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An improved link between industry, management and science: review of case history of the Southwestern Gulf of St. Lawrence snow crab fishery

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Abstract

This paper traces the evolution of snow crab fisheries science and its impact on the management of the southern Gulf of St. Lawrence snow crab (*Chionoecetes opilio*) fishery. This currently lucrative fishery (estimated landed value of more than 125 million Canadian dollars in 1994) has experienced the traditional rises and falls of most fisheries and the resulting socio-economic consequences and sometimes strained relations between the industry and the fisheries management agency, in this case the Canada Department of Fisheries and Oceans (DFO). Of note at this time is the remarkable degree of cooperation that has developed between the industry and DFO since the stock has drastically decreased (1987-1989). Since then the stock has been recovering steadily and is also better managed. The reasons for this are four-fold: (1) a recruitment pulse of small-sized crab occurred in 1988-1989; (2) substantial advances in the understanding of the complex biology of snow crab and the development of an accurate, reliable stock assessment methodology together have provided consistent, reliable and credible advice for forecasting the amount and geographic distribution of exploitable biomass for the upcoming fishing season; (3) the industry leaders worked very hard with their associations to convince fishers that their fishery was in peril and that close cooperation with DFO was the key for the future; (4) the industry and DFO (fisheries biologists and managers) worked as partners to develop a management approach based upon scientific advice to climb out of the trough. The paper also outlines the conundrum that fisheries managers currently face resulting from a combination of a moratorium of the entire Gulf of St. Lawrence groundfish fishery, the consequent pressure from displaced groundfish fishers to enter the lucrative snow crab fishery and an optimistic short term but pessimistic longer term forecast regarding snow crab abundance: do we redistribute the wealth; if so among whom and how and for how long?

Keywords: Gulf of St. Lawrence, snow crab, *Chionoecetes opilio*, trawl survey, geostatistical analysis, stock assessment, fisheries management, industry-science collaboration.

Relation entre industrie, gestion des pêches et science : exemple de la pêche du crabe des neiges du Golfe du St-Laurent.

Résumé

La présente étude décrit l'évolution des pêches du crabe des neiges (*Chionoecetes opilio*) et ses effets sur la gestion de stocks de l'espèce dans le sud du Golfe du Saint-Laurent. Cette pêche, actuellement lucrative (sa valeur estimative au débarquement était de plus de 125 millions de dollars canadiens en 1994), a connu les hauts et les bas qui caractérisent la plupart des pêcheries et les effets qui s'ensuivent, notamment les conséquences socio-économiques et les relations parfois tendues entre l'industrie et l'organisme de gestion des pêches, en l'occurrence le Ministère des Pêches et des Océans (MPO). On constate cependant aujourd'hui qu'une coopération d'un niveau remarquable s'est établie entre l'industrie et le MPO depuis la dernière période de diminution spectaculaire du stock (1987-1989). Depuis lors, le stock se reconstitue

et il est aussi mieux géré. Il y a à cela quatre raisons : (1) on a noté en 1988-1989 une intensification du recrutement de crabes de petite taille ; (2) les progrès notables réalisés dans la compréhension de la biologie complexe du crabe des neiges et l'élaboration d'une méthode précise et fiable d'évaluation du stock ont ensemble permis de rassembler des données systématiques, fiables et crédibles pour la prévision de la quantité et de la distribution géographique de la biomasse exploitable avant la saison de pêche ; (3) les responsables de l'industrie, de concert avec leurs associations, ont déployé de grands efforts pour convaincre les pêcheurs que leur stock était en danger et qu'une collaboration étroite avec le MPO était la voie de l'avenir ; (4) l'industrie et le MPO (ses biologistes et ses agents de gestion des pêches) ont élaboré en collaboration une approche de gestion fondée sur les avis scientifiques pour sortir du marasme. Cette étude expose de plus le problème difficile qui se pose actuellement aux responsables de la gestion des pêches par suite d'une part du moratoire de la pêche du poisson de fond sur toute l'étendue du Golfe du Saint-Laurent et des pressions exercées en conséquence par les pêcheurs du poisson de fond désoccupés pour obtenir les lucratifs droits de pêche au crabe des neiges, et d'autre part des prévisions optimistes à court terme mais pessimistes à long terme touchant l'abondance du crabe des neiges, problème qui pourrait se formuler ainsi : devons-nous redistribuer la richesse, et si la réponse est oui, à qui, comment et pour combien de temps ?

Mots-clés : *Chionoecetes opilio*, chalutage, analyse géostatistique, évaluation de stocks, gestion de stocks, Golfe Saint-Laurent.

INTRODUCTION

Hare and Dunn (1993) have provided a comprehensive history of the snow crab (*Chionoecetes opilio*) fishery in the Gulf of St. Lawrence to 1989. Suffice to say that starting in 1965, the snow crab fishery in the Gulf of St. Lawrence has since developed to a current landed value of about 125 million Canadian dollars. During its development, the industry benefited from the collapse of the Japanese snow crab fisheries in the mid-1970's, then the Alaskan crab fisheries in the mid 1980's and the consequent increased demand for crab meat from the Gulf of St. Lawrence. The value of landings increased tenfold as the fishery developed. Catches were initially projected to stabilize at approximately 5,000 t but in fact exceeded 30,000 t in 1982 (Hare and Dunn, 1993). Subsequently, catches declined and the stocks were thought to have collapsed; this apparent collapse was seen at the time, as a probable result of over exploitation. The fishery has since recovered but faces new challenges, both on the stock abundance and resource allocation fronts.

Fishery management strategies have identified harvesting approaches to meet the needs of industry while also attempting to conserve stocks. According to Hare and Dunn (1993), throughout the 1980's, the fishery was increasingly managed to achieve socio-economic goals with the management goals resulting in harvesting strategies to ensure unemployment benefits to more than 8,000 plant workers. They also point out that in areas where snow crab grounds approached coastal waters (*i.e.* Cape Breton and Prince Edward Island (PEI)), inshore fishermen were provided exclusive access to productive grounds.

The purpose of our review is to show how these management strategies have been influenced by the evolution of snow crab fisheries science and how the industry itself has played a crucial role both in the science and management of their fishery.

FISHERY PROFILE

Harvesting of snow crab in the southern Gulf of St. Lawrence began in the mid-1960s with incidental by-catches by groundfish trawlers off Gaspe peninsula, Quebec (Elner and Bailey, 1986). The fishery (*fig.* 1) is comprised of a principal fishery (Area 12) and three inshore supplementary fisheries (Areas 18, 19 and 25/26).

Area 12 represents the largest snow crab fishery (Chiasson *et al.*, 1992). It is worked by 130 fishers from New Brunswick, Quebec and Nova Scotia with each license holder entitled to a maximum of 150 traps. This fishery grew rapidly at first and the total catch peaked at 31,500 t in 1982 (*fig.* 2). In subsequent years, catches remained around the 25,000 t mark until 1986 when the landings dropped drastically by 50% in 1987 and remained at those levels in 1988. In 1989, after landing 7,880 t of crab, the fishery prematurely closed due to the high incidence of newly molted crabs in the commercial catch. In 1990, a management plan was enforced based on the agreement between DFO and industry with annual quota level of 7,000 t. Since then, catches have been 14,336 and 19,995 t in 1993 and 1994 respectively.

The snow crab fishing grounds along the western coast of Cape Breton island were initially fished by those fishers based in Cheticamp. Subsequently, fishers from Quebec and New Brunswick also fished the area from time to time. When the commercial value of snow crab went up in the late 1970's, the fishery was gradually extended until it covered all the fishing grounds along the island's western coast. In 1978, Area 19 was established as an inshore area opened

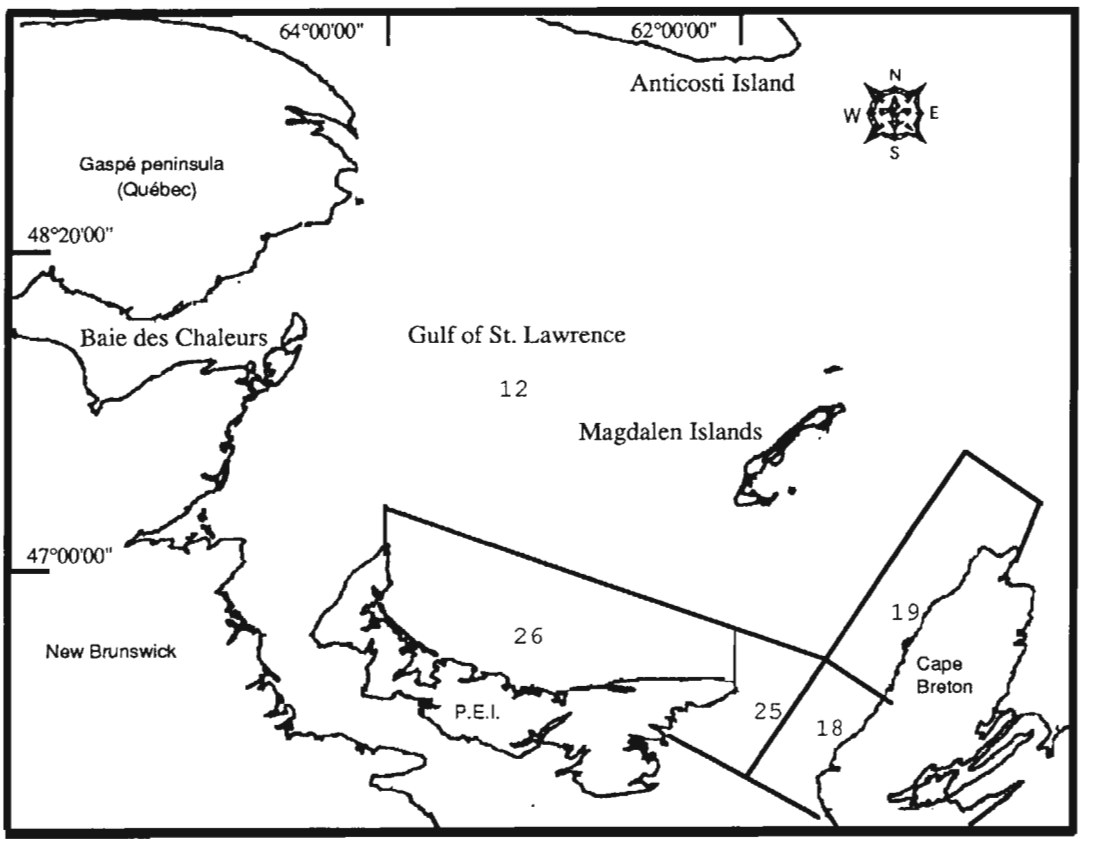

Figure 1. – Southern Gulf of St. Lawrence snow crab, *Chionoecetes opilio*, management zones (Hébert *et al.*, 1992 *a* modified).

only to inshore fishers using boats less than 13.7 m (45 feet) in length. Landings, which are subject to a quota, ranged between 900 t and 1,390 t from 1979 to 1991. In 1993, 74 fishers using a total of 20 traps each were engaged in this fishery. The quotas, which were set at 1,686 t in 1992, 1993 and 1994 were fully used. Area 18 was fished for the first time in 1979 by 14 inshore boats with exploration permits and a maximum limit of 30 traps per permit. In the following year, these permits were converted into fishing licenses and 9 additional permits were issued with a view to the exploration of areas further offshore. Crab fishing boats from Area 12 worked these same fishing grounds until 1982. In 1984, Area 18 was reserved exclusively for inshore fishers. The overall quota, which had initially been set at 835 t in 1981, was cut back to 626 t in 1986 and then increased to a level of 674 t in 1988, where it remained through the 1990 fishing season. In the spring of 1991 a quota of 200 t was set with a view to encouraging a spring fishery in the area and later in that year a quota of 674 t was set for the autumn of 1991 and the spring of 1992. The quota was raised to 749 t for 1992-1993 and has been left unchanged at that level for 1993-1994 and 1994-1995. Since 1992-1993, the number of fishers working this area has totaled 30.

The Prince Edward Island fishery, which comprises Areas 25 and 26, began on an exploratory basis in 1985 with 18 permit holders harvesting in both the spring and fall seasons. By the next year, the number of permits issued had increased to 30. Since 1989, this fishery has been conducted only in the spring due to a high incidence of white crab in the fall season. In 1990 the two areas in question were reserved exclusively for Prince Edward Island fishers. Each of the 30 operators have used 30 traps until 1992 then the trap limit was increased to 50 in 1993. The largest total catch recorded to date has been 1,239 t (in 1986). Since 1990 this fishery has been subject to a quota, which was originally 500 t but was increased to 800 t in 1993 and 1,000 t in 1994. Quotas have consistently been fully used except for 1994 in which the season was closed early (total landings at 923 t) due to a high incidence of soft-shelled crab in the catch.

At a time when the Gulf groundfish fishery is closed and with no optimistic signs regarding an increase in exploitable biomass of cod in the near future, the currently lucrative crab fishery is especially attractive to those fishers who are not snow crab license holders. Furthermore, there are only 264 vessels involved in this fishery, while many others sit tied up at docks during the cod fishery moratorium, leaving

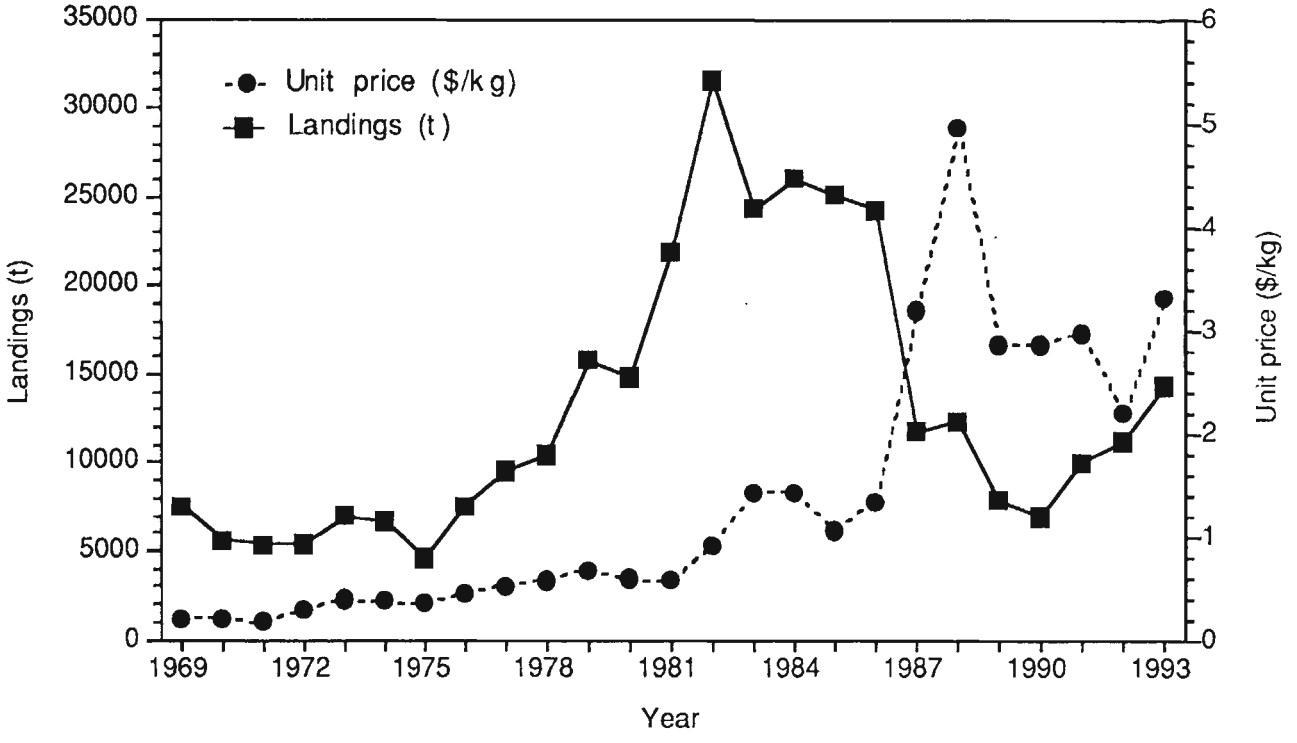

Figure 2. – Landings in metric tonnes (square) and unit price in Canadian dollars (circle) of snow crab in the southwestern Gulf of St. Lawrence fishery (area 12).

a relatively few very successful fishers operating out of communities. Needless to say, there are immense socio-economic differences either within the communities or among fishers and therefore political pressures are being exerted on DFO to ensure better distribution of the wealth.

ADVANCES IN SCIENTIFIC KNOWLEDGE

Biological characteristics of the snow crab

Our knowledge of snow crab biology (*e.g.* growth, reproduction, recruitment, movement) has increased significantly since the mid-1980's, coincident with a much higher priority given by DFO to research on this species and much of that progress was summarized by Hare and Dunn (1993). The most important finding has been the determination of the existence of a terminal moult in male crab (Conan and Comeau, 1986). They showed that snow crab do not continue to grow after each moult but stop at a "terminal moult" after which they no longer grow and appear to die within 4 years or so (pers. comm., G. Y. Conan, DFO, Moncton, N. B. Canada). Only males are harvested in the fishery and it has become apparent that most males reach their terminal moult around 95 mm carapace width (CW). Prior to their terminal moult, crab continue to moult once a year and these constitute the soft-shelled component which the industry has tried to avoid for many years. Research revealed that these soft-shelled or "white crab" comprised the annual biomass recruiting to the fishery, most but not all of these animals were going to moult into their terminal moult and hence become mature hard-shelled male crab available for exploitation. Conan *et al.* (1988*a*) also showed that all of the originally accumulated biomass of older crab had disappeared such that by the late 1980's only these smaller terminally moulting soft shelled crab would be available for future fisheries. This terminal moult phase is easily identified by applying a bivariate discriminant function developed for a set of carapace width vs chela height data (Conan and Comeau, 1986). Based on this finding, DFO biologists were able to forecast the biomass of harvestable crab for the next fishing season by examining only the terminal moult phase of commercial-sized males and by assuming that 100% of non-terminal molt individuals moult every year.

Stock assessment methodologies for snow crab

Advice on stock status and fisheries management has been provided by DFO biologists since the inception of the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) in 1978. However, prior to 1988, advice was based upon examining trends in

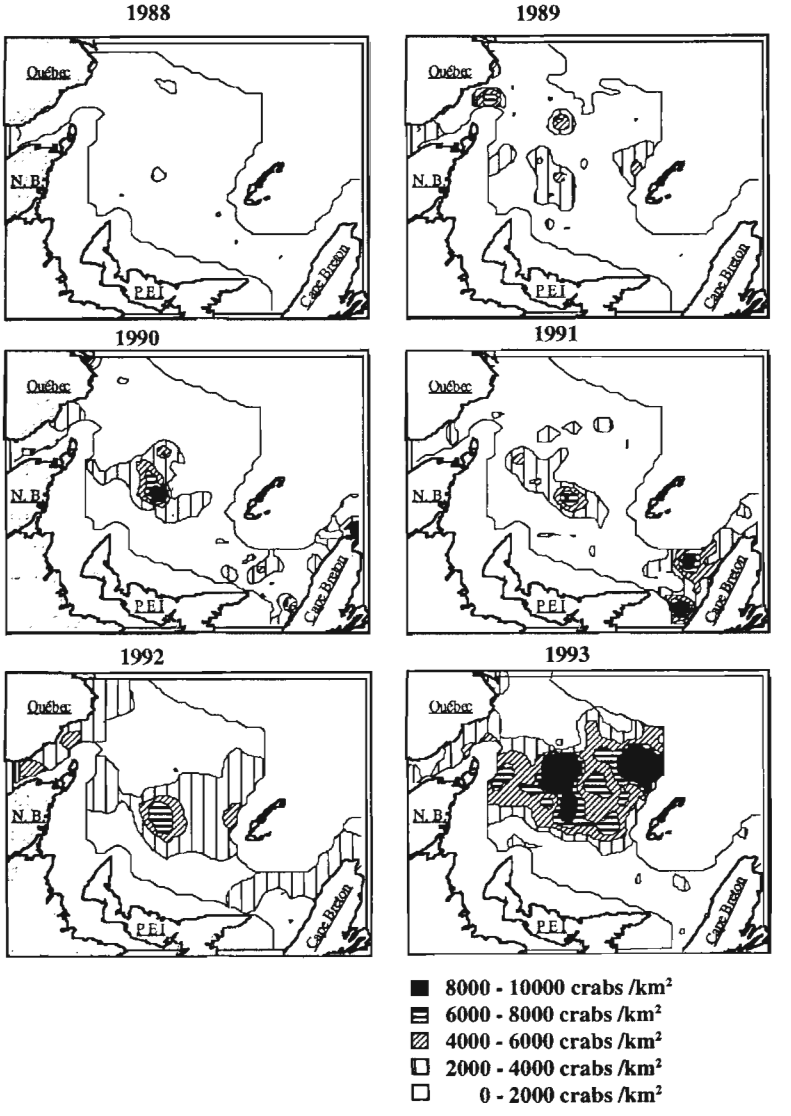

Figure 3. – Density contours for terminal molt crab larger than 95 mm carapace width estimated by Kriging from 1988 to 1993 based on the post fishery season trawl surveys (Hébert *et al.*, 1992*a* modified).

catch per unit effort derived from fishermen's logbooks and initial biomass estimates and exploitation rates, the latter two indices retroactively calculated using Leslie analysis (Leslie and Davis, 1939). By 1988, CAFSAC was being heavily influenced by continuing criticisms of that technique and especially the fact that a major assumption of the Leslie analysis was being invalidated by the impact of the searching activity of the fleet on catch rates (Miller and Mohn, 1989; Hare and Dunn, 1993). At that time, CAFSAC indicated that the crab fishery was focused entirely on incoming recruitment, that it did not have any reliable way of estimating biomass of any group of crab (especially pre-recruits and therefore long term catch forecast) and thus could no longer provide advice regarding TAC's for conservation purposes and exploitation rates.

In 1987, a bottom trawl survey was conducted on a pilot basis in a small area in the Area 12 fishery; then it was extended in 1988 to the entire Area 12 and Areas 25/26 as well. Since 1990, the entire southern Gulf of St. lawrence has been covered. The trawl used is a Bay of Biscay "Bigouden" type otter trawl with a 20-meter opening (Conan *et al.*, 1994). Trawl surveys in all areas of the Gulf were conducted after the commercial crab fishing season. Two hundred and twenty-five (225) stations were sampled throughout the area; stations were randomly selected within the defined sample area (30,000 km^2) in 1987 and have been used as fixed stations thereafter. A geostatistical method known as "kriging" (Matheron, 1970) has been used to estimate biomass and produce charts showing density contours for various biological categories of crab (Conan, 1985;

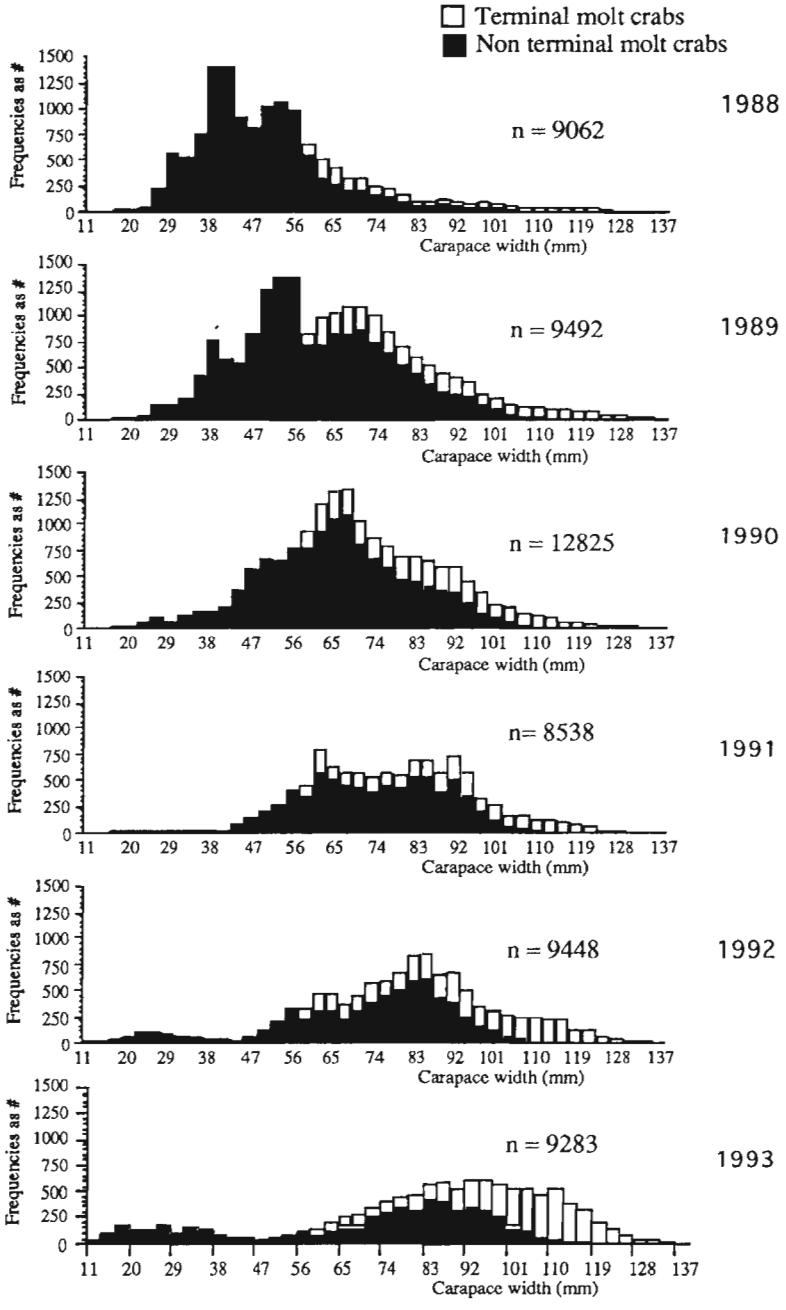

Figure 4. – Overall size distribution of male snow crab, *Chionoecetes opilio*, caught by trawl in the southwestern Gulf of St. Lawrence fishery (zone 12) after the 1988 to 1993 fisheries (CAFSAC, 1993 modified).

Conan *et al.*, 1988*b*). The current survey technique, originally developed by Conan (1985), is described in Hébert *et al.* (1992*a*). This survey provides the following information: estimates of numbers of male and female crab by differing size class and maturity stage, isodensity charts showing the geographic distribution of a given category of crab (*e.g.* hard-shelled males at harvestable size; *fig.* 3) and area specific size frequency distributions (*fig.* 4). These data are combined with a growth studies derived from laboratory and field research (Moriyasu and Mallet, 1986; Moriyasu *et al.*, 1987; Conan *et al.*, 1989*b*) to generate projections on the abundance of various groups (size and life stage) of crab that will be present at the beginning of the following fishing season. These annual post-fishery surveys combined with the growth models have produced useful and inter-annually consistent predictions of future recruitment as well as current exploitable biomass (*fig.* 5). This also provided fisheries biologists with the ability to

provide not just stock status reports but abundance forecasts for management consideration. It should be noted that, because of difficulties in predicting how many crab will enter terminal moult and become greater than 95 mm CW and how many crab will skip a moult (called skip moulters), our current capability to provide multi-year abundance forecasts is limited. Nonetheless, DFO biologists have been able to forecast a significant downturn in recruitment to the fishery after 1995 for the southern Gulf stock(s) due to poor recruitment of small-sized (around 30 mm CW) crabs in the early 1990's as observed from consecutive trawl survey size frequency distributions (*fig.* 4).

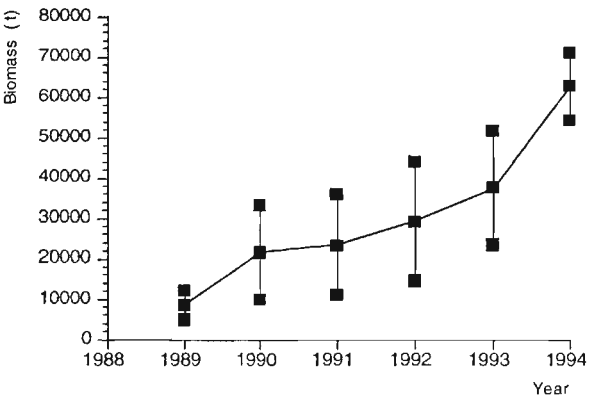

Figure 5. – Total projected biomass (in metric tonnes) based on post fishery trawl surveys for the 1989 to 1994 fishing seasons in the southwestern Gulf of St. Lawrence fishery (zone 12).

SCIENTIFIC BASIS FOR FISHERIES MANAGEMENT

Carapace size limits

Snow crab in Atlantic Canada have been managed under the strategy of harvesting only large males. Harvesting of females and crab less than 95 mm CW has been prohibited on the assumption that snow crab stocks would be protected from recruitment overfishing if females were not harvested; males were thought to mature and mate before they reached the minimum legal size (Watson, 1969). This strategy was questioned in the late 1980's when Conan and Comeau (1986) observed males: (1) above the minimum legal size to be morphometrically immature (meaning that some males may be harvested before they can actively participate in mating) and (2) some mature males below the minimum size in a terminal moult condition (implying that they might never become a legal size but could mate). Based upon these observations, Conan and Comeau (1986) noted that the current management strategy may not entirely protect the reproductive capacity of the stocks. Most snow crab stocks were fully exploited and largely dependent upon new recruitment to the fishery each year and that catches or stock sizes could not be predicted because of growth mechanism (*e.g.* factors determining the size at terminal moult, mechanism of occurrence of skip moulting) was not well understood and recruitment to the fishery could not be forecast.

In 1990 one of the Area 12 fisher's associations requested DFO to examine the possibility of increasing the current minimum size of 95 mm CW. The conclusion of the study was that "CAFSAC could not see any benefit of increasing the minimum legal size and, specifically, did not feel that a size increase would promote stability in the fishery. The short-term effect of increasing the minimum size would be to reduce the size of the legally catchable population, thus probably also reducing the catch per unit effort of legal-sized crabs. Whether this results in a lower total catch depends on how the fishery is regulated (*e.g.* by fishing season or by quota). In future seasons, if the TAC is set at a high level, the exploitation rate on the legal crabs will be very high and the fishery will depend very heavily on recruitment. There is thus reason to believe that increasing the minimum size may promote instability in the fishery if the quota is not reduced accordingly. Although increasing the minimum size would allow males more opportunities to mate, there is no reason to believe that reproductive success is endangered at present. Also, effects of a change in size on the yield per recruit cannot be evaluated reliably at this time".

While definitive evidence of terminal moult remains controversial (*e.g.* Donaldson and Johnson, 1988; Conan *et al.*, 1988; Conan *et al.*, 1989*a*; Dawe *et al.*, 1991) acceptance of the concept (Jamieson and McKone, 1988) suggested that the reproductive potential of the southwestern Gulf of St. Lawrence stock may not have been efficiently protected by application of the minimum legal size (95 mm CW). It was assumed that morphometrically mature males less than 95 mm CW unable to mate with multiparous females, the most abundant female parental stock, whereas most morphometrically mature males over 95 mm CW were heavily exploited as soon as they moulted to legal size and, therefore, did not have the opportunity to mate before being caught (Conan and Comeau, 1986). The recent findings (Ennis *et al.*, 1990, 1991; Comeau *et al.*, 1991) revealed that the critical size limit of terminal moult males for successful mating with multiparous females seems to be flexible depending on the size structure of the male population and the density of large males in the population. In populations with a sufficient number of large males, the smaller sized males are excluded from mating as a result of competition among the males (Comeau *et al.*, 1991). However, smaller terminal moult males may copulate with multiparous females when competition among males is reduced by decreasing abundance. Further research must be pursued to fully understand the mechanism of mating and reproductive potential of male crab.

In addition, the mechanism of terminal moult is not well understood. The size at which terminal moult occurs varies from 50 to 120 mm CW, and it is therefore possible that all new recruit undergo terminal moult at smaller sizes than a new increased size limit (pers. comm., G. Y. Conan). In conclusion, it is recommended not to increase the current size limit of 95 mm CW.

Prohibition of retention of females

The current resource conservation measures state that all females caught in traps must be returned to the sea to protect the spawning stock. Female snow crabs rarely attain the commercial harvesting size limit (95 mm CW). The percentage of ovigerous females usually exceed 95% in the commercially exploited populations and thus, it is been believed that egg production is being maintained at safe levels despite heavy exploitation of large males (Elner and Bailey, 1986). Nevertheless, the past experience in Area 12 suggests that the prohibition of harvesting females is not sufficient to protect from overfishing. In addition, recent studies (Mallet *et al.*, 1993; Sainte-Marie, 1993) have revealed that the complete sequence of egg development takes two years which is contrary to that reported in the literature (Watson, 1970; Kon, 1980). Females normally live about 5 years after terminal moult and therefore they produce no more than two or, at the most, three clumps of eggs in their life span (Mallet *et al.*, 1993). These findings suggest that the populations' reproductive potential is very low compared to what was believed and indicates the extreme fragility of the stock. Although, there are strong market demands for ovigerous females by the Japansese market for crab roe, DFO Gulf fisheries biologists are recommend that the current regulation of not exploiting females be maintained until the reproductive and recruitment mechanisms and stock-recruitment relationship are better understood.

Protection of soft-shelled animals

Throughout the history of this fishery, it is clear that the industry always has sought protection for the soft-shelled crab. Their reasoning appears to have been mostly market driven (quality related) but nonetheless, there was a consistent call for the prohibition of retaining soft-shelled crabs in the catch. In the early of exploitation history, a 20% meat yield at processing plants was used as a measure to limit the catch of soft-shelled crabs mainly due to economic reasons. High exploitation rates result in the reduction of the accumulated hard-shelled crabs and therefore increasing the dependence on newly recruited crabs (most of which would be caught as recently moulted). By 1985, it was apparent to biologists that "the fishery could not be safely managed on the basis of a quota representing half of the initial biomass each year. Most of this biomass has been accumulated over many years. The soft-shelled crab represents the annual recruitment, the renewed part of the stock (Conan and Comeau, 1986; Kon *et al.*, 1993). The quota should be defined as a function of the amount of soft-shelled crab recruited over the previous year, not as a function of total crab on the grounds, if one wants to avoid over-exploitation" (pers. comm., G. Y. Conan). Furthermore, soft-shelled males regardless of size and morphometric maturity, cannot participate in mating (Moriyasu and Conan, 1988) thus, harvesting newly molted crabs also reduces the reproductive potential of the stock. In reviewing the results of the research on moulting in snow crab, it is apparent now that protecting soft-shelled crab from exploitation is imperative to protect the future fisheries because this life stage represents the incoming exploitable biomass. In-season monitoring of white crab by fishery observers has been implemented since 1989 and all the information is analyzed by DFO biologists. In-season weekly progress reports and annual summaries are provided to DFO fishery managers and the industry.

Seasons

The fishing seasons imposed are as follows: for the Cape Breton fishery, regulation limit the season to 8 weeks mid-July to mid-September for Area 19. There is not fixed season for Area 18 but the fishery usually starts in August/September when the local lobster fishing season is over. The relatively short season is in accord with developing this particular fishery as a supplementary (to lobster, groundfish) fishery with a limited number of participants (Elner and Bailey, 1986). For Areas 12 and 25/26, the season extends from ice break up (April-May) to whichever factor is reached first: achievement of the quota or the incidence of greater than 20% (by number) of soft-shelled male crab of all sizes (*i.e.* legal and sub-legal sizes) in the commercial catch at sea over two consecutive weeks based on onboard investigations by observers (Hébert *et al.*, 1992*b*). The number "20" seems to have been derived from what was economically feasible for processing plants to make an acceptable quality of the final product. This measure came into place in the 1980's and extended to all southern Gulf snow crab fisheries prior to a full understanding of the role of soft-shelled crab and represented a consensus of both industry and scientists. Again, and regardless of the reason for its initial institution, this management measure would seem to have been well considered given current knowledge about this life stage.

Quotas and other effort controls

Various effort controls were put in place as the fishery developed. These included limited entry (*i.e.* licenses), trap limits per boat, minimum trap mesh size, maximum trap volume and eventually, quotas (global and boat). Until 1985, CAFSAC provided advice using

"exploitation rates" calculated from Leslie analysis, setting 50-60% as an acceptable target based upon work done in Cape Breton (Mohn and Elner, 1987). Then in 1985, preemptive or "reference" global quotas or TACs were established for Area 12 without any biological basis. CAFSAC did provide advice in 1986 and 1987 on whether current exploitation rates would actually achieve the TAC for the upcoming fishing season. Conan (1985) emphasized the inappropriateness of the Leslie analysis application to snow crab stocks and introduced a new approach by means of geostatistical analysis (kriging). By 1988, CAFSAC realized that the Leslie analysis was inappropriate for the assessment of Gulf stocks because the basic assumptions for the model were being violated (*e.g.* occurrence of the recruitment to the fishery during the fishing season and active movement of fishing fleet). It was also noted that because the fishery was a recruitment fishery and that it had no means of forecasting recruitment or exploitable biomass, CAFSAC could no longer provide advice vis-à-vis exploitation rates or the appropriateness of the TAC. It was also for these reasons that the impending collapse of the mid-shore fishery (1987-1989) could not be detected by CAFSAC. Subsequently in 1988, the quota was removed from the management plan with industry setting their own quotas through a series of consultations with DFO based upon the scientific advice received from the DFO Gulf fisheries biologists (albeit not officially provided by CAFSAC). By 1990, CAFSAC was again providing advice, on management measures, now using the results of the post-fishery biomass survey to calculate exploitation rates and making qualitative forecasts regarding the future recruitment to the fishery. By 1992, CAFSAC was providing alternative management strategies based upon the quantitative results of the biomass survey (and growth models) and was confidently using the results from the multi-year series of size/frequency plots to forecast next year's recruitment. It also warned of the potential declining recruitment in the immediate future after 1995.

Individual vessel quotas and at-port landing controls (with 100% vessel coverage) were implemented in 1989 and allowed the fishing industry to establish a comprehensive production plan. These changes have resulted in an improvement of the quality of the final product because the fishing industry was able to control the daily or weekly quantity of crab being brought to port for processing. This measure also reduced the number of illegal traps traditionally submerged year round on the fishing grounds which increased the catch and caused a high mortality of crabs during the winter by the effects of ghost fishing (Vienneau and Moriyasu, 1994). Furthermore, the quota level was being accurately monitored and controlled and this further discouraged illegal landings. All these new measures have been agreed to and financially supported by the Gulf of St. Lawrence snow crab industry.

Stock units

Prior to 1991, CAFSAC assessed the status of snow crab populations on the basis of five management units. In 1991, however, it was concluded that the concentrations of snow crab in the various areas based on geostatistical analysis (kriging) were actually interrelated and in fact constituted a single biological unit. Accordingly, the snow crab of the southern Gulf of St. Lawrence have been assessed as a single stock since 1992 as reflected in the annual biomass post fishing season survey mentioned previously. However, relevant details pertaining to the individual areas are also included; these are based on the geographic distribution of snow crab as observed by means of trawl surveys and analysis of fishing operations. This approach yields a general overview of changes occurring in the southern Gulf of St. Lawrence as a whole, thereby affording a means of interpreting fluctuations in the abundance of crab in the several management units.

IMPACTS ON FUTURE FISHERY MANAGEMENT STRATEGIES

At this time it is believed that the Gulf snow crab fishery is a recruitment fishery and that the species undergoes a terminal moult and lives for another 3-4 years thereafter. Based on the survey results in the last six seasons, the level of the current male parental stock biomass does not seem to effect or determine future recruitment instead, environmental factors seem to have a much larger role to play. Indeed, there is some empirical evidence (Comeau *et al.*, 1991; Starr *et al.*, 1994) that would argue that the recruitment does not appear every year. Hébert *et al.* (1992*a*) and current 1994 trawl survey data (M. Moriyasu, unpublished) showed that recruitment of the 30 mm CW size group has occurred only twice (1988 and 1994) within the past 6 years of surveys. This phenomenon appears to have occurred not only in the southern Gulf of St. Lawrence but also in the northwestern Gulf of St. Lawrence (pers. comm. B. Sainte-Marie, DFO Mont-Joli, Quebec, Canada) and in Japan (pers. comm. T. Kon, Fukui Prefectural Fishery Experimental Station, Fukui, Japan). Consequently, it can be argued that the Gulf crab fisheries should be managed on a "pulse fishery" basis, whereby most of the exploitable biomass can either be taken quickly in one or two years or extended over a larger period. In the former case, the fishing industry cannot expect a continuous fishing activity. Once the harvestable biomass is caught the fishery should be closed until the next pulse appears resulting in sporadic harvesting. In the latter case, one has to account for quality issues, in that older, terminally moulted crab are not as attractive to a market-wise consumer such as the Japanese, which are the most important crab importers from eastern Canada.

ROLE OF THE FISHING INDUSTRY

Throughout the history of this fishery, one can find instances of major disagreements regarding management strategies between the industry and DFO. There were several efforts (*e.g.* 1969, 1974, 1980, 1985) at achieving a common view as discussed in Hare and Dunn (1993). However, after the collapse of the fishery in 1989, industry worked with DFO to develop a new approach to fishery management. Several principles were agreed upon relating to the importance of stock conservation and enhancement objectives over other management or socio-economic objectives, such as the protection of the moulting stock; new measures to provide more rational exploitation patterns and control individual effort. Of particular note was the principle that "quota levels should be established below the most conservative estimates of annual recruitment in the fishery to increase future catches" (Hare and Dunn, 1993).

For Area 12 fishers, this led to the development of a remarkable reference point for management: the industry and DFO agreed that 70% of the lower confidence limit of the exploitable biomass estimate for 1990 should be used on an experimental basis to set the quota for the 1991 season. This was equivalent to a 32% exploitation rate which moved to 38% in 1992 based on the increasing trends in exploitable biomass and that has now become the reference point around which the global TAC for Area 12 is set. It should be noted that the exploitation rate had been 50-60% or greater in the past. Acceptance of this conservative approach by fishers involved a major change in attitude whereby they were willing to accept both the advice of scientists and also their own leaders. Since that time, consultations with Area 12 industry have been very cordial and scientific advice is sought and given in a very positive spirit. Indeed, all reasearch and assessment activities are now conducted in collaboration with local snow crab fishers, the industry, processors and provincial government officials. The frequent contacts between DFO biologists and fishers and processors through consultative meetings (dealing with issues of the general biology of crab, stock condition and gear development, commercial vessel charter for research and assessment and visiting processing plant for exchanging ideas and findings) are key points for the fostering of a mutually beneficial relationship. Consequently, DFO has established a strong relationship between fishers and the industry and all decisions relative to the management of the mid-shore snow crab fishery have resulted from this basic DFO-client dialogue. We have the industry's confidence and there exists a "partnership spirit" relative to the assessment and management of the Area 12 snow crab stock.

However, it would be misleading to suggest that all is well on the entire southern Gulf crab front! As indicated earlier in this paper, there are several inshore crab fisheries off PEI and Cape Breton. From a scientific perspective, the advice has been that there are no biological distinctions between the various crab fisheries and hence a global exploitable biomass forecast/estimate is provided annually for the entire southern Gulf. In the past, the PEI fishers have sought access to full crab licenses within the Area 12 zone; these have not been provided by DFO and instead an inshore fishery continues using the exploitable biomass estimates from those areas as the basis for setting annual quotas. PEI fishers have never been satisfied with these estimates but with the sharp rise in prices in 1994, they have asked for more intensive surveys. They have criticized the current surveys as underestimating the actual biomass and therefore they have not been satisfied with DFO's scientific and management approach as have the Area 12 industry. Similar concerns were voiced by Cape Breton fishers who do not have crab licenses, but who, because of the downturn in the groundfish fishery and the high prices of snow crab, now want in. DFO has not been willing to allow additional effort and hence no new licenses are being issued. The current participants in the Cape Breton fishery appear to be satisfied with DFO management and science and have maintained relations with DFO similar to those of Area 12.

Industry's attention is now also focusing on exploratory fisheries for other brachyuran and anomuran crab species such as the toad crab (*Hyas coarctatus* and *H. araneus*) and northern stone crab (*Lithodes maja*). At this time, there is no scientific basis for management of these species but approaches similar to snow crab are very possible if the biomass surveys occur.

FUTURE FISHERIES SCIENCE

Although we have been improving our understanding of the life cycle of this species and are now capable of predicting long term stock trends within limits, precise estimates of biomass fluctuations cannot be obtained until the moulting mechanism and dynamics (skip moulter) are fully understood. In addition, the environmental factors seems to play an important role in moulting cycle of snow crab. Taylor *et al.* (1994) mentioned that abnormally low water temperature interrupted the moulting cycle of snow crab which resulted in the stock collaps in Newfoundland snow crab fishery in 1985. The factors controlling the annual recruitment should be studied so that the robustness of the long term biomass estimates can be re-enforced. An in-depth biological investigations on the reproductive potential of both male and female crabs as well as the dynamics of juvenile crabs are necessary. Also the trawl survey should be continued at the current level (225-250 stations) until a new recruitment pulse appears (DFO Gulf biologists forecasted that the recruitment may appear in 1999-2000 based on the trawl survey currently being conducted). The fishers and industry are fully aware of the current stock status

and have insisted upon taking conservative measures to rebuild the stocks in collaboration with DFO biologists. The consensus among all the players is that the post-season trawl survey and related research activities are the best tools for the conservation of the resource and better management of the stock and that DFO should maintain its current research activity level in the future.

Due to the uncertainty of the future funding of key elements of current snow crab research, the Area 12 industry has unanimously agreed to financially support the current level of snow crab research and assessment activities being conducted by DFO in the southern Gulf. A joint industry/DFO agreement on snow crab stock assessment and related research in the Gulf of St. Lawrence was signed for a 5-year period by Area 12 and 25/26 crab industry. However, we still face the challenge of bringing the other participants (*i.e.* inshore crab fishers from Cape Breton) together into this partnership.

FUTURE FISHERIES MANAGEMENT

Research projects conducted between 1990-1995 enabled DFO Gulf biologists to estimate not only an accurate level of commercial biomass one year in advance but also to predict a long term stock trends. A recent revision of the stock status and an in-depth data analysis together with biological observations clearly demonstrated that the long-term stabilization of the fishery cannot be anticipated for the southwestern Gulf of St. Lawrence snow crab stock. This fishery entirely depends on the arrival and strength of the recruitment pulse. The current high biomass level is exclusively due to the arrival of a good recruitment of juvenile crabs (about 30 mm CW) which were first observed in the 1988 survey. Once the recruitment of juveniles appears in the trawl survey catch, it takes approximately 5-6 years for the recruitment to enter the commercial fishery. A new recruitment pulse in this fishery has just been observed this year (this is the second pulse since 1988), which suggests that there will not be a reasonable recruitment level to sustain the current catch level after the 1995 season and that a stock decrease will persists until 1998-1999.

For snow crab, given the biological advice that there is a terminal moult, that the fishery is a recruitment one, that a pulse fishery would appear scientifically justifiable and that poor recruitment is forecast for the fishery for 3 years or so after 1995, the industry and fisheries managers have been left with difficult decisions. Despite the scientific advice, there is the reality that in 1994 and likely for a few years to come, that many fishers who cannot fish because of the closure of the groundfish fishery want to be able to fish and take advantage of the windfall profits that are currently occurring in the crab fishery. In 1994, DFO chose to take the long term approach and not issue additional licenses. This was in line with its general policy of restricting effort on established fisheries and discouraging any additional effort. In 1994, the Area 12 industry chose to not undertake a pulse fishery of a two year duration but rather spread their planned effort over the next several years at a relatively low exploitation rate so that the fishery could be sustained. A relatively low level of exploitation (*i.e.* 31-40%) enabled the depressed stocks to grow faster when a strong recruitment pulse was present. However, the same approach cannot be used when the recruitment to the fishery becomes poor as being forecasted after 1995. An appropriate exploitation rate needs to be re-evaluated by fisheries science, management and the industry based on the strength and timing of the future recruitment.

The snow crab industry is also aware of the immense pressures to share wealth. The cod closures and the record high crab prices are evident and magnify the situation for both snow crab fishers and non-licensed fishers. To this end, the Area 12 snow crab fishers offered to harvest 2,000 t of snow crab in 1994 and to contribute 5.3 million Canadian dollars to a fund which is administered by groundfish only license holders in the southern Gulf. It is these fishers who are the most adversely affected by the cod moratorium. In addition, snow crab fishery in the Areas 12 and 25/26 are only the second domestic fishery to contribute to at-sea observer control (the northern shrimp fleet is the other). These measures are as much a reflection of the maturity of the fishers as an industry as it is a consequence of the current levels of income. Discussion are ongoing regarding measures for 1995 management of all crab zones across the southern Gulf.

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