwestern Gulf of St. Lawrence snow crab fishing season has begun in the spring (late in April or early in May), when the Gulf is clear of ice, ending not later than July as a rule. The 1982 season was an exception: snow crab fishing came to an end in August but then resumed in September, continuing on into November. In 1991 the southwestern Gulf of St. Lawrence snow crab fishing fleet consisted of 130 boats, including 81 from New Brunswick, 47 from Quebec and two from Cape Breton Island.

Moulting, which in the case of the snow crab takes place in the spring, is a process in the course of which the crab loses its old shell in order to be able to grow larger. The crabs that moult are those in the immature and juvenile categories (Comeau and Conan 1992). A soft-shell crab (commonly referred to as a white crab) is one that has just moulted and is characterized by a soft, pale pink shell with a hardness reading of less than 68 on a durometer (Anonymous 1990). The meat of soft-shell crabs is of poor quality, and not acceptable for the processing plant. Accordingly, when the fishermen sort their catch they throw the soft-shell crabs back into the sea. The result is heavy mortality among these crabs.

The rapid decline in catches and the growing incidence of soft-shell crabs and crabs under legal size (with shells measuring less than 95 mm in breadth) in catches led in 1989 to an unprecedented step: the fishery was shut down, for the first time in its history, after it had been open for only six weeks (Mallet *et al.* 1990). Since that time, Department of Fisheries and Oceans (DFO) managers have developed a plan designed to rebuild stocks while endowing the industry with long-term stability. An individual quota has been allocated to each boat, calculated as follows: 80 per cent of the total quota is divided equally, while the remaining 20 per cent is distributed on the basis of each boat's catch record over the period extending between 1984 and 1989 (Anonymous 1991). Landings are now verified by a team of weighmasters. The most important feature of the snow crab fishery plan is that fishing automatically comes to an end as soon as soft-shell crabs, as iden-tified by durometer readings, have accounted for 20% of the total numbers of crabs caught for two consecutive weeks (Anonymous 1991). This measure is essential to protect recruitment to the snow crab fishery for the following reasons: (1) it serves to stabilize numbers of mature hard-shell crabs $\geq$ 95 mm (B_s) in the fishery without dependence on yearly recruitment, (2) the soft-shell crabs, which cannot mate during their post moult period, will be able to participate in reproduction in the spring of the following year, just before the crab fishing season (Moriyasu and Conan 1988), and (3) these crabs will potentially be of good commercial quality by the next season.

MATERIALS AND METHODS

Since 1990 DFO has been implementing a new program aimed at protecting recruitment to the snow crab fishery. This program features intensive sampling operations carried out aboard commercial fishing boats in order to determine the week-by-week occurrence of soft-shell crabs in the catches.

Observers were stationed on board of commercial crab fishing boats on the basis of the concentration of the fleet's fishing effort. Information about the concentrations of fishing effort was obtained from overflights by aircraft, from patrol vessels, and from entries in the fishermen's logbooks, which are handed in to fisheries protection officers or weighmasters after every landing.

A 3.2 kilograms (7 pounds) durometer (Foyle *et al.* 1989) with a graduated scale extending from 0 to 100 units was used to determine crab shell hardness. A subsample consisting of 20 male crabs selected at random was taken from each crab trap sampled at sea. The following biological data were recorded for each crab sampled: breadth of shell (size) and height of propodite (both values being rounded off to the nearest millimetre) and shell hardness. Additional information was also recorded: the name of the boat, the sampler's name, the position of the trap, the date of sampling, the total number of crabs in the trap, the depth at which each trap had been placed, and the total quantity landed by the boat aboard which the sample was taken.

A subsample consisting of 100 male crabs selected at random was taken on shore from the catches landed by each boat that had been sampled at sea. The following data were recorded in the case of these crabs: breadth of shell and height of propodite to the nearest millimetre, shell hardness, sampling date, name of boat and total quantity landed by the boat.

The size distributions found for crabs sampled both on shore and at sea were assigned to 1 mm size classes. Size-to-weight relationship were calculated for two categories of crabs (soft-shell and hard-shell) on the basis of samples taken in the course of trawling and trapping operations carried out between 1986 and 1988 in the southwestern Gulf of St. Lawrence. Soft-shell crabs were sampled in June and July, while hard-shell crabs were sampled during the period extending between June and October.

The size-to-weight relationship is expressed by the equation:

$$W_T = a \times B_s{}^b \quad \ldots \quad (1\text{-}1)$$

in which W_T is the total wet weight of the crab in grams, B_s is shell breadth in mm, "a" is the abscissa at the point of origin and "b" the slope.

This equation can also be expressed as a natural logarithm (Log):

$$Log(W_T) = A + b \times log(B_s) \quad ... \quad (1\text{-}2)$$

in which A is log a.

The least squares line was fitted to the data after transformation into a natural logarithm had been performed by means of Abacus Concepts' StatView™ software on a MacIntosh II CX computer.

Size-to-weight relationship in the case of soft-shell crabs is expressed by the function $F_{(x)}$:

$$F_{(x)} = W_T = 2.995 \times 10^{-5} B_s^{3.524} \quad ... \quad (1\text{-}3)$$

Size-to-weight realationship in the case of hard-shell crabs is expressed by the function $F'_{(x)}$:

$$F'_{(x)} = W'_T = 2.665 \times 10^{-4} B_s^{3.098} \quad ... \quad (1\text{-}4)$$

The information obtained from the samples taken on shore and aboard the boats, and the size-to-weight relationship, which had previously been worked out, were used to calculate the weekly and seasonal soft-shell crabs occurrence levels, and a map was produced showing the distribution of the sites where samples were taken aboard the fishing boats during the 1991 season.

Estimation of the occurrence of soft-shell crabs

Samples taken in port

Size distributions for the subsamples and total quantities (in kilograms) landed by the boats were obtained from the sampling operations conducted on shore. The predetermined size-to-weight relationship for soft-shell crabs (1-3) and hard-shell crabs (1-4) can be used to transform the size distributions for the several categories into total weight for each category. The total weight of the subsamples measured on shore for each of these categories (W_s: soft-shell crabs, $W_{H<95}$: hard-shell crabs < 95 mm, and $W_{H\geq95}$: hard-shell crabs ≥ 95 mm) can be expressed by the formulas on the following page:

Total subsample weight in the case of soft-shell crabs (W_S):

$$W_s = \sum_{i=\alpha}^{\beta} N_i F_i = N_\alpha F_\alpha + \ldots\ldots\ldots + N_\beta F_\beta \qquad \ldots (2\text{-}1)$$

in which α and β are respectively the smallest and largest size classes,
N_i is the number of individuals in the category of soft-shell crabs belonging to size class i,
$F_{(i)}$ is the individual weight calculated for size class i by applying the regression $F_{(x)}$ for the category of soft-shell crabs (1-3).

Total subsample weight in the case of hard-shell crabs < 95 mm ($W_{H<95}$):

$$W_{H<95} = \sum_{i=x}^{94} N'_i F'_i = N'_x F'_x + \ldots\ldots\ldots + N'_{94} F'_{(94)} \qquad \ldots (2\text{-}2)$$

in which $\times$ and 94 are respectively the smallest and largest size classes,
N'_i is the number of individuals in the category of hard-shell crabs < 95 mm belonging to size class i,
$F'_{(i)}$ is the individual weight calculated for size class i by applying the regression $F'_{(x)}$ for the category of hard-shell crabs (1-4).

Total subsample weight in the case of hard-shell crabs ≥ 95 mm ($W_{H\geq95}$):

$$W_{H\geq95} = \sum_{i=95}^{\delta} N''_i F'_i = N''_{95} F'_{95} + \ldots\ldots\ldots + N''_\delta F'_{(\delta)} \qquad \ldots (2\text{-}3)$$

in which 95 and δ are respectively the smallest and largest size classes,
N''_i is the number of individuals in the category of hard-shell crabs ≥ 95 mm belonging to size class i,
$F'_{(i)}$ is the individual weight calculated for size class i by applying the regression $F'_{(x)}$ for the category of hard-shell crabs (1-4).

The total catch weight landed (L_T) by the boats aboard which the samples were taken comprises the three categories of crabs referred to above. Landed weight for each of the categories L_S, $L_{H<95}$ and $L_{H\geq95}$ may be expressed by using the weight of the subsamples in each of the categories W_S, $W_{H<95}$ and $W_{H\geq95}$ in accordance with formulas (2-1), (2-2) and (2-3) and by the formulas shown below:

Estimated landed weight of soft-shell crabs (L_S):

$$L_S = L_T \frac{W_S}{W_S + W_{H\geq95} + W_{H<95}} \quad \text{... (3-1)}$$

Estimated landed weight of hard-shell crabs < 95 mm ($L_{H<95}$):

$$L_{H<95} = L_T \frac{W_{H<95}}{W_S + W_{H\geq95} + W_{H<95}} \quad \text{... (3-2)}$$

Estimated landed weight of hard-shell crabs ≥ 95 mm ($L_{H\geq95}$):

$$L_{H\geq95} = L_T \frac{W_{H\geq95}}{W_S + W_{H\geq95} + W_{H<95}} \quad \text{... (3-3)}$$

Samples taken at sea

Size distributions for the three categories (soft-shell crabs, hard-shell crabs < 95 mm and hard-shell crabs ≥ 95 mm) were obtained from the sampling operations conducted at sea, aboard commercial crab fishing boats. The total weight of the subsamples taken in the three categories can be arrived at by means of calculations similar to those used in the case of the samples taken in port:

Total subsample weight in the case of soft-shell crabs (W'_S):

$$W'_S = \sum_{i=\varepsilon}^{\Phi} n_i F_i = n_\varepsilon F_\varepsilon + \dots\dots\dots + n_\Phi F_{(\Phi)} \qquad \dots (4\text{-}1)$$

in which ε and Φ are respectively the smallest and largest size classes,
n_i is the number of individuals in the category of soft-shell crabs belonging to size class i,
$F_{(i)}$ is the individual weight calculated for size class i by applying the regression $F_{(x)}$ for the category of soft-shell crabs (1-3).

Total subsample weight in the case of hard-shell crabs < 95 mm ($W'_{(H<95)}$):

$$W'_{H<95} = \sum_{i=\gamma}^{94} n'_i F'_i = n'_\gamma F'_\gamma + \dots\dots\dots + n'_{94} F'_{(94)} \qquad \dots (4\text{-}2)$$

in which γ and 94 are respectively the smallest and largest size classes,
n'_i is the number of individuals in the category of hard-shell crabs < 95 mm belonging to size class i,
$F'_{(i)}$ is the individual weight calculated for size class i by applying the regression $F'_{(x)}$ for the category of soft-shell crabs (1-4).

Total subsample weight in the case of hard-shell crabs ≥ 95 mm ($W'_{H\geq 95}$):

$$W'_{H\geq 95} = \sum_{i=95}^{\eta} n''_i F'_i = n''_{95} F'_{95} + \dots\dots\dots + n''_\eta F'_{(\eta)} \qquad \dots (4\text{-}3)$$

in which 95 and η are respectively the smallest and largest size classes,
n''_i is the number of individuals in the category of hard-shell crabs ≥ 95 mm belonging to size class i,
$F'_{(i)}$ is the individual weight calculated for size class i by applying the regression $F'_{(x)}$ for the category of soft-shell crabs (1-4).

Assuming that all crabs in the category of hard-shell crabs ≥ 95 mm are landed, i.e. that none of them is thrown back into the sea, we may presume that the total landed weight of crabs in the category of hard-shell crabs ≥ 95 mm is equal to the total weight caught at sea for the same category:

$$L_{H\geq95} = C_{H\geq95}$$

Since the value of $L_{H\geq95}$ is already known, the size of the catch in the case of the category of hard-shell crabs ≥ 95 mm can be estimated simply by replacing the value of $C_{H\geq95}$ by $L_{H\geq95}$. The size of the catch, in terms of weight, for the other two categories can be estimated by using the ratio of total subsample weight for hard-shell crabs ≥ 95 mm sampled at sea to that of the other two categories:

Estimated weight of catch in the case of soft-shell crabs (C_S):

$$C_S = L_{H\geq95} \frac{W'_S}{W'_{H\geq95}} \qquad \text{... (5-1)}$$

Estimated weight of catch in the case of hard-shell crabs < 95 mm ($C_{H<95}$):

$$C_{H<95} = L_{H\geq95} \frac{W'_{H<95}}{W'_{H\geq95}} \qquad \text{... (5-2)}$$

In order to calculate the occurrence of soft-shell crabs, we must take the weight values we have obtained for the various categories and change them into count values. Catch size in terms of numbers of individuals for each of the three categories (C'_S, $C'_{H<95}$ and $C'_{H\geq95}$) can be estimated by using total catch weight at sea for each of these categories [C_S, $C_{H<95}$ and $C_{H\geq95}$; formulas (5-1), (5-2) and (3-3)], the size-to-weight relationship for soft-shell and hard-shell crabs (formulas 1-3 and 1-4 respectively), and also the size distributions found for the subsamples in all three categories:

Numbers of soft-shell crabs caught at sea before being thrown back into the water (C'_S):

$$C'_S = \sum_{i=\varepsilon}^{\Phi} C_S \frac{n_i F_i}{W'_S} \frac{1}{F_i} = \frac{C_S}{W'_S} \sum_{i=\varepsilon}^{\Phi} n_i \qquad \text{... (6-1)}$$

in which ε and Φ are respectively the smallest and largest size classes,
n_i is the number of individuals in the category of soft-shell crabs belonging to the size class whose median value is i,
$F_{(i)}$ is the individual weight calculated for size class i by applying the regression $F_{(x)}$ for the category of soft-shell crabs (1-3),
C_S is estimated catch weight for the category of soft-shell crabs (5-1),
W'_S is estimated total weight for the subsample measured on board in the case of the category of soft-shell crabs (4-1).

Numbers of hard-shell crabs < 95 mm caught at sea before being thrown back into the water ($C'_{H<95}$):

$$C'_{H<95} = \sum_{i=\gamma}^{94} C_{H<95} \frac{n'_i F'_i}{W'_{H<95}} \frac{1}{F'_i} = \frac{C_{H<95}}{W'_{H<95}} \sum_{i=\gamma}^{94} n'_i \qquad \text{... (6-2)}$$

in which γ and 94 are respectively the smallest and largest size classes,
n'_i is the number of individuals in the category of hard-shell crabs < 95 mm belonging to size class i,
$F'_{(i)}$ is the individual weight calculated for size class i by applying the regression $F'_{(x)}$ for the category of hard-shell crabs (1-4),
$C_{H<95}$ is estimated catch weight for the category of hard-shell crabs < 95 mm (5-2),
$W'_{H<95}$ is estimated total weight for the subsample measured on board in the case of the category of hard-shell crabs < 95 mm (4-2).

Numbers of hard-shell crabs ≥ 95 mm caught ($C'_{H\geq95}$):

$$C'_{H\geq95} = \sum_{i=95}^{\Pi} C_{H\geq95} \frac{n''_i F'_i}{W'_{H\geq95}} \frac{1}{F'_i} = \frac{C_{H\geq95}}{W'_{H\geq95}} \sum_{i=95}^{\Pi} n''_i \qquad \text{... (6-3)}$$

in which 95 and η are respectively the smallest and largest size classes,
n''_i is the number of individuals in the category of hard-shell crabs ≥ 95 mm belonging to size class i;
$F'_{(i)}$ is the individual weight calculated for size class i by applying the regression $F'_{(x)}$ for the category of hard-shell crabs (1-4),
$C_{H\geq95}$ is estimated catch weight for the category of hard-shell crabs ≥ 95 mm (3-3),
$W'_{H\geq95}$ is estimated total weight for the subsample measured on board in the case of the category of hard-shell crabs ≥ 95 mm (4-3).

It follows that the percentage occurrence, in terms of numbers, of soft-shell crabs in catches before they are thrown back into the sea can be estimated by:

$$\text{percentage}_S = \frac{C'_S}{C'_S + C'_{H\geq95} + C'_{H<95}} \times 100 \qquad \text{... (7-1)}$$

The overall (weighted) percentage of soft-shell crabs caught by the fleet as a whole can be estimated by adding up the estimated numbers of soft-shell crabs caught by each boat j aboard which samples were taken, divided by the figure obtained by adding up the numbers caught by each boat j multiplied by 100, assuming the concentration of soft-shell crabs to be homogeneous over the entire surface of the southwestern Gulf of St. Lawrence snow crab fishery:

$$\text{Overall percentage}_S = \frac{\sum_{j=1}^{\iota} (C'_S)j}{\sum_{j=1}^{\iota} [\,(C'_S)j + (C'_{H\geq95})j + (C'_{H<95})j]} \times 100 \qquad \text{... (8-1)}$$

in which j is the boat aboard which the sample was taken, the total number being i.

Sampling operations conducted by means of a trawl

Sampling operations using a 20-metre Norway nephrops trawl have been conducted every year since 1988. These operations, which are carried out after the fishing season is over, cover nearly the entire southwestern Gulf of St. Lawrence; their purpose is to estimate the biomass of the various biological categories (Mallet *et al.* 1989, 1990, 1992; Chiasson *et al.* 1991). A geostatistical method known as "kriging" (Conan 1985, Conan *et al.* 1988) has been used to estimate biomass in the case of soft-shell crabs ≥ 70 mm (B_s), morphometrically mature hard-shell crabs ≥ 95 mm (B_s) and morphometrically mature soft-shell crabs ≥ 95 mm (B_s). In the case of soft-shell crabs ≥ 70 mm (B_s), biomass is estimated on the basis of the biomass of juvenile crabs > 56 mm (B_s) in the autumn (after the end of the current year's fishing season), on the assumption that crabs in this category will moult to a shell breadth ≥ 70 mm (in accordance with the regression line for growth at moulting, Moriyasu *et al.* 1987) before and during the following year's fishing season. A shell breadth of 70 mm is typical of the smallest crabs that are commonly caught in commercial traps. Morphometrically mature hard-shell crabs ≥ 95 mm (B_s) constitute the commercially harvestable component of the stock. Morphometrically mature soft-shell crabs ≥ 95 mm (B_s) represent the year's recruitment to the fishery for the following year's fishing season. Most of the soft-shell crabs caught in crab traps during the season are soft-shell crabs ≥ 70 mm (B_s). This category comprises three subgroups: crabs that have attained a size of less than 95 mm at their terminal moult (i.e. soft-shell crabs which do not constitute part of the year's recruitment), crabs that have attained a size of more than 95 mm at their terminal moult (i.e. soft-shell crabs which constitute the year's recruitment to the fishery for the following season), and crabs that have not reached their terminal moult and will moult again during the following season (soft-shell crabs).

Mean weighted weekly and yearly occurrence values for soft-shell crabs are calculated on the basis of the total estimated numbers of soft-shell crabs caught at sea, taking into account the quantities of the various categories of crabs landed by each of the boats sampled. Mean unweighted weekly and yearly occurrence values for soft-shell crabs are simply the percentage of soft-shell crabs sampled.

RESULTS AND DISCUSSION

The distribution of crab traps from which samples were taken aboard commercial fishing boats under the soft-shell crab occurrence monitoring program (see Figs. 1 and 2) affords a good reflection of the fishing effort characterizing the southwestern Gulf of St. Lawrence snow crab fishery.

The total numbers of crab traps sampled in the context of this program were 1141 in 1990 and 1086 in 1991.

Geostatistical analysis reveals a gradual numerical increase in the biomass of morphometrically mature hard-shell crabs ≥ 95 mm (B_s), from 14.6 million in 1989 to 36.4 million in 1990, 43.6 million in 1991 and 52.1 million in 1992 (see Table 2). Concurrently, the catch rate (CPUE) increased from 22.11 kg/trap in 1989 to 27.30 kg/trap in 1990 and 30.70 kg/trap in 1991 (see Table 3).

A substantial decline in numbers of soft-shell crabs found in commercial traps has been observable since 1989: the mean unweighted yearly occurrence of soft-shell crabs in samples taken aboard fishing boats fell from 37.2% in 1989 to 16.8% in 1990 and 11.6% in 1991 (see Table 3), while the mean weighted yearly occurrence levels for these crabs were 15.0% in 1990 and 11.5% in 1991 (see Table 4). This general trend suggests that the early closing of the fishery in 1989, owing to large numbers of soft-shell crabs in catches, coupled with a preventive measure consisting of the soft-shell crab monitoring program which was initiated in 1990, has had a positive impact on the stock of snow crabs in the southwestern Gulf of St. Lawrence (zone 12).

Unweighted weekly soft-shell crab occurrence levels varied over a range extending between 10.2% and 26.1% in 1990, compared to a range extending between 6.0% and 18.7% in 1991 (see Table 4). Weighted weekly occurrence levels for these crabs varied over a range extending between 7.9% and 23.2% in 1990, compared to a range extending between 6.1% and 17.9% in 1991 (see Table 4). The weighted figures convey more accurate information than their unweighted counterparts; however, if there is not much difference in the quantities landed by the various boats sampled, the percentage values as estimated by both methods are comparable. For the 1990 season, unweighted weekly occurrence values were consistently larger than the weighted percentages by a factor that ranged from a minimum of 0.8% to a maximum of 4.7%. In the 1991 season, in contrast, differences in weekly occurrence levels as calculated by these two methods varied over a range extending between -5.5% and 2.5%.

While the weighted calculation method yields results that are more accurate than those obtained by the unweighted calculation method, there are a number of assumptions that must be verified. For example, the overall occurrence level found for soft-shell crabs does not reflect the actual situation if these crabs are caught mainly in one particular part of the Gulf; this distortion could be corrected by means of a subzone management approach. Furthermore, if there are some fishermen who are throwing morphometrically mature hard-shell crabs measuring more than 95 mm back into the sea, the sampling technique will have to be modified to take this factor correctly into account. In 1991, as a result of demand from the Japanese market, fishermen selected crabs that were more than 102 mm in size; this resulted in underestimation of the total catch of morphometrically mature hard-shell crabs ≥ 95 mm (B_s), and consequently the soft-shell crab occurrence rate was overestimated. Close observation of fishing activities is essential if the method used to estimate the occurrence of soft-shell crabs is to reflect the new practices in which snow crab fishermen are currently engaging.

The factors that influence the catchability of soft-shell crabs in commercial traps are very poorly understood at present. Between 1989 and 1991, a steady increase in biomass was observed in the case of morphometrically mature hard-shell crabs ≥ 95 mm (B_s) and soft-shell crabs ≥ 70 mm (B_s), along with a gradual decline in the mean yearly occurrence of soft-shell crabs in commercial traps. During that same period, however, the ratio of morphometrically mature hard-shell crabs ≥ 95 mm (B_s) to soft-shell crabs ≥ 70 mm (B_s), in terms of their respective biomass values, remained relatively stable, varying over a range extending only between 1:7.88 and 1:8.44. In 1992, there was a further increase in biomass in the case of morphometrically mature hard-shell crabs ≥ 95 mm (B_s), while in the case of soft-shell crabs ≥ 70 mm (B_s) biomass declined considerably from the value that had been observed in the previous season, with the result that the ratio fell off to 1:4.33. Preliminary results from the soft-shell crab monitoring program during the 1992 fishing season indicate a further decrease in the occurrence of soft-shell crabs in commercial catches. These findings suggest that the occurrence of soft-shell crabs in commercial catches is directly related to the biomass of morphometrically mature hard-shell crabs ≥ 95 mm (B_s), regardless of biomass size in the case of the soft-shell crab population itself. The explanation of this may be that soft-shell crabs tend to avoid entering a trap if it already contains a number of hard-shell crabs. Observations of the feeding behaviour of these two types of crab in an aquarium setting have also shown that the hard-shell crab is invariably dominant (M. Moriyasu, unpublished data).

Changes in weekly soft-shell crab occurrence values during the fishing season may be explainable by a decline in the numbers of morphometrically mature hard-shell crabs ≥ 95 mm (B_s) as a result of heavy harvesting early in the season, larger numbers of postmoulters entering the traps, and the fact that the fishermen move their traps around in an effort to avoid soft-shell crabs and upgrade the quality of their catches. The geographic density distributions of soft-shell crabs and morphometrically mature hard-shell crabs ≥ 95 mm (B_s) also affect the occurrence of soft-shell crabs in commercial catches. A better understanding of the mechanisms controlling soft-shell crab catch rates will have to await further research on the moulting cycle and analyses in greater depth of the geographic density distribution patterns found in the case of these various biological categories.

Soft-shell crabs in the traps may be a source of problems for the fishery, including lower meat yields relative to total crab weight in processing plants and high mortality among soft-shell crabs that have been thrown back into the sea. From an economic standpoint, a hard-shell crab is considerably more valuable than a soft-shell crab. In the case of the Cape Breton Island coastal fishery (zone 18), for example, the unit price rose from 50¢ a pound in 1991 to approximately $ 1.75 a pound in 1992, thanks to a substantial increase in the biomass of morphometrically mature hard-shell crabs ≥ 95 mm (B_s) coupled with a much lower percentage of soft-shell crabs in the catches than had been the case in previous seasons. It follows that harvesting soft-shell crabs is not a good economic strategy (the disparity in total income being 3.5 to 1 in the Cape Breton instance). As regards mortality among soft-shell crabs, the survival rate varies considerably depending on size (B_s) and extent of damage sustained during handling after being caught (missing legs and initial vitality). The mortality rate among soft-shell crabs after release into the sea may be as much as 24%, and may go as high as 36% if the crabs in question are larger than 90 mm in size (Réjean Dufour, personal communica-tion, DFO, P.O. Box 1000, Mont-Joli, Quebec, G5H 3Z4). It is thus desirable to avoid catching soft-shell crabs insofar as possible in order to reduce mortality after their release into the sea.

The use of a 20 percent soft-shell crab occurrence level in catches for two consecutive weeks as the trigger for an automatic shutdown of the snow crab fishery rests mainly on economic criteria: that percentage represents the economic viability limit for fishermen and the industry. But while the 20% level was not originally set for scientific reasons, the fact remains that it is a reasonable one for recruitment protection purposes.

The snow crab fishery is sensitive to year-to-year fluctuations in recruitment population groups consisting of individuals which may be of commercial size ($B_s \geq 95$ mm) owing to intensive harvesting of that part of the stock consisting of morphometrically mature hard-shell crabs ≥ 95 mm (B_s) (Mallet *et al.* 1992). And the numbers of the morphometrically mature soft-shell crabs ≥ 95 mm (B_s) which constitute the recruitment biomass declined from 35.0 million in 1989 to 26.7 million in 1990 and to 24.2 million in 1991. Harvesting soft-shell crabs adversely affects recruitment to the fishery by reducing the biomass of morphometrically mature hard-shell crabs ≥ 95 mm (B_s) in subsequent years. Given the importance of protecting recruitment to the snow crab fishery, yearly monitoring of the week-by-week occurrence of soft-shell crabs in catches by means of sampling operations carried out aboard fishing boats is essential for effective stock management. Soft-shell crabs should not be harvested; they should be left to develop into good commercial quality specimens for the next fishing season and to maintain the reproductive potential of the stock (Chiasson *et al.* 1991).

One change that might be useful as a means of enhancing the effectiveness of the soft-shell crab occurrence monitoring program would be to establish a number of subzones within zone 12. This change would be desirable because soft-shell crabs are not evenly distributed over the entire surface of the southwestern Gulf of St. Lawrence fishery (Mallet *et al.* 1992). The boundaries of these subzones would be determined on the basis of areas of fishing effort concentration in previous years and soft-shell crab population density curves as obtained by trawl sampling after the end of the previous year's fishing season. Effective monitoring of the week-by-week occurrence of soft-shell crabs in commercial catches during the fishing season could provide an indicator of the overall state of the stock. For example, a large percentage of soft-shell crabs in the traps over a period of two consecutive weeks in the fishing season would suggest that much smaller numbers of morphometrically mature hard-shell crabs ≥ 95 mm were likely to be caught during the remainder of the season; the fishery could then be shut down in any zones where the occurrence of soft-shell crabs had been in excess of 20% for two consecutive weeks.

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Table1. Total landing values (dollar amounts paid to fishermen) and tonnages landed since 1968 in the southwestern Gulf of St. Lawrence (zone 12).

Year	Landings (t)	Unit price ($/kg)	Total earnings (x 10^6 dollars)
1969	7580	0,20	1,52
1970	5634	0,21	1,18
1971	5374	0,18	0,97
1972	5392	0,29	1,56
1973	6969	0,39	2,72
1974	6704	0,38	2,55
1975	4632	0,35	1,62
1976	7568	0,44	3,33
1977	9537	0,52	4,96
1978	10462	0,57	5,96
1979	15794	0,67	10,58
1980	14854	0,59	8,76
1981	21877	0,58	12,69
1982	31585	0,92	29,06
1983	24342	1,43	34,81
1984	26062	1,43	37,27
1985	25158	1,06	26,67
1986	24267	1,34	32,52
1987	11782	3,19	37,58
1988	12355	4,95	61,16
1989	7882	2,86	22,54
1990	6950	2,86	19,88
1991	10019	2,97	29,76

Table 2. Comparison of biomass in number x 10^4 for soft-shell crab ≥ 70 mm, morphometrically mature hard-shell crabs≥ 95 mm and morphometrically mature soft-shell crabs ≥ 95 mm in the southwestern Gulf of St. Lawrence (zone 12) as estimated by the geostatistical method (Kriging) in the course of trawling cruises in 1988, 1989, 1990 et 1991.

	1989	1990	1991	1992
Biomass (numbers) of mature hard-shell crabs ≥ 95 mm	1458,67	3642,58	4358,62	5213,14
Biomass (numbers) of soft-shell crabs ≥ 70 mm	11904,48	28700,96	36802,08	22578,57
Biomass (numbers) of mature soft-shell crabs≥ 95 mm	3495,24	2670,35	2418,46	-

Table 3. Landings, fishing effort, catch per unit effort (CPUE) and occurence of soft-shell crabs in the southwestern Gulf of St. Lawrence (zone 12) snow crab fishery since 1989.

Year	1989	1990	1991
Landings (t)	7882	6950	10019
Fishing effort (numbers of traps lifted)	356442	254578	326671
C.P. U. E. (kg/trap)	22,11	27,30	30,70
% soft-shell crabs (unweighted)	37,2	16,8	11,6

Table 4. Weekly and seasonal occurence of soft-shell crabs in the southwestern Gulf of St. Lawrence (zone 12) during the 1990 and 1991 fishing seasons.

	1990		1991	
Week	Weighted	Unweighted	Weighted	Unweighted
1	14,0	17,9	6,1	6,0
2	12,5	13,3	6,8	7,7
3	20,7	24,3	15,8	18,6
4	7,9	10,2	17,9	18,7
5	23,2	26,1	17,6	12,1
6	15,9	20,6	7,2	5,7
7			7,4	6,5
Season	15,0	16,8	11,5	11,6

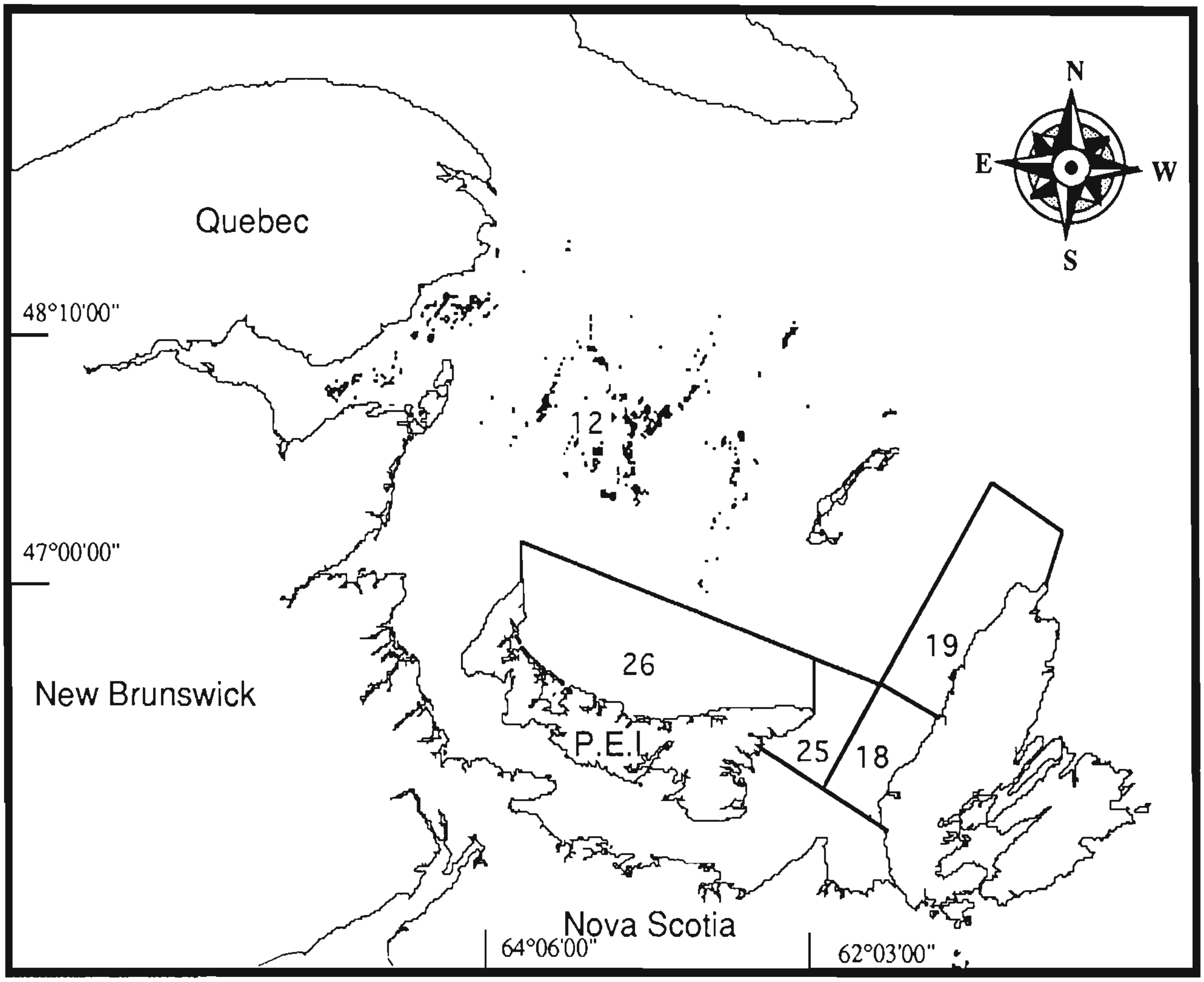

Figure 1. Sampling program carried out aboard boats engaged in the commercial snow crab fishery in zone 12 in 1991: location of sampling sites

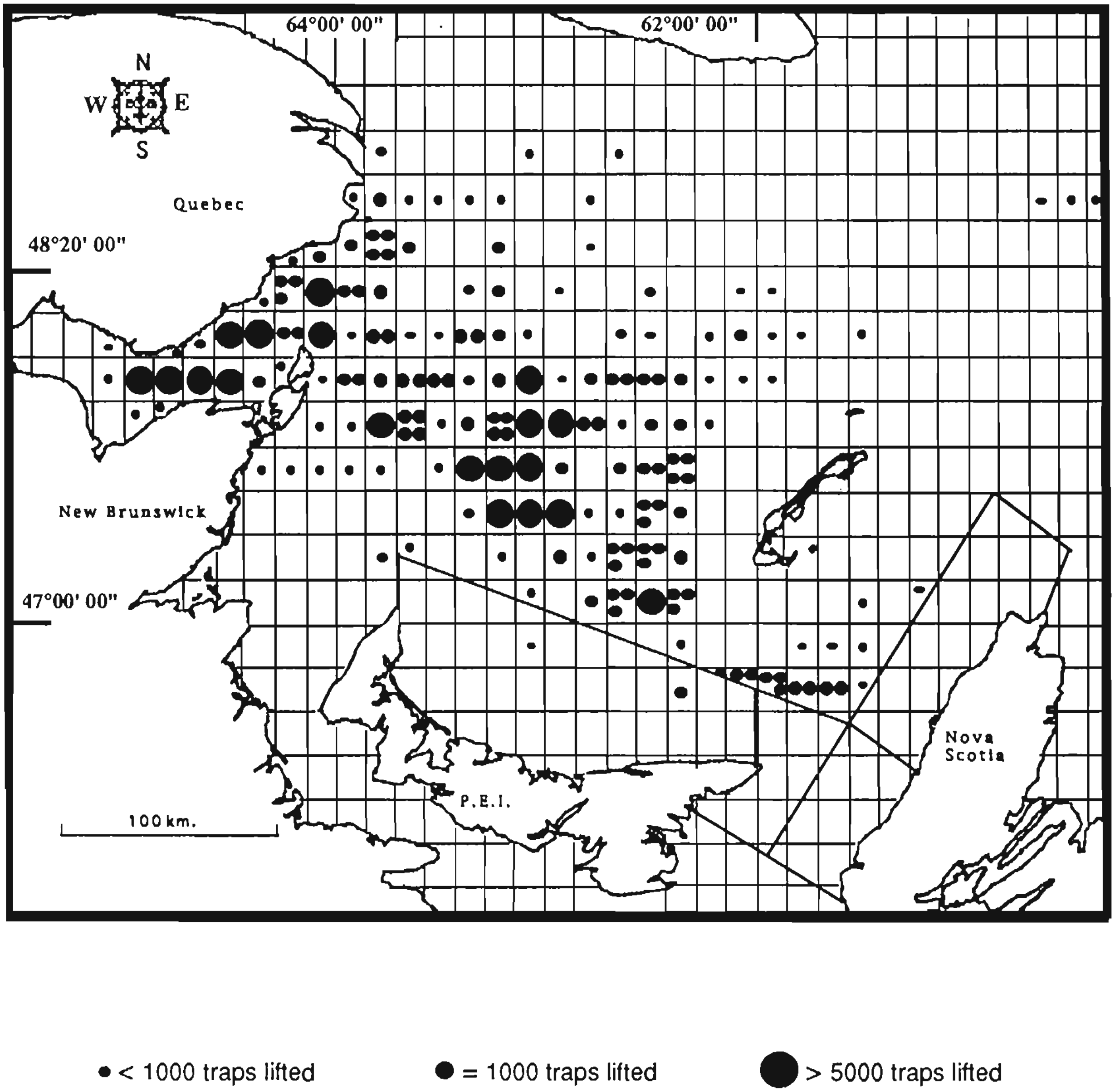

Figure 2. Seasonal geographic distribution of fishing effort in the southwestern Gulf of St. Lawrence (zone 12) during the 1991 season.