Canadian Stock Assessment
Proceedings Series 97/16

Évaluation des stocks canadien
Série des procès-verbaux 97/16

Snow Crab Harvesting Strategies
Gulf Fisheries Centre, Moncton, New Brunswick
January 29, 1997

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November 1997

Fisheries and Oceans Science
Pêches et Océans

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Abstract

During recent snow crab stock assessments the need for a general review of snow crab harvesting strategies was identified. This review is based on a series of discussions among DFO scientists and fishery managers during late 1996 and early 1997. Major conclusions are:

- Even though exploitation rates which would be considered high for other species can be sustained in the snow crab fishery (since only one fraction of the population, large males, is harvested), exploitation rates on snow crab stocks should be limited. No strict guideline for exploitation rate can be provided. A range of exploitation rates could be consistent with conservation at any given time.
- Conservation would be served by releasing legal-size "adolescent" (those with small claws) animals at sea. However it does not appear practical at this time to require release of adolescent crabs.
- Returning soft-shelled crab to the sea is very important for conservation but careful handling of animals to be released is essential.
- Although snow crab populations can sustain relatively high exploitation rates under the right conditions, this is only true in the context of responsible approaches to discarding: careful handling of animals to be returned to the sea, no high-grading (discarding of legal-sized marketable animals which are of lower market value). If responsible fishing is not practiced, exploitation rates should be lowered accordingly.

Résumé

Lors des évaluations récentes de ressources de crabe des neiges le besoin d'une revue générale des stratégies de pêche pour le crabe des neiges s'est fait sentir. Cette revue est le résultat de discussions impliquant des chercheurs et des gestionnaires des pêches du MPO à la fin de 1996 et début de 1997. On a conclu que:

- Même si des taux d'exploitation qui seraient considérés comme très hauts pour d'autres espèces peuvent être soutenus par les stocks de crabe des neiges (vu qu'une fraction seulement de la population, les grands mâles, est pêchée) les taux d'exploitation sur les stocks de crabe des neiges devraient être limités. On ne peut pas fournir de lignes directrices spécifiques quant aux taux d'exploitation appropriés. Une gamme de taux d'exploitation pourraient être appropriée pour la conservation à tout moment donné.
- Le retour à la mer d'animaux "adolescents" de taille légale (ceux possédant de petites pinces) aiderait à la conservation de la ressource. Par contre il ne semble pas pratique à l'heure actuelle d'exiger le retour à la mer de crabes adolescents.
- Le retour à la mer de crabes à carapace molle est très important pour la conservation mais il est essentiel que les crabes qui seront retournés à la mer soient manipulés avec soin.
- Les populations de crabe des neiges peuvent soutenir des taux d'exploitation élevés, mais seulement dans le cadre d'une approche responsable à la remise à l'eau: il faut que les animaux qui seront remis à l'eau soient manipulés avec soin, et il ne faut pas pratiquer le rejet en mer d'animaux de taille légale et aptes à être vendus à cause de leur faible valeur marchande. Si la pêche responsable n'est pas pratiquée, le taux d'exploitation devrait être réduit.

Preface

This document results from a series of discussions among DFO scientists and fishery managers during late 1996 and early 1997. During snow crab assessments early in 1996 and during the 1996 fishing season the need for a general review of snow crab harvesting strategies was identified, based on the intense interest in harvesting this species, on the anticipated decline in abundance throughout the Atlantic zone, and on the availability of new biological information.

The process which resulted in this document was as follows. A teleconference of DFO snow crab biologists was held August 19, 1996, to discuss recent biological information and possible implications for harvesting strategies. Following review by participants, the results of the teleconference were written up as a Discussion Paper. The Discussion Paper was the basis for discussions at a meeting of fishery managers and scientists at the Gulf Fisheries Centre, Moncton, NB, January 29, 1997. Following wide review the results of the meeting were summarised in the present document.

The following participated in the preparation of this document:

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Introduction

Considerable new biological information on snow crab has become available in the past several years. Recent studies indicate that recruitment is characterised by successive periods of good and poor recruitment, of several years' duration (recruitment "waves" and "troughs"), and have confirmed that terminal moult is characteristic of this species. An intrinsic cycle of abundance of duration around 8-10 years has been suggested to be characteristic of the species. New information is now available on fecundity and fertility in exploited populations, and on environmental conditions as they may relate to abundance of snow crab.

Pressure to harvest snow crab is high and stocks throughout Atlantic Canada are presently in a declining phase of the quasi-cyclical abundance pattern. A number of issues related to management and conservation of snow crab stocks are regularly raised in discussions leading to development of management plans. For example, the appropriate approach to harvesting snow crab in the current situation of declining abundance and increasing age in the harvestable population has been discussed; srategies ranging from the aggressive (increase exploitation rate to harvest animals which might otherwise be lost to natural mortality) to the conservative (keep harvests low in the face of declining stocks) have been considered.

This document reviews issues raised in recent management discussions in light of recent additions to biological knowledge.

Management Measures in Effect

Although no specific management objectives or definition of conservation exist to guide snow crab fishery management, the general objectives applicable to other fishery resources are applicable to snow crab: resource conservation (for example protection of spawning capacity, avoidance of resource waste), attainment of sustainable social and economic benefits.

Conservation of the snow crab resource is ensured through a variety of measures including size limits, prohibition on harvesting females, mesh and effort regulations, harvest limits, soft-shell closure protocols. Fishermen contribute to conservation by voluntarily discarding legal-size soft shelled animals. The combination of a number of measures is considered a particularly strong approach to resource conservation.

Many of the measures noted also have social and economic benefits by allowing yield to be spread among years and by ensuring that a high level of catch is taken from the available resource, consistent with conservation requirements.

Environmental conditions and abundance

In light of what is currently known about snow crab biology, it would be expected that abundance at a given moment would result from the apparent intrinsic abundance cycle (dependent on regular variations in recruitment) (Sainte-Marie et al. 1996) and from long or short-term variations in environmental factors which would affect habitat availability or stock productivity.

Although it is not possible to clearly prove cause and effect, it is noteworthy that the high current levels of snow crab abundance are associated with environmental conditions favorable for snow crab.

Following several years of anomalously cold conditions, the area of bottom covered by temperatures suitable for snow crab (approximately -1.5 to +5 C) increased substantially in the early 1990's in most continental shelf areas of Atlantic Canada. Snow crab typically are associated with the cold intermediate layer, a layer of cold water found at intermediate depths (50-150 m) over much of the Canadian Atlantic. During the cold conditions of the early 1990's the thickness of the CIL has been greater than normal (DFO 1996a). The most recent (1996) data show that temperatures are moderating and the extent of bottom covered by the CIL is contracting on the Grand Banks and Scotian Shelf; however this warming has not yet affected the Gulf of St. Lawrence (Drinkwater 1997).

The abundance of cod, a predator of snow crab, has been at very low levels over wide areas where snow crab is found. The impact of the decline of cod and other groundfish on snow crab abundance is difficult to quantify. Studies of cod stomach contents show that cod prey on snow crab mainly at sublegal sizes (Waiwood and Elner 1982; Bailey 1982; Robichaud et al. 1991) but the quantities consumed and how these might vary with changes in cod abundance, crab abundance, and temperature changes have not been reliably estimated under recent conditions. If reduced predation has had an impact it would probably be to increase survival of juvenile crab to the harvestable stage.

Considerable information, some anecdotal, exists to indicate that snow crab have been very abundant in recent years. Stock assessments (DFO 1996b, c, d) show that catch rates and abundance have been very high during the early 1990's. Off Newfoundland the areas where commercial concentrations of snow crab exist have expanded greatly since the early 1990's with fishermen indicating that in areas where they could not catch crab in the mid or late 1980's there are now commercial concentrations. Trawl surveys in the northern and southern Gulf of St. Lawrence have shown that both densities and areas of high density increased in the early 1990s, while two surveys in the mid-1990's off Newfoundland and Labrador showed snow crab to be widely distributed and very abundant. Although it is known that snow crab undergo large natural fluctuations in abundance in a quasi-cyclical pattern, and that the pattern was peaking in all areas of

the Canadian Atlantic in the first half of the 1990s, it would appear that the overall level of abundance and the overall range of concentrations of crab have been higher than during previous peaks in the cycle.

It is generally considered that the recent cold environmental conditions and low levels of cod and other groundfish populations are anomalous, not part of normal environmental variability. If this proves to be true, a return to normal conditions could coincide with an overall decrease of the level of snow crab abundance. Management of the snow crab resource should take this possibility into consideration in the coming years.

Careful monitoring of snow crab stocks and environmental conditions will be particularly important in the coming years to test the hypothesis that crab abundance is related to these environmental conditions. In addition laboratory studies of the effect of temperature on life history processes (growth, maturation, egg incubation) would be useful.

Exploitation Rates and Harvest Controls

Exploitation rate on the whole stock

Controls on the amount of snow crab harvested have sometimes been considered of secondary importance for snow crab conservation, since many other measures are in effect to support conservation. Indeed it has been suggested that harvesting 100% of the legal sized male component would have little effect because enough sublegal males and females would be protected by the size limit to maintain population reproductive capacity.

Exploitation rate (the proportion of harvestable animals in a stock removed by the fishery in a given season) is often used as a reference in discussions of snow crab harvesting. Data on population abundance and catch are needed to establish an exploitation rate. More general discussion of exploitation intensity is possible even without such information; in areas where abundance estimates are not available it is still useful to consider whether exploitation should be intensive or more conservative.

CAFSAC based harvesting advice on a target exploitation rate of 50-60% from Leslie analyses (see for example Anon. 1984). No target exploitation rate has been referred to in recent assessments, even where information on biomass is adequate to estimate exploitation rates (DFO 1996). In the southern Gulf stock total allowable catches (TACs) have been equivalent to nominal exploitation rates of 34-38% in 1993-96 (DFO 1966b).

Essentially 100% of females have been observed to carry eggs over the wide range of abundance seen in the past two decades and despite apparently high exploitation rates in some

areas. Because no significant variation in female fertilisation rate has been observed, high exploitation rates have not been considered a threat to reproductive capacity (eg Anon. 1984).

Assessing reproductive potential on the basis of eggs carried may be misleading, however. Recent studies (Sainte-Marie and Carrière 1995)have shown that at the temperatures around 0° C characteristic of snow crab habitat, infertile eggs take several months to be shed or to become visibly distinct from fertile eggs, so surveys soon after the mating season could provide faulty information on fertilisation rates. In some years, number of unfertilised eggs borne by females can be high (Carrière 1995).

Recent information suggests that removing too many legal-size large-clawed males from the population might have an impact on population egg production capacity. A study in Newfoundland (Fogo Island to Downing Basin) indicated that, at a given size, fecundity of females in heavily exploited areas was 15-20% lower than in unexploited areas (Taylor 1996). Because recruitment occurs in pulses, and females from a recruitment pulse mature sooner than males, abundance of females will peak several years earlier than that of large males and large changes in adult sex ratio can occur as a pulse moves through the population (Sainte-Marie et al. 1996). This is a natural phenomenon in snow crab populations but fishery removals of large-clawed males could accentuate these fluctuations, in which case there could be inadequate numbers of males to fertilize all females, possibly affecting population fertility.

The northern Gulf information has not yet been published and estimates of potential effects on population fertility have not yet been made. In light of the studies cited, the earlier consensus view that harvesting most legal size males from a population would have little impact on reproduction should be reconsidered. However available information does not provide an adequate basis to determine safe limits on removals of legal-size males. The relationship between parent stock size and subsequent recruitment is not known for snow crab, so the level at which reproductive capacity must be maintained to ensure subsequent recruitment is unknown. However precautionary management would require that the above factors be considered in establishing harvesting strategies for snow crab.

Additional information on the stock-recruitment relationship and on production of fertile eggs as influenced by sex ration would be required to develop any objective reference points based on spawning biomass for snow crab populations.

Exploitation rate and population fractions

The task of defining biologically appropriate harvesting rates is complicated because there are several categories of animals in harvested populations (adolescent and adult, soft and hard shell, new and old shell, undersize and legal size), each with its own dynamics and a specific level of market preference. If exploitation rates are allowed to become very high, increased handling of

those fractions of the population which are normally returned to the water (eg soft shelled, sublegal males) could occur, leading to an increase in non-catch mortality and lower yields in future. By increasing handling mortality on sublegal large-claw (adult) males which may be important for mating when abundance of large males is low, high exploitation rates could also affect reproductive potential.

It has been suggested that exploitation rate could be increased when proportion of old-shelled animals is high, since these animals will be lost to natural mortality if not harvested. Theoretically, if harvesting could effectively be targetted on old-shelled animals, this might be worth considering. In reality such a strategy is likely to have negative conservation consequences. It is generally impossible to target fishing on old-shelled animals, so that new-shelled animals would also be subjected to the higher exploitation rate unless they were discarded, which is unlikely. If high-grading (discarding of old-shelled animals or other legal-sized animals with low market value) occurs, the higher exploitation rate would actually be targetted to the new-shelled fraction of the population, greatly increasing removals of these and not having the desired impact on reducing abundance of old-shelled animals. Maintaining new-shelled animals in the population is necessary since their presence would help to damp future fluctuations in catch and they will contribute to the reproductive pool in the future.

Exploitation rate and geographical divisions of a single stock

There is little concrete information on stock definition in snow crab in the Canadian Atlantic. The southern Gulf of St. Lawrence is considered to represent a single stock area (DFO 1996) but relationships between this "stock" and others, and the definition of stocks in other areas is not known. Snow crab larvae live planktonically for 3-5 months so there is potential for interchange between areas. Population abundance fluctuations are generally synchronous in the different Canadian Atlantic areas but whether this is because there is a single "stock" or because stocks are responding to similar conditions is not known.

Most snow crab "stocks" or fishing areas are divided into subzones which represent only part of a stock. There is no clear information available at present to suggest that there would be adverse biological consequences of harvesting a higher proportion of available biomass in a subzone than in the stock as a whole. However, there is the possibility that genetically distinct sub-populations may exist which should be individually protected. In addition it is known that fractions of the population (eg old-shelled animals, young animals) can occur in separate patches within the whole population. Accordingly, it may be an appropriate precautionary approach to spread harvesting over the whole population distribution.

It is critical to ensure that the exploitation rate on the stock as a whole is considered in establishing conservation measures. Any impact of very high removals in peripheral or small subzones on the stock as a whole may be limited if exploitation rate on the stock as a whole is

maintained at a moderate level. It appears that removals of the order of 60-70% of available biomass in coastal zones in the southern Gulf have had little impact on dynamics of the whole stock (DFO 1996b). A recent 5-year co-management agreement in Crab Fishing Area (CFA) 19 (part of the southern Gulf stock area) allows fishers to set the annual removal rate in a range of 40-50%; outside this range agreement with DFO is necessary.

Strictly speaking the term "exploitation rate" should not be applied to subzones of a stock, but only to the stock as a whole. "Percent removal of available biomass" may be a better term when speaking of subzones.

Assessment, monitoring and fishery management may be improved by spreading catches, since this would allow obtaining CPUE and biological data on a small geographical scale. If distinct sub-populations or population fractions would be adversely impacted by diferential exploitation, spreading catches over the whole stock area would help to maintain stock diversity.

Summary and conclusions

Exploitation rates at the level of the whole stock or fishing area should be limited, even though exploitation rates which would be considered high for other species can be sustained in the snow crab fishery, because only one fraction of the population (large males) is subject to exploitation. Excessive exploitation rates could accentuate natural population fluctuations, leading to periods of low or no catch when recruitment is low, and may prove to have an impact on reproductive potential. Excessive exploitation rates might also lead to increased incidence of soft-shelled crab, by increasing dependence on incoming recruitment, and can lead to increased incidental mortality on animals returned to the water. On the other hand, exploitation rates that are set too low can lead to high proportions of dirty crab, high-grading (release of legally caught animals which have lower market value), and loss of yield to natural mortality.

No strict guideline for exploitation rate can be provided. A range of exploitation rates could be consistent with conservation at any given time. Exploitation rate should be considered in developing annual harvesting plans, taking into consideration factors such as stock status in relation to recruitment, production dynamics of the specific area or stock, characteristics of the fishery and of fishermen.

Although there is no clear biological information to indicate that spreading catches over a stock area would have conservation benefits, this can provide fine-scale information for assessments and may represent a precautionary approach to conserving stock diversity.

Social and economic factors may also be important in setting TACs. While these may be outside the realm of conservation strictly speaking, good social and economic performance of the fishery is conducive to conservation, since under these circumstances responsible fishing is likely

to be favoured by harvesters. In most fisheries in Atlantic Canada year-to-year stability of catch is considered important in order to maintain markets; in this case exploitation rate or exploitation intensity might be adjusted to fluctuations in abundance to smooth out these natural fluctuations. Such a strategy would imply taking a catch less than the maximum permitted by short-term conservation requirements in years of high abundance, but should not compromise conservation requirements in years of low abundance if catch limits were set at appropriate levels. Information for implementing such a strategy (in particular knowledge of conservation requirements at all times in the abundance cycle) is still incomplete but is improving.

In populations for which biomass estimates are available, the exploitation rate can be estimated or set as a target. In many snow crab populations, information on biomass is not available, therefore setting a TAC based on a target exploitation rate is not possible. The considerations above should be useful in setting TACS whether these are based on a target exploitation rate and estimated biomass, or on a more general perception of population status and the appropriate harvesting intensity.

Protection of Legal-size "Adolescent" Male Crab

The question of whether legal-size "adolescent" crab (those with small claws) should be specifically protected has been raised. Not having gone through terminal moult these animals have considerable growth potential and probably have limited capacity to contribute to reproduction. Although normally most legal-size adolescent crabs would be protected by measures for protecting soft shelled crab (since most small-claw animals are soft shelled during fishing seasons), proportions of hard-shelled legal size adolescents ("skip molters") have been relatively high in some areas recently. A strict interpretation of the Atlantic Fishery (General) Regulations (which prohibit discarding any legally-caught fish) would lead one to conclude that discarding of legal-size adolescent animals would be illegal.

It would be biologically desirable to protect adolescent crabs, since their considerable growth potential (especially in weight) could help to damp future population fluctuations due to recruitment pulses. Experienced fishers can recognise adolescent males and it might be possible to develop gauges or other techniques for identifying them. Fishers in some areas recognise the advantages of protecting adolescent animals.

There would be significant practical difficulties in making the protection of adolescent crabs mandatory. Inexperienced fishers might not recognise them well and it might be difficult to develop a gauge sufficiently precise and unequivocal to be used for enforcement purposes. Sorting the catch for adolescents to discard might increase total sorting time so that discarding of soft shelled and undersize animals would be delayed, increasing mortality on those fractions. In some areas or at some times adolescents may make up a significant part of the legal size catch so there

could be a desire to land them. Also regularising discarding of legal-size adolescent animals might be seen as increasing opportunities for discarding of old-shelled animals (high-grading) which is undesirable from a conservation point of view.

In conclusion, conservation would be served by releasing legal-size adolescent animals. From a biological point of view, discarding of adolescent crabs should be allowed, so fishers could contribute to conservation in this way without infringing the regulations. However it does not appear practical at this time to require discarding of adolescent animals. A protocol has been developed in Laurentian Region by fishers, scientists and managers which will allow discarding of soft-shelled animals (which include most of the adolescent animals) and this approach might be considered elsewhere.

Protection of Soft-shelled Crab

At present there is a policy in most Atlantic snow crab fishing areas of closing fisheries when a ceiling proportion (typically 20%) of soft-shelled crab in catches is reached. This is not written into regulations and is not applied in some areas, such as eastern Nova Scotia where catches commonly include a high percentage of soft crab. This policy is applied in different ways in different regions, ie in some areas it is applied to subzones which can be reopened during the season once the problem is no longer present, while in others it applies to the whole zone which remains closed until the following year.

Releasing soft-shelled crab at sea, while technically not permitted according to a literal interpretation of the general prohibition on discarding in Atlantic fisheries, is tolerated in all areas (the no-release rule on soft crab was enforced in the southern Gulf in 1995 only).

Whether protection of soft-shelled crab is a conservation measure, as opposed to an economic measure, has been questioned. Protection of soft-shelled crab is an important conservation measure. Soft-shelled animals that are not caught or returned to the sea have an opportunity to contribute to the reproductive pool as well as to become available for capture later when the shell has hardened and meat yield and quality have increased considerably. Protection of soft crab is particularly important since high incidence of soft crab is typical of the early phase of an increase of population abundance due to a recruitment wave. Landing soft crab represents significant resource waste since meat yields and quality are higher in hard shelled animals.

Unrecorded mortality on soft crab could contribute to decreasing accuracy and precision of resource assessments, which depend critically on accurate records of removals from the stock. This represents another reason for careful handling and return of soft crab to the sea.

Fishermen generally support protection of soft-shelled animals. Avoiding capture of soft-

shelled crab by adjusting seasons or using closure protocols is an effective conservation measure, as is discarding of soft crab.

Although there is no biological basis for the 20% figure in soft-shelled closure protocols (this was originally established by consensus in industry), there is no biological basis for recommending any change to this.

Discarding of soft-shelled crab at sea is very important for conservation but careful handling of animals to be discarded is essential. Crabs should be handled such that loss of limbs, exoskeleton damage (breakage and punctures) and exposure to wind, heat and extreme cold is minimised, and should be returned to the water as quickly as possible. This is particularly important during the summer months when dessication and heat stress are a potential factor in mortality. When soft-shelled crabs are discarded carefully, discarding mortality can be low. Depending on conditions, studies have estimated discarding mortality at about the same level as that for hard-shelled crabs, less than or equal to 32% (Taylor et al. 1989) or around 14% (Dufour et al 1997). Fishers should take the necessary measures to ensure that discarding is done appropriately, in the interests of ensuring a healthy resource in the future.

Responsible Fishing Practices

Resource conservation depends upon fishers' harvesting in responsible ways. The importance of careful handling for fractions of the population to be discarded has been emphasised above. Discarding legal-sized crab because of market preferences for larger animals or for new-shelled animals ("high-grading"), which has apparently occurred in some areas in recent years, can have negative biological consequences. Once crabs have gone through terminal moult, their carapace continues to age; if legal-size animals are discarded because they are smaller than the market prefers, or because their shell is older than required by the market, they will simply continue to age and will eventually succumb to natural mortality. Large-scale discarding of such animals and targetting a preferred fraction of the population would have the effect of increasing the exploitation rate on the preferred fraction. Selectively removing newer-shelled larger males could increase the extent of population decline in the future and could threaten future reproductive potential since these animals will be the most successful at mating in future.

Responsible fishing practices become increasingly important as exploitation rate increases. High exploitation rate increases the probability of repeated handling of the non-catch fraction of the population. High-grading can focus high exploitation rates on a single important fraction of the population. Although snow crab populations can sustain relatively high exploitation rates under the right conditions, this is only true in the context of responsible approaches to discarding. If responsible fishing is not practiced, exploitation rates should be lowered accordingly.

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