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Implications on assessment of the British Columbia prawn populations with the adoption of a quota management system

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Abstract

The prawn trap fishery in British Columbia is currently managed to prevent both growth and recruitment overfishing. Growth overfishing is controlled through size limits and manipulation of fishery opening times, while recruitment overfishing is managed using a fixed escapement policy. Implementation of this policy is achieved by inseason at-sea monitoring of the index of spawner abundance (based on catch per trap), and closures are implemented when this index falls below a set minimum monthly index.

During the last three years fishing intensity in the prawn trap fishery has risen dramatically, with the 1998 fishery lasting only 93 days coastwide. It has been suggested that a less intense fishing pattern over a longer period would be favourable, and fisheries managers have been considering the possibility of adopting a quota type system for prawns and abandoning the current fixed escapement framework.

This paper discusses the critical problems and questions that must be answered in order to develop a quota management system, such as determining the population size, the spatial scale of the population, and how the population responds to exploitation, and considers methods of addressing these problems. It is noted, however, that many such methods may prove difficult to implement for prawns and that the data and analytical requirements would be substantial, making assessments of the prawn stocks highly expensive.

The paper concludes that entering into a quota system for prawns would be a very expensive and time-consuming undertaking, considering the data and analytical requirements. The problems that the prawn fishery is facing may need to be further examined to determine whether there are alternatives other than a quota management system.

Résumé

La pêche au casier de la crevette de la Colombie-Britannique est actuellement gérée de façon à éviter la surpêche de la croissance et du recrutement. La surpêche de la croissance est contrôlée par l’imposition de limites de taille et la modification des dates d’ouverture, tandis que celle du recrutement est géré par l’application d’une politique visant la protection des géniteurs. Le respect de cette politique est assuré par des contrôles en mer, en cours de saison, de l’indice d’abondance des géniteurs (fondé sur les captures par casier) et des fermetures imposées lorsque l’indice tombe en deçà d’une valeur mensuelle minimale établie.

L’intensité de cette pêche s’est accrue de façon considérable au cours des trois dernières années de sorte que la pêche de 1998, à la grandeur de la côte, n’a duré que 93 jours. Il a été suggéré qu’une pêche moins intense répartie sur une plus grande période serait préférable et les gestionnaires des pêches ont examiné la possibilité d’adopter un régime par quotas pour la crevette en remplacement du régime actuel prévoyant la protection fixe des géniteurs.

Ce document discute des problèmes et questions critiques auxquels il faut trouver des solutions pour l’élaboration d’un régime de gestion par quotas, notamment la détermination de l’importance de la population, sa répartition spatiale et sa réaction à l’exploitation, en plus d’examiner des méthodes permettant de trouver des solutions. Il est signalé que plusieurs de ces méthodes peuvent s’avérer difficiles à mettre en œuvre pour la crevette et que les besoins de données et d’analyses seraient appréciables, ce qui rendrait l’évaluation des stocks de crevettes très coûteuse.

Il est conclu que l’adoption d’un régime de gestion par quotas pour les crevettes serait très coûteux et exigerait beaucoup de temps, étant donné les besoins en données et en analyses. Les problèmes de la pêche de la crevette pourront exiger un examen plus poussé qui permettrait de déterminer s’il existe d’autres régimes que celui de la gestion par quotas.

Request

Industry has asked fisheries managers to consider adopting a quota type management system for the prawn trap fishery. This paper was prepared to discuss of some of the implications and assessment requirements that would arise from such an undertaking.

Key Biological Considerations

To evaluate management options, it is important to remember some key biological information about the animal being exploited. The prawn is a protandrous hermaphrodite which functions initially as a male and then as a female in its final year of life. Prawns are short-lived with a maximum life span of four years. The fishery targets on the animals in the final two years of their lives (as age 2+ males and age 3+ females). Once a female has spawned and is carrying eggs on her abdomen, she will no longer moult and grow. During this phase of life the overall biomass of females declines due to losses from natural mortality.

History of the Present Management Strategy for the Prawn Fishery

The prawn fishery in British Columbia is presently managed to meet two biological objectives: to prevent growth overfishing and to prevent recruitment overfishing.

Growth over-fishing is controlled through a combination of size-limits and manipulation of the opening times. Boutillier (1984) recommended an increase in age at first capture to 25 months based on a Ricker yield per recruit analysis. Boutillier (1985) estimated that a coast-wide size limit of 30.0-mm carapace length (CL) would approximate this age at first capture. It was also noted that adopting a single coast-wide size limit did not take into account variations in growth rates between areas and between years. In 1996 and 1997, at the request of the industry, the size limit was increased to 32.0 mm and then to 33.0 mm CL (Morrison et al. 1998).

Since 1979, **recruitment over-fishing** for the commercial prawn fishery has been managed in British Columbia using a fixed escapement policy. This fixed escapement management system was developed based on empirical data collected from a series of assessment cruises carried out in the early to mid-1970's in Knight and Kingcome Inlets, the largest prawn producing areas on the coast of British Columbia (Boutillier 1988, 1993). The target spawner index (known as the Minimum Monthly Index, or MMI) was set at a biological reference point (BRP) of 1 female spawner per trap in March (the month of egg hatching) using a Pardiac trap soaked for 24 hours. This BRP has been modified in more recent years to reflect the change in gear to larger, more effective traps and is now set at 1.7 females per trap in March using a SAK trap soaked for 24 hours. This BRP level was established by taking survey indices of the mean number of female spawners per trap in March from areas with consistently good production. Minimum monthly spawner indices (MMI) for the months prior to March were back-calculated using an annual natural mortality estimate of 1.3 (Boutillier 1987).

The assumption in the development of this management strategy was that production characteristics for prawns were stable over time. That is to say, since historically harvestable quantities of prawns were produced at this spawner index, they would continue to be produced as long as the spawner index level was maintained. There were a number of assumptions and obstacles that needed to be addressed to implement this type of management system.

The first problem was that the index used to estimate escapement was based on a measurement of effort that had remained constant over time and did not reflect the methods of fishing used by the commercial industry which are changing constantly. To address this issue, a process of gear testing to statistically evaluate the effective fishing effort of various fishing methods was, and is, routinely conducted. The results of these gear testing studies are used to develop correction factors to be used in estimating effective fishing effort. In 1989, the MMI system was updated to a set of indices that better reflected catches obtained using some of the more recent fishing technologies (Boutillier 1988).

The second shortcoming was fixing escapement targets based on historical production of a single area did not allow the management to be tuned to specific spawner/recruit production dynamics to maximise production potential. Boutillier (1993) compared the productivity characteristics of the original spawner index with the peak productivity from a spawner/recruit relationship developed from data collected in the Howe Sound experimental prawn fishery. The results of the analysis indicated that for Howe Sound, peak production would be achieved if there was a 3-fold increase in the target spawner index. It was recognised in the paper that the spatial and temporal limitations of the data were such that the only recommendation that could be made was to start a probing management action, which systematically increased the escapement target index criteria over a broad range of areas and fisheries. Starting in 1996, as part of a strategy to rebuild spawning stocks, more conservative closure criteria were implemented. This new criteria meant that, closures were implemented when the sample mean was at or below the target MMI. Prior to 1996, closures were only implemented when the upper 75% confidence interval from the sample was at or below the target MMI.

In general, a fixed escapement management system tends to give a maximum yield but is subject to the largest variations in catch (Zheng et al. 1993). It is also felt that this type of system is logistically difficult to implement. For example, salmon fisheries must take place before the escapement target on the spawning grounds can be assessed (Eggers 1993). This situation arises in salmon because the quality of the product is reduced substantially as the salmon nears the spawning grounds.

For the prawn fishery the logistical problems seem to be addressed by monitoring fixed escapement targets concurrently with enforcement of on-grounds effort controls. Using industry-funded observers, commercial catches are sampled at the time the fishing gear is retrieved. The at-sea monitoring of the fishery provides sample spawner abundance indices from a number of traps per string and a number of strings over a broad area. The mean index of spawner abundance from the samples taken in any area within a week is then compared to an escapement threshold, minimum monthly index (MMI) of females/trap (Boutillier 1987). Closures are implemented in statistical management areas or subareas when the estimated sample mean of female spawner per standard trap is less than or equal to the MMI. Once a closure is implemented it remains in effect until the following April. This protects the remaining female spawning cohort until they have spawned and carried their eggs through to the end of the larval hatching period.

In 1988, because of the inability to monitor the fishery in the winter months, a coast-wide winter closure was implemented. The ability to provide inseason sampling and monitoring of the commercial prawn fishery increased greatly in 1995 with the implementation of the trap-limitation program management fee. Spawners-index monitoring is now conducted inseason using eleven Prawn Charter at-sea Observers, who are contracted to ensure compliance with the trap-limitation program. The spawners-index sampling encompasses examination of sex and cohort composition of the commercial prawn catch on a per trap basis. The number of female spawners (3+ yr.) per trap was standardised to trap types. Observers try to sample traps which have been soaked overnight, to minimise biases that may occur with very short soaks (which tend to underestimate the female index) and very long soaks (which tend to overestimate the female index). The standardised index is compared to the MMI, which has been adjusted to account for the natural mortality that will occur until egg hatch (Boutillier 1987). In the last 4 years, fishing intensity has risen dramatically. Fortunately the observer sampling has been able to keep pace with this increase and has allowed the managers to take quick action on areas as they are fished down to the spawner index cut-off levels. As a result of this increased effort, the coast-wide fishing season has become shorter, falling from 230 days in 1994 to 93 days in 1998. The landings have also increased substantially over this same time frame as can be seen in Figure 1 below.

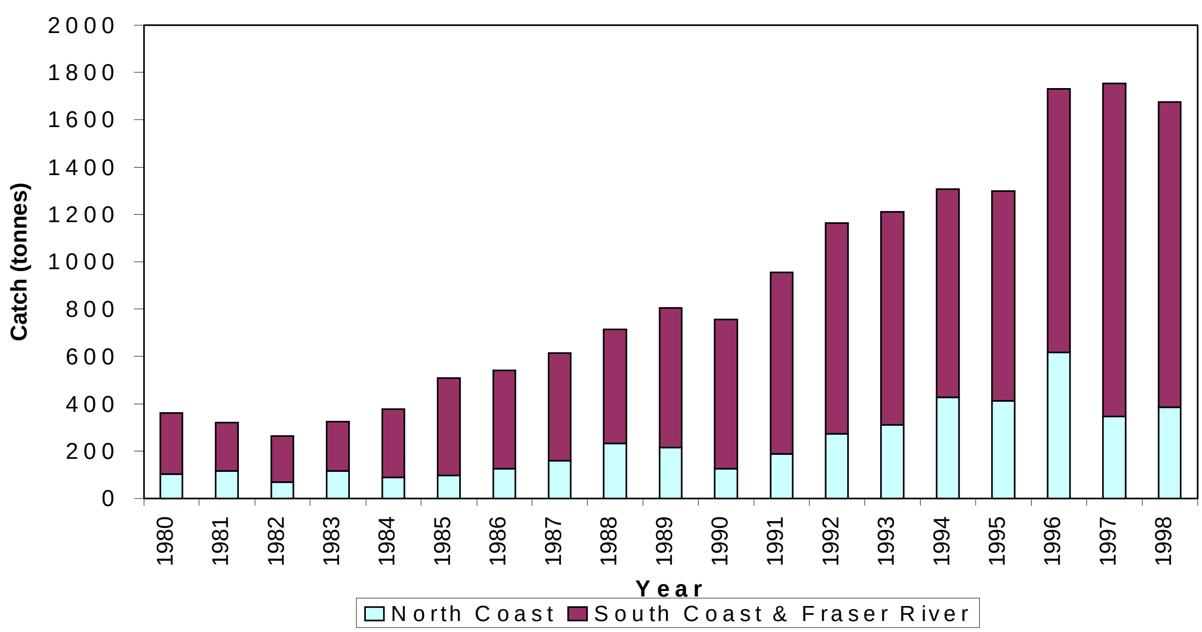

Figure 1. Catch (in tonnes) in the prawn trap fishery in British Columbia, 1980 to 1998.

New Management Strategy

At present, two harvest attitudes are prevalent in the prawn trap fishery. Some fishers prefer the current fishery, which is fully competitive, intense, of short duration, and promotes harvest prior to growth. Other fishers favour a less intense fishing pattern over a longer period, with the intention of optimising growth and markets. Increasingly, individual quotas have been discussed within the industry as a possible way for all fishers to meet their personal objectives, regardless of which fishing style they choose to employ on an individual basis. In addition, there are concerns over the sustainability of this fishery. Some fishers fear that if effort continues to increase as in recent years, the current management system may be overwhelmed to a point where managers would not be able to respond quickly enough to close areas before overfishing occurred. Throughout the commercial prawn trap fleet, there is a desire for greater certainty for personal planning. With all of these factors in mind, industry has asked fisheries managers to consider the possibility of a quota type system for the prawn trap fishery.

Quota systems can be implemented in two ways: either through a fixed exploitation rate (also known as a constant harvest rate) or a fixed quota system.

Zheng et al. (1993) describes the benefits and drawbacks to these two types of quota systems. A fixed quota system generates stable yields however the yield must be low to sustain the population. This type of system has generally fallen out of favour (Zheng et al. 1993).

A constant harvest rate system generates a good balance between average yield and yield variations. There are a number of proponents for this type of system, who feel it is a strategy that is robust to population fluctuations, is easily understood, is practical to implement and avoids unnecessarily high variation in catch (Walters and Parma 1996). The main criticism to this approach is related to implementation when using stock assessment data that is known to be inaccurate (Eggers 1993) and the high risk of depensatory effects. This system by itself may not be able to protect a population that drops to a low level. Zheng et al. (1993) point out that a variation on this method is to combine a fixed harvest rate with a critical conservation limit threshold which halts all fishing when the population drops below a critical low level.

For both quota management systems, the questions that must be answered are very similar: What is the population size? What is the spatial scale of the population? How does the population respond to exploitation?

How can the population size be determined?

The challenge with a quota system is to provide reliable estimates of population size prior to the fishery. Due to the selectivity of the fishery and the biology of the prawn, this means being able to estimate the size of the stock of age 2+ and age 3+ animals at the beginning of the season.

Hilborn and Walters (1992) describe the four general approaches to estimating total stock size. These include: 1) direct counts and surveys; 2) reconstruction of historical catch, effort, age and size data (virtual population analysis (VPA) and catch-at-age analysis); 3) mark recapture and change in ratio methods; and 4) depletion estimates.

Conducting surveys requires the collection of information on the density of animals that can then be mapped over the entire area that the population occupies. With trap surveys the major problem is providing accurate density estimates because of the difficulty of determining the effective fishing area of a trap. Without this density estimate, the total population size within an area can not be calculated, and all that can be provided is a standardised relative index of abundance.

Prediction of the stock size by reconstruction of the previous year's catch composition may work in VPA and catch-at-age models generally. However, these models are generally applied in situations where there are a number of year classes that are exploited over an extended period of time, and the breeding population is composed of multiple year classes. In the case of prawns, the maximum time an animal will be exploited is two years and the animals are functioning as females in their final year of life. It may be possible to use catch-at-age sampling and analysis to predict the relative strength of 3+ animals in year 't+1' from the catch composition of 2+ animals in year 't'. But it would not be possible to predict age 2+ animals in year 't+1' because the 1+ animals are not available to the fishery in year 't'. Thus, we would only be able to predict a proportion of the next year's stock size. Use of these types of models requires extensive biological sampling and accurate catch and effort information on appropriate spatial scales. The sampling intensity required would be 3 to 5 samples of 1000 individuals taken from each stock assessment area, over the period of the fishery.

Mark-recapture techniques are generally very expensive and time-consuming. For most abundance estimation procedures it is recommended that 25% of the population be tagged (Hilborn and Walters, 1992). Tagging techniques for prawns have been developed but they are fraught with problems: 1) tag loss due to moulting; 2) high tagging mortality; 3) tagging inhibiting growth, etc.

If the population can be divided into two natural classes then techniques such as a change-in-ratio analysis can be used to estimate the population size (Dawe et al. 1993). For prawns, the natural break would be the age classes of 2+ and 3+ animals. This type of program would have dedicated assessment platforms sample fixed fishing sites using standardised fishing procedures. Surveys would be required immediately before and after the fishery and inseason sampling of the commercial catch would also be required to estimate the catch proportions of each age class. The fishery would have to be structured with multiple openings and closures to allow inseason assessment of the population to ensure that the target harvest rate or quota is not exceeded. For comparison purposes, information from this type of program could also be used in other assessment models such as index-removal methods.

The depletion estimation procedure is a technique that examines how measured removals of animals influence the relative abundance indices (e.g. CPUE or survey biomass index). For a short-lived animal like the prawn this would require a series of abundance indices be established prior to the fishery and that deliberate depletion experiments be conducted on these index sites. The results of these index site estimates would then be used to “calibrate” relative abundance indices for other areas of the coast.

Generally, quotas are suited to long-lived species. Because each year class is a part of the population for a longer period, tracking changes in stock strength is easier. Stock changes can be detected in time to make changes to the harvest rate, increasing it to take advantage of good recruitment, and decreasing it when poor recruitment is seen. Because prawns are a short-lived species, living only to a maximum of four years and generally being available to the fishery for a maximum of two years, tracking changes in stock strength is difficult.

To assess a fixed harvest rate strategy, it will be critical to understand the implications of the expected temporal scale that managers are expecting information. Will managers be expecting inseason assessments or will they require forecasted predictions a year (or more) in advance? Eggers (1993) points out that even with salmon, which have been studied extensively, it is not possible to predict with any degree of certainty the strength of the returning year class. The further in the future one goes from the actual time of the fishery the more risk exists that the forecasting relationship will break down. This is mainly due to the number of factors that have to be accounted for in the relationship and the likelihood of them changing and affecting the population size estimate. In general, inseason estimates will be more reliable than trying to forecast the population size from the egg production three years earlier.

What is the spatial scale that we should be conducting assessment on?

Spatial scales for prawn stocks should probably be very small. Tagging of adult prawns has shown little movement (measured in miles) once they have settled out (unpublished data Boutillier). There are other indicators that the animals once settled out do not move. These indicators include factors such as differences in parasite loads and growth rates, both of which can vary considerably between prawn stocks only separated by 10’s of miles (Bower and Boutillier 1990, Bower et al. 1996). Prawns are ubiquitous and have been fished coast-wide in up to 73.6% of the Pacific Fisheries Management Subareas. The number of adult stocks could feasibly be in the 100’s. If this is so, the feasibility of setting individual quotas for each stock and then monitoring the catches is impractical.

However, since the prawn has a free-floating/free-swimming pelagic larval stage for up to three months, it is likely that the concept of meta-populations that share larvae may well apply to prawns. However, it may be difficult to show and understand how these relationships will ultimately affect the recruitment process. Sequential recruitment of populations of the smooth pink shrimp, *Pandalus jordani*, have shown potential indicators of meta-population trends off the west coast of Vancouver Island (Boutillier et al. 1997). At times, catch sampling information does show good recruitment of a single year-class synchronously over a fairly large area (unpublished data Boutillier). This however, may be more an indication of good environmental conditions over a very large area having positive effects on a number of populations rather than a single population response. There are instances of a single year class settling in a particular area, spending its life there and leaving the area virtually barren when it dies. Some of these instances have been documented in logbooks and catch sampling in bays off the open waters of the west coast of Vancouver Island.

Throughout the history of the prawn fishery, the spatial scale used for management purposes has changed considerably. With every year of the fishery, assessments and management decisions are consistently being made on a finer and finer scale. In 1994, 15 separate management decisions were made, and by 1998 this had increased to 45 separate management decisions.

If one manages the fishery on too large a spatial scale, the likelihood of sequential localised overfishing is a very real possibility. One would then have to rely upon a meta-population process to provide the necessary recruitment for the areas that were over-fished. If a meta-population does not exist or the net flow is low and the over-fished populations are isolated then it is very possible to reduce the populations to a level where fishing will be halted for an indeterminable amount of time. An example of this can be seen in the Prince William Sound prawn trap fishery in Alaska which began to show signs of stress in 1989 and has remained closed since 1992 without any sign of recovery (Orensanz et al. 1998). If the spatial scales used were too small, besides being impractical to implement, a quota management system would lead to a situation where establishing meaningful predictive relationships from these assessments would be difficult if not impossible.

How does the population respond to exploitation? What target level of fishing mortality (F) should be used or what is the quota that would be set?

With a quota system, the dynamic response of the population to fishing needs to be fully understood. Zheng et al. (1993) note that it takes a minimum of 15 to 20 years of data to start to resolve some of the questions that must be answered in order to implement a quota management system. The process can take even longer if there is a strong environment influence on recruitment success. If the aim is to set a fixed harvest rate, Walters and Parma (1996) suggest that the prudent approach is to set the exploitation rate at less than 50% of the natural mortality rate. They point out that when the rate is too low there is a compensatory increase in stock biomass.

Developing appropriate biological reference points that set conservative upper bounds to allowable fishing mortalities has been the focus of a great deal of work in the 1990's since the adoption of precautionary approaches to fisheries. Examples of the reference points include F_{MSY}, $F_{0.1}$, MSY, B_{MSY}, $F_{20\%}$, $F_{35\%}$, etc. These are outlined by Gabriel and Mace (1998) and the ICES 1997 Report of the Study Group on the Precautionary Approach to Fisheries Management. The first step is to recognise that there are two distinct types of reference points: conservation or limit reference points (LRP) and management or target reference points (TRP). Limit reference points constrain the fishery so that harvesting is within safe biological limits so that the stocks can produce maximum sustainable yields while target reference points meet management objectives. Under precautionary approaches, if LRPs are exceeded then the management action would be one that facilitates stock recovery usually to B_{MSY}. Zheng et al. (1993) outline a number of ways of calculating limit reference points, however, each method requires some basic information. ICES (1997) Study Group on the Precautionary Approach to Fisheries Management produces a table of the types of reference points that have been used, what they are, the kind of data that is required to calculate them and the type of reference point they are intended to be. The data requirements for estimating these parameters can be very considerable. Generally for prawns, this would require a collection of additional biological information beyond estimates of stock size to include size at age, natural mortality, spawning stock size and recruitment and exploitation patterns on a stock by stock basis. This level of biological sampling is not routinely collected in this fishery. At present, such data is only collected in the Howe Sound, where it is used to evaluate the present management system (Boutillier 1993).

Depending on how the biological reference points are chosen, one must be very careful to monitor the fishery and ensure that the exploitation pattern does not change. This is especially true if the fixed quotas are set based on some historical fishing pattern e.g. the 25th percentile of an area's landings. With a quota in the prawn fishery, fishers would want to take their quota from the most valuable animals, which in the case of prawns are the largest and oldest animals. Since these animals are protandrous hermaphrodites and since prawns do not have the compensatory mechanism of some of the other Pandalid shrimp of becoming primary females, this would mean that the fishery could end up targeting solely on the female component of the stock. This would be acceptable if the quota were based on an index of females available to harvest, however if it were based on the historic catch pattern of combined year classes then the risk of overfishing would be substantially increased.

Conclusion

Garcia (1996) reviewed the risks associated with fishing short-lived and late-maturing shrimp and found that the potential for drastically reducing the fecundity-per-recruit is very high. He concluded that it was absolutely necessary to have these fisheries controlled through recruitment-related reference points expressed in terms of spawning biomass, recruitment, fishing effort and other measurable and controllable fishery variables.

Entering into a quota system for prawns would be an expensive undertaking considering the data and analytical requirements. To get a database from which we could model the populations' compensatory mechanisms to biological processes such as growth and recruitment would take 15 to 20 years. Due to the data limited situation for this fishery in relation to the data demands imposed by a quota system, one would have to consider this a new and developing fishery and impose very strict precautionary principles.

Through the developmental phase of a quota management system for prawns the landings will drop significantly and in the long term the landings will probably be lower but more consistent then the fixed escapement management system. In weighing the cost and benefits to the industry of these different management systems, a clearly defined set of problems must be developed and ranges of options need to be developed. Before entering into a new management system, managers and industry must understand if there are alternative management systems that will just as readily address these problems without putting the stocks and the fishery at risk?

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