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Progress Report on the Development of an In-season Management and Assessment Framework for Prince Rupert Humpback Shrimp (*Pandalus hypsinotus*)

Rapport d'étape sur l'établissement d'un cadre de gestion et d'évaluation pour la crevette à front rayé (*Pandalus hypsinotus*) de Prince Rupert

D. T. Rutherford, H. Nguyen, and J. S. Dunham

Fisheries and Oceans Canada
Science Branch
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, B.C V9T 6N7

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Table of Contents

List of Tables

List of Figures

Abstract

The Prince Rupert Harbour humpback shrimp trap fishery takes place in Pacific Fishery Management Areas (PFMA) 4-10 and 4-11. This is a relatively small fishery with an average of 5 active vessels in a season. The maximum recorded catch was 77,601 kg in 1998 and has averaged 23,000 kg from 1999 to 2005. Output from a surplus production model suggests a *MSY* of 28,274 kg of humpback shrimp from Prince Rupert Harbour. This *MSY* value is qualified in that is not to be interpreted as a recommended or definitive *MSY* value.

Weekly CPUE (kg/trap) obtained from logbook data shows a declining trend throughout the duration of the fishing seasons. Annual CPUE was relatively stable from 1984 to 1994 then showed a declining trend to 2000. Annual CPUE has been increasing from 2001 to 2005.

Currently the humpback shrimp trap fishery in Prince Rupert Harbour is managed by a seasonal closure, vessel trap limits and restrictions. There are no biologically-based decision rules to prevent recruitment overfishing. Thus, shrimp stocks are vulnerable to a large increase in effort during the commercial fishing season. In response to this concern an in-season assessment and management framework is under development. The in-season biological sampling program is not currently providing the data necessary for application of biologically based in-season control models. The in-season sampling program has a major problem in that the limited in-season samples cannot be obtained from a consistent trap type, given the diversity of gear used in the commercial fishery, thus making effort standardization impossible. There are two ways of rectifying this situation, either by manage the fishery so all the in-season data needed is obtained from a standardized trap type, or alternatively by conducting controlled experiments to “standardize” effort from all the different commercial gear types. The former approach is recommended.

Résumé

La pêche au casier de la crevette à front rayé dans le port de Prince Rupert est pratiquée dans les zones de gestion de la pêche du Pacifique (ZGPP) 4-10 et 4-11. Cette activité est de peu d'envergure, puisque cinq bateaux en moyenne s'y adonnent activement au cours d'une saison. Le maximum de prises jamais enregistré a été de 77 061 kg en 1998 et la moyenne, pour 1999 à 2005, est de 23 000 kg. Le résultat d'un modèle de production excédentaire indique un RSM de 28 274 kg de crevettes à front rayé du port de Prince Rupert. Cette valeur du RSM est relative, c'est-à-dire qu'elle ne devrait pas être interprétée comme une valeur recommandée ou définitive.

Les PUE (kg/casier) hebdomadaires tirées des données des journaux de bord révèlent une tendance à la baisse pendant la durée de toutes les saisons de pêche. Les PUE annuelles étaient relativement stables entre 1984 et 1994, puis ont diminué jusqu'en 2000. Elles ont augmenté entre 2001 et 2005.

Actuellement, la pêche de la crevette à front rayé dans le port de Prince Rupert est gérée à l'aide de périodes d'interdiction saisonnières, de limites de casiers par bateau et de restrictions. Il n'existe pas de règles décisionnelles fondées sur des facteurs biologiques pour empêcher la surpêche des recrues. Ainsi, les stocks de crevettes sont sensibles à toute augmentation marquée de l'effort pendant la saison de pêche commerciale. En réponse à cette préoccupation, la préparation d'un cadre d'évaluation et de gestion en cours de saison a été amorcée. Le programme d'échantillonnage biologique en cours de saison ne fournit pas actuellement les données nécessaires à l'application de modèles de contrôle en cours de saison fondés sur les données biologiques. Le programme d'échantillonnage se heurte à un problème important, car il n'est pas possible d'obtenir des échantillons limités en cours de saison provenant d'un type donné de casiers, étant donné la diversité des engins utilisés pour la pêche commerciale, ce qui rend l'effort de normalisation impossible. Il y a deux moyens de corriger cette situation : soit de gérer la pêche de façon que toutes les données nécessaires pendant la saison soient obtenues d'un type normalisé de casiers, soit en menant des expériences contrôlées pour 'normaliser' l'effort de tous les types d'engins différents utilisés pour la pêche commerciale. La première solution est recommandée.

1.0 Introduction

There are in excess of 87 species of shrimp in British Columbia (BC) waters, of these seven species are commercially harvested in trawl and trap fisheries. Management and assessment frameworks are in place for two pink shrimp species (*Pandalus jordani* and *P. borealis*) and sidestripe shrimp (*Pandalopsis dispar*) that are harvested in trawl fisheries along the coast of BC (Boutillier *et al.* 1999). Within the trap fishery an assessment and management frame work is in place for the spot prawn (*Pandalus platyceros*) (Boutillier and Bond 1999, 2000).

Humpback shrimp are harvested by both trap and trawl gear along the coast of BC; however, restrictions were placed on the harvest of this species in 1998. The restrictions were implemented as a result of increased targeting of humpback shrimp in both the shrimp trap and trawl fisheries that became evident in the 1990's and, at that time, no assessment or biologically-based management programs were in place to control the harvest to ensure sustainability. In 1997 the Minister of Fisheries and Oceans directed that "any directed fishery for humpback shrimp, *Pandalus hypsinotus*, in non-traditional areas or with new or modified trawl or trap gear will be subject to the Pacific Region Guidelines on New and Developing Invertebrate fisheries". The guidelines require a phased approach to fishery development. Following the phased approach of Perry *et al.* (1999), "Phase 0" and "Phase 1" assessments for humpback shrimp have been completed (Boutillier and Nguyen 1999, Dunham *et al.* 2002). Because the Prince Rupert humpback shrimp trap fishery has been in operation in Prince Rupert Harbour since the early 1980's, it was considered exempt from the new and developing fisheries guidelines. Nevertheless, it was recognized that an assessment and management program needed to be developed for this fishery to ensure sustainability.

Currently the humpback shrimp fishery in Prince Rupert Harbour is managed by a seasonal closure. The fishery opens in September and closes in December. This fishery is not presently managed using biologically-based decision rules designed to prevent recruitment overfishing. Thus, shrimp stocks are vulnerable to recruitment overfishing if there is a large increase in effort in the four month fishery.

Two in-season decision rule options proposed by Dunham *et al.* (2002) for a trap only fishery are under consideration for the Prince Rupert humpback shrimp fishery. They include: 1) a fixed harvest rate model and 2) a fixed escapement model. The fixed harvest rate model could be estimated by monitoring trends in standardized fishery dependent CPUE indices throughout the fishing season. The fixed escapement model could be assessed by monitoring a target escapement index against an in-season standardized fishery dependent CPUE escapement index (spawner index) for female shrimp. For both these options an in-season monitoring program is needed to collect the appropriate fishery dependent data prior to any implementation of an in-season assessment and management model.

This paper provides an update on the progress toward the development of an assessment and management framework for the Prince Rupert humpback shrimp trap fishery and, more specifically, deals with the progress to date on the development of the required in-season monitoring and sampling program. The need for such a report came out of general discussions that took place at the November 30th, 2005 Invertebrate PSARC sub-committee meeting. In this report we build on the information and options presented by Boutillier and Nguyen (1999) and Dunham *et al.* (2002) by initiating a sampling and monitoring program to collect the data necessary to evaluate the mortality rate and fixed escapement models described in Dunham *et al.* (2002).

In this paper we first provide a history of the Prince Rupert humpback shrimp fishery and present some biological information on this humpback shrimp stock. Secondly, we document and report on the progress to date of a sampling program that was implemented in 2003 to provide the input data needed for application of the trap-based assessment models proposed in Dunham *et al.* (2002). Lastly, we propose adjustments to the current fishery and sampling program that are needed to facilitate data collection requirements.

1.1 History of the Prince Rupert Harbour Humpback Shrimp Fishery

The Prince Rupert Harbour humpback shrimp trap fishery takes place in Pacific Fishery Management Areas (PFMA) 4-10 and 4-11 (Figure 1). This is a relatively small fishery with an average of 5 active vessels in a season. The number of vessels ranged from a low of 1 in 1987 to a high of 11 in 1998 (Table 1). The first official record of any commercial harvest of humpback shrimp from this area was in 1983, a small scale commercial harvest likely occurred prior to this but no catch records are available. This fishery is included in the Shrimp by Trap Management Plan (DFO 2005) and is only open to commercial harvest by “W” and “FW” licence holders, the same licence that is required for commercial harvest of prawns. Although this fishery is part of the shrimp trap management plan, it operates under a separate set of management controls.

Several management actions have occurred over the duration of this fishery (Table 2). Pre 1989 the Prince Rupert humpback shrimp fishing season was open year round with no trap mesh restrictions. The first year of seasonal closures occurred in 1989 and a 3 month closure was invoked for this fishery from January 1, 1989 to March 31, 1989. In addition a portion of 4-11 was closed on November 23, 1989 due to dioxin contamination. Mesh restrictions were introduced into the prawn by trap fishery in 1989 but these did not apply to the Prince Rupert humpback fishery. From 1989 to 1994 the fishery regulations remained unchanged with the 3 month seasonal closure and dioxin closure in effect. The dioxin closure was rescinded in 1995 prior to the seasonal opening which was moved to April 19. This April 19 opening date remained in effect for 1996 and 1997. In 1998 the opening date was changed slightly to April 23. In 1999 a minimum mesh size of 1.5 inches was implemented upon request of the Prince Rupert fishers. This request was supported by industry representatives of the Prawn Sectoral Committee. The opening date in 1999 was April 22. There were no changes for fishing year 2000 except for a start date of May 1. In 2001 a single haul restriction was implemented in the fishery whereby fishers are only allowed to haul their gear once per day.

The next major change to this fishery occurred in 2003 when the Prince Rupert Harbour Commission proposed a delay in commercial fishing to keep gear out of the harbour during the busy summer months. The Prawn Sectoral Committee reviewed this request and supported a September 1 opening date for this fishery. This delayed date did not have any significant impact on the fishery because, even though start dates in previous years were much earlier, fishers tended not to commence fishing in Prince Rupert Harbour until after the commercial prawn season closed. Mesh restrictions, single haul and a September 1st start date have continued through 2004 and 2005.

2.0 Methods

2.1 Data Sources

Catch and effort information from the Prince Rupert humpback trap fishery was obtained from commercial fishing logs. Data were extracted from the PRAWNLOGS database maintained by the Shellfish Data Unit, Marine Ecosystems and Aquaculture Division (MEAD). Biological and catch by sex per trap data were obtained from the PRAWNTRP biological database maintained by the Shellfish Data Unit, MEAD.

2.2 Biological Data Collection

Length and sex data presented in this report were obtained from samples collected in 2000 and 2003. The 2000 samples were collected July 6 and 7 during a DFO research survey and were captured using three ring cone nesting traps covered in 22.5 mm stretched black knotless web (A2 trap type, see Appendix 1 for complete description). Two strings consisting of 10 traps each were set on July 6 in 60-95 m and hauled July 7 for a total soak time of 18 hrs.

The 2003 samples sexed and measured for length were collected from the commercial fishery and were captured using a variety of trap types (A2, C2, L7 trap types, see Appendix 1 for complete descriptions), all of which were compliant with the commercial fishery minimum mesh restrictions. A total of 8 samples were collected between October 7-9, 2003.

2.3 Commercial Fishery Data

Annual commercial catch per unit effort (CPUE) was calculated as:

$$CPUE=C/E$$

Where C = commercial humpback shrimp catch in kg, and E = number of trap sets.

Weekly CPUE estimates were calculated for the 2003 to 2005 commercial fishing seasons using the above equation. Year 2003 was chosen as the starting point for investigating weekly CPUE trends because this was the start of the September 1 openings and also corresponded to the implementation of the fishery monitoring and sampling program.

2.4 Fishery Monitoring and Sampling Program

Dunham *et al.* (2002) proposed several assessment and management models that could potentially be applied to humpback shrimp fisheries. For trap based fisheries the models require the collection of number of shrimp caught by trap and sexual stage, from the commercial fishery throughout the duration of the fishery. Accordingly a sampling program was initiated in 2004 to start collecting this information for potential input into an assessment and management model.

For the Prince Rupert Harbour humpback shrimp fishery, an on-grounds monitor was funded by industry to collect data on number of humpback caught per trap, by sexual stage, and record this information on to pre printed field data sheets (Appendix 2). The design of the sampling program was to have a monitor sample a minimum of 5 strings over a maximum 3 day period every 2 weeks during the commercial fishery. Logistically, every trap on a string could not be sampled (approximately 75 traps/string); therefore, strings were sub-sampled. The sub-sample consisted of recording the number of humpback shrimp captured, by sex, from every 3rd trap on the string. The catch by sex per trap sampled was determined. An overall mean catch, by sex per trap, was then calculated for the string

Two catch indices were developed based on the above data collection. The first was a mean total humpback catch per trap (Mean Total) calculated as follows:

$$Total_{String} = \frac{\sum_{i=1}^{S} \frac{C_i}{v_i}}{S}$$

where C= total number of humpback shrimp in a trap.

i = 1,2,…,S where S is number of traps in a string

v_i = trap efficiency rating (v_i =1)

Then, the Mean Total Index for a specified period can be determined by

$$MeanTotal_{Period} = \frac{\sum_{i=1}^{P} Total_{String(i)}}{P}$$

i = 1,2,…,P where P is number of strings within a specified period.

This index is required for application of the fishing mortality rate model.

The second index was based on the mean number of humpback shrimp which would contribute to the upcoming spawning population. This is the same index method used for prawns and is referred to as the mean spawner index (Mean SI) and is calculated in the same manner as the above index as follows:

$$SI_{String} = \frac{\sum_{i=1}^{S} \frac{N_i}{v_i}}{S}$$

where N= number of humpback shrimp in a trap that would contributed to the spawning population sample year

i = 1,2,…,S where S is number of traps in a string

v_i = trap efficiency rating (v_i =1)

Then, the Mean Spawn Index for a specified period can be determined by

$$MeanSI_{Period} = \frac{\sum_{i=1}^{P} SI_{String(i)}}{P}$$

i = 1,2,…,P where P is number of strings within a specified period.

This index is required for application of the fixed escapement model.

The data collection methods mimic those used in-season for the commercial prawn fishery. The monitor for the Prince Rupert humpback shrimp fishery recorded the data on pre-printed field data sheets (Appendix 2). Datasheets were then forwarded to the industry service provider for keypunching, data verification, and electronic transfer to the DFO shellfish Data Unit for upload into the regional PRAWTRP database.

2.5 Surplus Production Model

The time series of catch and effort data afforded the application of surplus production modelling to provide some insight into the maximum sustainable yield (*MSY*) and the fishing effort at which *MSY* will be achieved (E_{MSY}). The following model of Pella-Tomlinson (1969) was used:

(1) $$B_{t+1} = B_t + \frac{r}{p} B_t \left(1 - \left(\frac{B_t}{K}\right)^p\right) - C_t$$

where B_t is the exploitable biomass at start of year t
r is the intrinsic growth rate
K is the average biomass level prior exploitation.
the parameter *p* controls the shape of the relationship between sustainable yield and biomass

(2) $$qB_t = \frac{C_t}{E_t}$$

where q is the catchability coefficient
E_t is the fishing effort during year t

By equilibrium condition we assume that the rate of biomass change over years is constant (i.e., $B_{t+1} = B_t$ = constant) and that Eq. (2) is exact. We can solve Eq. (1) for C_t after assuming $B_{t+1} = B_t$ and after substituting

$$\frac{C_t}{(qE_t)} = B_t$$

for B_t in Eq. 1 to give

(3) $$C_t = \frac{rC_t}{pqE_t}\left(1 - \left(\frac{C_t}{qE_t K}\right)^p\right)$$

which, in turn, can be solved for C_t / E_t to give

$$(4) \qquad C_t / E_t = \left((qK)^p - \frac{pq^{p+1} K^p E_t}{r} \right)^{1/p}$$

If we re-parameterize the constants, by defining $(qK)^p$ to be a new parameter *a*, and the second term $\frac{pq^{p+1} K^p}{r}$, to be a new parameter *b*, then we have the form (Polacheck *et al*., 1993)

$$(5) \qquad C_t / E_t = (a - bE_t)^{1/p}$$

and therefore, the equilibrium catch is

$$(6) \qquad C_t = E_t (a - bE_t)^{1/p}$$

If value of *p* is assumed to be one (*p*=1), then *a* = *qK*, and $b = (q^2 K)/r$, estimates for *a* and *b* can be obtained using standard linear regression techniques to Eq.(5) (Appendix 3). Differencing Eq.(6) with respect to E_t gives

$$(7) \qquad E_{MSY} = \frac{a}{2b} = \frac{r}{2q}$$

substituting Eq.(7) into Eq.(3) gives

$$(8) \qquad MSY = \frac{(a/2)^2}{b} = \frac{rK}{4}$$

3.0 Results

3.1 Biological Sampling Results

A total of 593 humpback shrimp were obtained during the July 2000 sampling period and all were sexed and measured for carapace length (CL). All sexual stages were present (males, transitionals, females, gravid females and spent females) except for immature males (Table 3). A total of 339 humpback shrimp were collected and sampled for sex and CL from the commercial fishery in October 2003. The only sexual stages present in that sample were immatures, males, and females (Table 3).

The mean CL of humpback shrimp sampled in July, 2000 and October 2003 was 27.0mm (SD=2.54) and 26.0mm (SD=4.41) respectively (Table 3). As expected females were the largest with a mean CL of 27.9 mm and 28.7 mm for 2000 and 2003 respectively. The average CL of males was larger in the July 2000 sample than in the October 2003 sample, 25.6 and 22.1 mm respectively. Transitional humpback shrimp were only observed in the 2000 sample and had a mean CL of 27.3 mm. Immature humpback shrimp were only observed in the October 2003 sample and, at that period in time, had a mean CL of 11.5 mm (Table 3).

3.2 Commercial Catch and Effort

Since 1983 the Prince Rupert humpback shrimp trap fishery has reported, through the logbook program, average landings of 17,000 kg of humpback shrimp per year from 1983 to 2005. Catch has ranged from a low of <1,000 kg in 1983 to a high of 77,601 kg in 1998 (Table 1). A fairly consistent increase in catch was observed from 1983 to 1998. Catch then declined significantly the following year and remained stable from 1999 to 2005 averaging 23,000 kg

(Figure 2, Table 1). The majority (over 75% on average) of humpback shrimp were harvested from PFMA 4-10.

The number of vessels participating in this fishery has ranged from a low of 1 in 1987 to a high of 11 in 1998 (Figure 3). The vessel high of 11 in 1998 corresponded to the year of the record high catch of 77,601 kg. Vessel activity tended to be low throughout the late 1980's to the mid 1990's with the exception of 1984 and 1985 where 6 and 10 vessels respectively were active (Figure 3). After the record high activity in 1998 the number of vessels active stabilized to approximately 7 per season.

Annual fishing effort measured as the number of trap sets in a season follows a different trend than vessel activity. Effort was low and stable from 1984 to 1993 then increased substantially and peaked in 1998. Effort declined sharply in 1999 and has been showing a decreasing trend since, however current levels are still significantly higher than the effort during the 1984-1993 period (Figure 4).

Annual CPUE estimates from 1985 to 1995 remained above a 0.28 kg humpback shrimp per trap average. CPUE peaked in 1993 at 0.46 kg per trap. A sharp decline in CPUE was observed in 1996 and this declined continued through to 2001. However, since 2001 CPUE has shown an increasing trend (Figure 5).

Weekly CPUE estimates during the commercial fishery were variable but generally showed a declining trend within each of the three years reported here (2003-2005). The decline was most evident during the first 5 weeks of the fishery (Figure 6).

3.3 Fishery Monitoring and Sampling Program

Fishery dependent catch index samples were collected from a variety of trap types with no consistent trap type sampled within a given year (Table 4). The majority of index samples were obtained from PFMA 4-10 where the majority (>75%) of commercial fishing occurs. However, in 2004 index samples collected on week 11 of the fishery were obtained from PFMA 4-11. Similarly in 2005 the majority of index samples were obtained from PFMA 4-10 except for index samples collected on week 8 and 13 of the fishery which were obtained from PFMA 4-11 (Table 4).

The fishery dependent catch index samples, Mean Total and Mean Spawner Index, obtained in 2004 both showed a general decreasing trend as the fishery progressed through the 18 week season (Figures 7 and 8). Despite showing a general trend in 2004 the trend was weak and highly variable from sample to sample. No trends in either of the indices were observed in 2005 (Figure 7 and 8).

3.4 Surplus Production Model

The model outputs are MSY = 42,455 kg and E_{MSY} = 297,343 trap sets. However, if the outlier year (1998) that occurred during build up of the fishery is removed from the analysis, then model results are MSY= 28,274 kg and E_{MSY} = 185,229 trap sets (Figure 9).

4.0 Discussion

Annual CPUE in the Prince Rupert humpback shrimp fishery remained consistently above 0.28 kg/trap from 1985 to 1995. Commencing in 1994 both effort and catch started to increase substantially and CPUE started on a declining trend and fell well below the 1985-1995 average. The declining trend lasted from 1997 to 2001 signalling a concern for stock sustainability. Minimum mesh size restriction that had been in place in the commercial prawn fishery since 1989 were explicitly applied to the Prince Rupert humpback shrimp fishery commencing in 1999. CPUE in the fishery increased in 2001, although no direct links between the introduction of minimum mesh size restrictions and increased CPUE can be determined. It is plausible that the larger mesh size allowed for greater release of smaller humpback shrimp and these smaller shrimp recruited to the fishery in 2001. The general increasing trend in CPUE since 2000 may potentially be a result of reduced fishing on the smaller size class and also may be a function of the reduced fishing season (Sept to Dec) implemented in 2003. The preceding is all conjecture at this point; nevertheless the increasing trend in CPUE under relatively constant effort is encouraging but only if commercial fishing effort has stable spatial distribution and a constant catchability coefficient (q).

One of the constraints encountered in designing the in-season sampling and monitoring program was that the Prince Rupert humpback shrimp trap fishery was already established and fishing practices were entrenched. The look of the fishery was, not surprisingly, very similar to the prawn trap fishery so developing a monitoring program similar to that of the prawn fishery seemed appropriate. However, a major problem arose in that in-season index samples obtained through the newly implemented sampling program did not track in-season declines in CPUE determined post season from the logbook data. It is important to note that commercial CPUE is weight based and index samples are number based. One could assume that logbook CPUE is not an accurate proxy of in-season stock status and in-season sampling is a stronger indicator of in-season stock status. However, both sources of data are fishery dependent so it seems probable that the logbook data which contains significantly more measurements is a stronger indicator. Furthermore, the in-season sampling program has a major problem in that the limited in-season samples cannot be standardized to a consistent unit of effort within the current commercial fishery. Different trap types have been shown to have different fishing characteristics and catch efficiencies (Boutillier 1985, 1986, Boutillier and Slone 1987). Bait type has also been shown to effect catch efficiency (Rutherford *et al*. 2004). In the prawn fishery this problem is addressed by carrying out trap standardization studies (Boutillier 1986, Rutherford *et al*. 2004), but in the case of the Prince Rupert Fishery the humpbacks are much smaller than prawns so efficiency ratings developed for prawns cannot be applied here. In addition, in-season sampling was not carried out through to the end of the commercial fishing season.

The problem identified above of standardizing in-season sampling effort and catch can be resolved either by implementing and enforcing the use of a single trap type in the fishery: requiring a portion of the traps fished on every string to be of a single type, or by conduct trap standardization studies to determine an efficiency rating for each trap type and fishing pattern sampled during the in-season monitoring program.

Another anomaly in the results from the in-season sampling program is the high indices observed in the last week of sampling in 2005. We suggest that this may not only be a result of trap type differences, but a combination of a functional result of dispersion of fishing location, response to sporadic and very low fishing effort near the end of the seasonal opening and spatial variation in sampling. It is important to note that the majority of samples were obtained from

PFMA 4-10 with occasional samples obtained from PFMA 4-11. All samples in the last week of 2005 were obtained from PFMA 4-11.

The biological sampling (CL by sex) conducted to date only provides general information on size. Additional biological information will be required to fully develop the SI method for Prince Rupert Harbour humpback shrimp. Sample requirements include number of eggs per mature female by size and age. Stratification by size is necessary since fecundity is a function of size (Dunham *et al.* 2005). Age at maturity data are required for development of SI thresholds. No primary females have been observed to date but additional sampling should be carried out to confirm this. Some measure of natural mortality (M) is also required for the SI model. This can be obtained by sampling a minimum of two time intervals, or in the interim using the natural mortality rate determined for humpback shrimp in Drury Inlet by Dunham *et al*. (2005). Sample sizes of 1,000 shrimp are desirable for determining age composition since length/frequency analysis is used. Sampling should also be stratified by sub-area with initial emphasis put on collecting samples from PFMA 4-10 since the majority of fishing effort occurs there.

Biological samples that have been collected to date were obtained from trap gear. Dunham *et al*. (2002) showed that trap catches, even those traps with small mesh size, are biased toward larger shrimp and not representative of the true population. Trawl gear is less selective; therefore, it would be useful to have fishery independent trawling done on the Prince Rupert shrimp grounds to obtain a sample of humpback shrimp that more accurately represents the true population.

The use of surplus production models has received mixed reviews for fisheries assessment and model outputs need to be interpreted with caution (Hilborn and Walters 1992). These models have however shown to produce reliable estimates of management parameters if good contrast in the data exists. The Prince Rupert Humpback catch and effort data provide good contrast but some of the management changes that have occurred over the years may invalidate some of the assumptions. The model is applied here only to provide a rough bound on *MSY* and effort (E_{MSY}) levels for this fishery. The model output for MSY (28,274 kg) is slightly above the recent (2003-2005) average catch of 24,606 kg per year. Similarly the model output for E_{MSY} (185,229 trap sets) is above the recent fishery average of 124,380 trap sets annually. Given the very general assumptions of surplus production models the outputs presented here are only provided as a guide for future harvest and effort and certainly should not be interpreted as a recommended or definitive value for *MSY*.

5.0 Conclusions

The fishery dependent in-season sampling and monitoring program is not currently providing the data necessary to test the application of the in-season fishing mortality rate model or the escapement based model outlined in Dunham *et al.* (2002). The data need to be obtained from a standardized effort which can be accomplished by either having samples collected from a consistent trap type, or alternatively by conducting controlled experiments to “standardize” CPUE. The former approach is likely more cost efficient in terms of assessment cost. The latter is the approach used in the commercial prawn fishery, but problems are encountered with influxes of fishing technologies being introduced into the fishery prior to any standardization studies. Standardization studies are also expensive in terms of field, vessel, and analytical time (Rutherford *et al.* 2004).

An in-season assessment and management model is needed to ensure sustainability of Prince Rupert Harbour humpback shrimp. The development of this in-season sampling and monitoring program should continue for 2006 and the program needs to incorporate changes to address the problems and obstacles encountered to date. Once a satisfactory program has been developed the next step will be to test application of the trap based assessment models proposed for humpback shrimp by Dunham *et al*. (2002). Additional biological information will be required to develop target indices for the escapement model.

6.0 Recommendations

1. Standardized trap and bait type be implemented in this fishery for collection of in-season assessment data.

2. Development of the in-season sampling program should continue for 2006 fishing season. (Subject to endorsement of recommendation 1)

3. Start collecting additional biological information on Prince Rupert humpback shrimp.

7.0 Acknowledgments

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Table 1. Number of vessels, number of trap sets, and commercial humpback shrimp catch (kg) from Prince Rupert Harbour, 1983-2005.

Year	N Vessels	N Trap Sets	Commercial catch (kg)
1983	2	2473	[a]
1984	6	12270	2860
1985	10	14893	4787
1986	3	15911	4600
1987	1	10100	[a]
1988	3	16845	4870
1989	3	33728	12123
1990	2	10754	[a]
1991	2	19075	[a]
1992	2	30632	[a]
1993	3	20125	9292
1994	3	36198	10656
1995	5	69454	24746
1996	5	76762	16781
1997	9	190620	35519
1998	11	372921	77601
1999	7	188200	23381
2000	7	178270	21434
2001	8	140707	23717
2002	7	117312	21647
2003	7	124395	22202
2004	7	122443	23874
2005	7	126303	27743

[a] confidential, less than 3 vessels reporting

Table 2. Summary of management actions for the Prince Rupert humpback shrimp trap fishery.

Year	Management Action
1983	First official record of commercial humpback shrimp landings in Prince Rupert Harbour
1984	Mandatory logbook reporting
1989	First year of 3 month (Jan-March) seasonal closures. Prior to 1989 fishery open year round
	Portion of PFMA 4-11 closed Nov 23rd due to dioxin concern
	Minimum mesh restrictions implemented in prawn trap fishery but did not apply to Prince Rupert Humpback fishery
1989 - 1994	Fishery regulations remained unchanged, 3-month closure and dioxin closure in effect
1995	Seasonal opening changed from April 1 to April 19
	Dioxin closure rescinded prior to fishery opening
1998	Opening date changed to April 23rd
1999	Minimum mesh size of 1.5" implemented at the request of Prince Rupert fishers
	Opening date April 22
2000	Opening date May 1
2001	Single haul restriction implemented
2003	Opening delayed to September 1 in response to Prince Rupert Harbour Commission request
2004	Start of in-season sampling program

Table 3. Mean carapace length (CL), by sex, of humpback shrimp sampled from Prince Rupert Harbour in 2000 and 2003.

Year	Month	N	Sex	Mean CL (mm)	SD
2000	July	178	Male	25.6	2.50
		161	Transitional	27.3	2.21
		250	Female	27.9	2.27
		2	Gravid	27.5	8.63
		2	Spent	27.7	2.19
		593	All	27.0	2.54
2003	October	8	Immature	11.5	1.31
		116	Male	22.1	1.95
		215	Female	28.7	2.13
		339	All	26.0	4.41

Table 4. Number of samples, trap types, and location, by year and week, of fishery dependent index samples collected from the commercial Prince Rupert humpback shrimp trap fishery.

Year	Sampling Week	N samples	Trap Types[1]	Area
2003	6	8	A2, C2, L7	4-10
2004	1	9	A2, L7, M7	4-10
2004	4	5	A7	4-10
2004	6	5	A7	4-10
2004	8	4	A2, L7	4-10
2004	11	4	L7	4-11
2004	12	4	L7, M7	4-10
2005	2	7	A2	4-10
2005	4	5	A7	4-10
2005	7	4	L7, M7	4-10
2005	8	5	A2	4-11
2005	10	6	A2, A7	4-10
2005	11	3	L5	4-10
2005	13	5	A2	4-11

[1] see appendix 1 for description of trap types

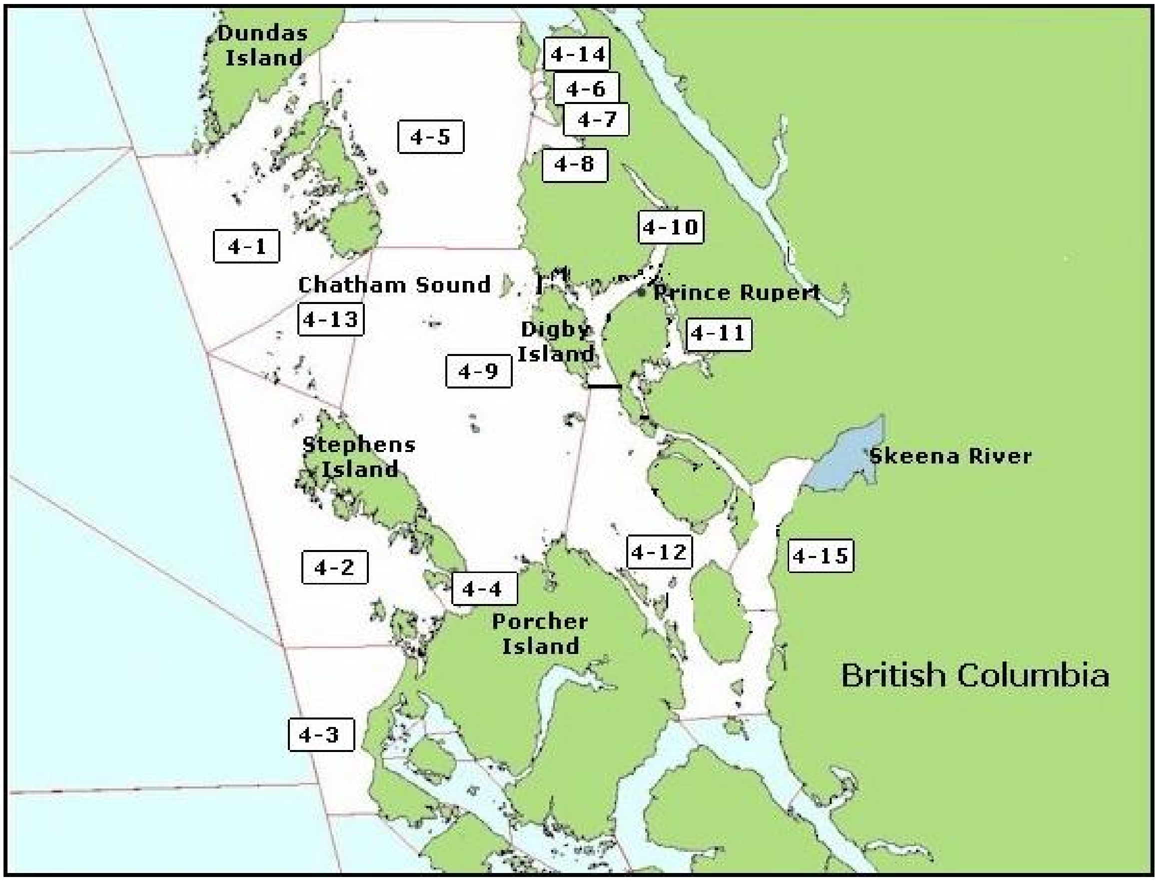


Figure 1. Map of PFMA 4 showing location of sub-areas 4-10 and 4-11 (Prince Rupert Harbour).

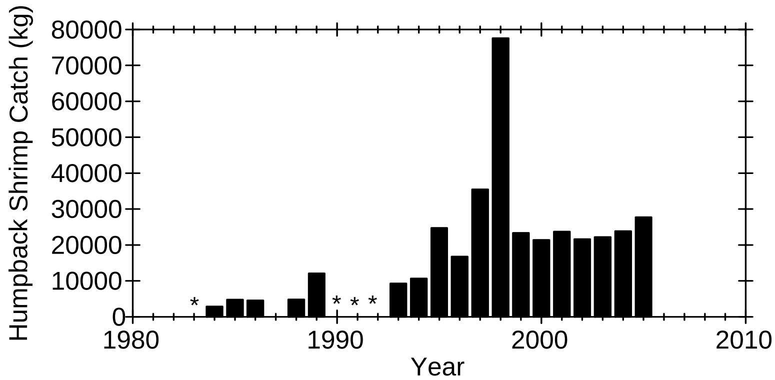


Figure 2. Annual humpback shrimp catch from Prince Rupert Harbour. Asterix designates confidential data, less than 3 vessels reporting

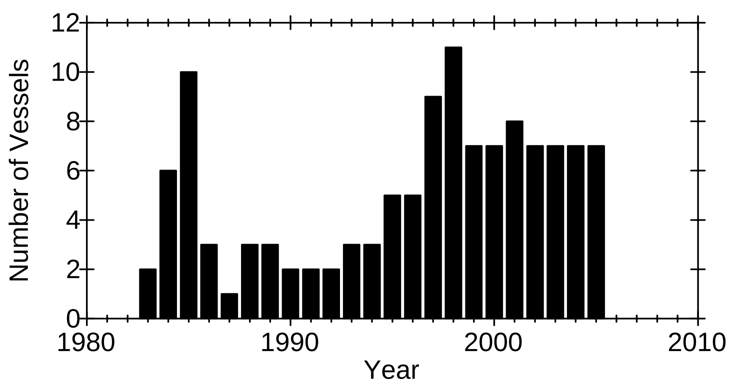


Figure 3. Number of vessels, by year, particpating in the Prince Rupert humpback shrimp trap fishery.

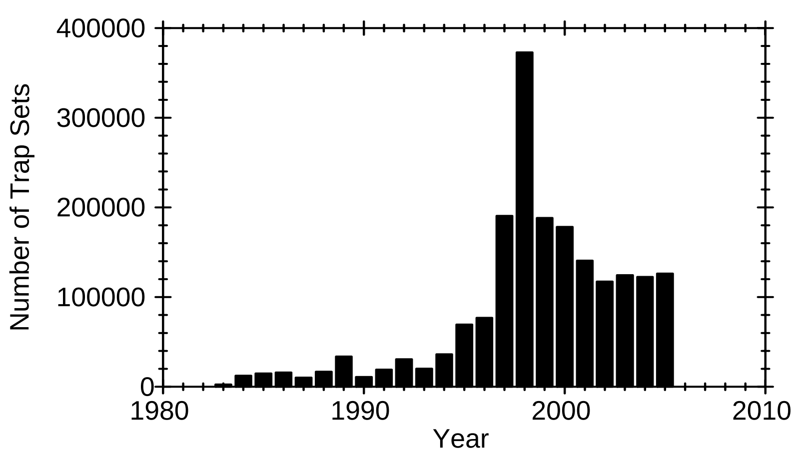


Figure 4. Number of trap sets, by year, in the Prince Rupert humpback shrimp trap fishery.

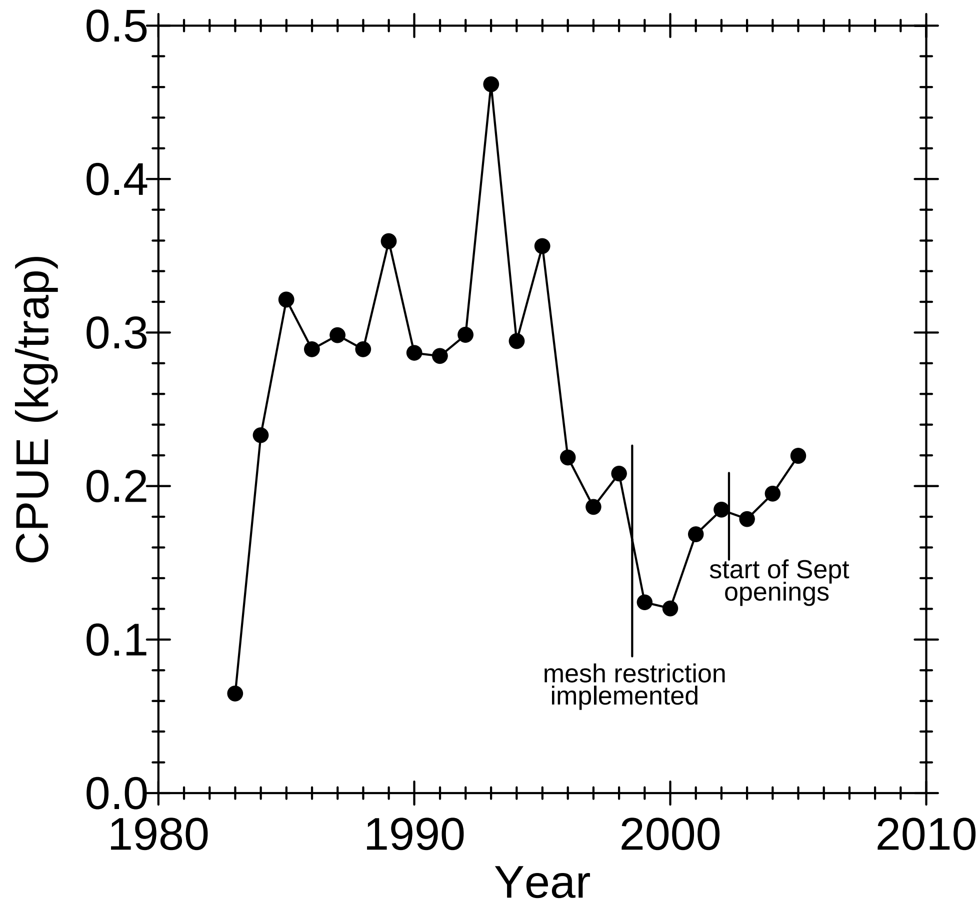


Figure 5. Annual CPUE (kg/trap) for the Prince Rupert Harbour commercial humpback shrimp fishery, 1983-2005.

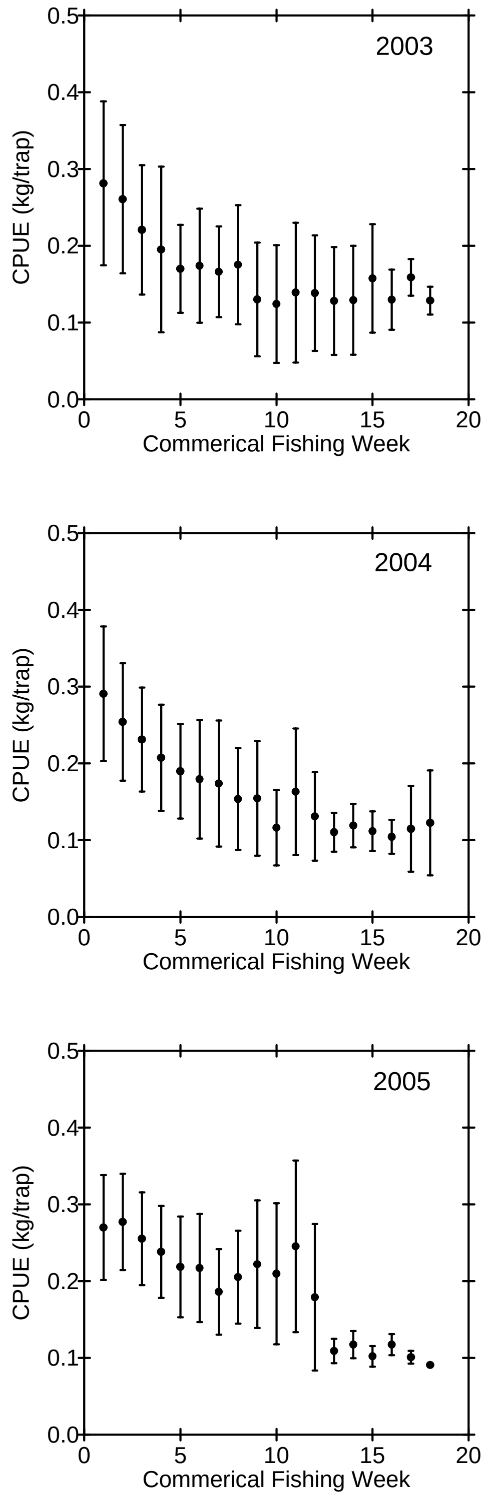


Figure 6. Weekly CPUE (kg/trap) in the Prince Rupert Harbour commerical humpback shrimp fishery. Error bars designate +/- 1 Standard Deviation. (Commerical fishing week 1 commences September 1).

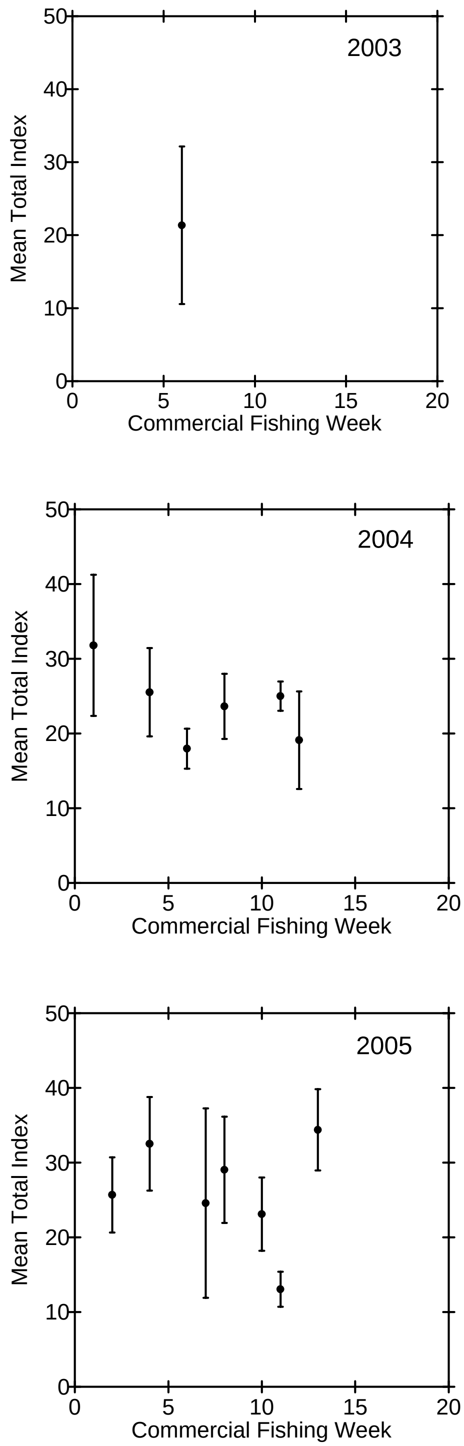


Figure 7. Variation in Mean Total Index obtained from the Prince Rupert commercial humpback shrimp trap fishery, 2003 to 2005. Refere to Table 4 for details on trap type and location of weekly samples. Error bars designate +/- 1 Standard Error.

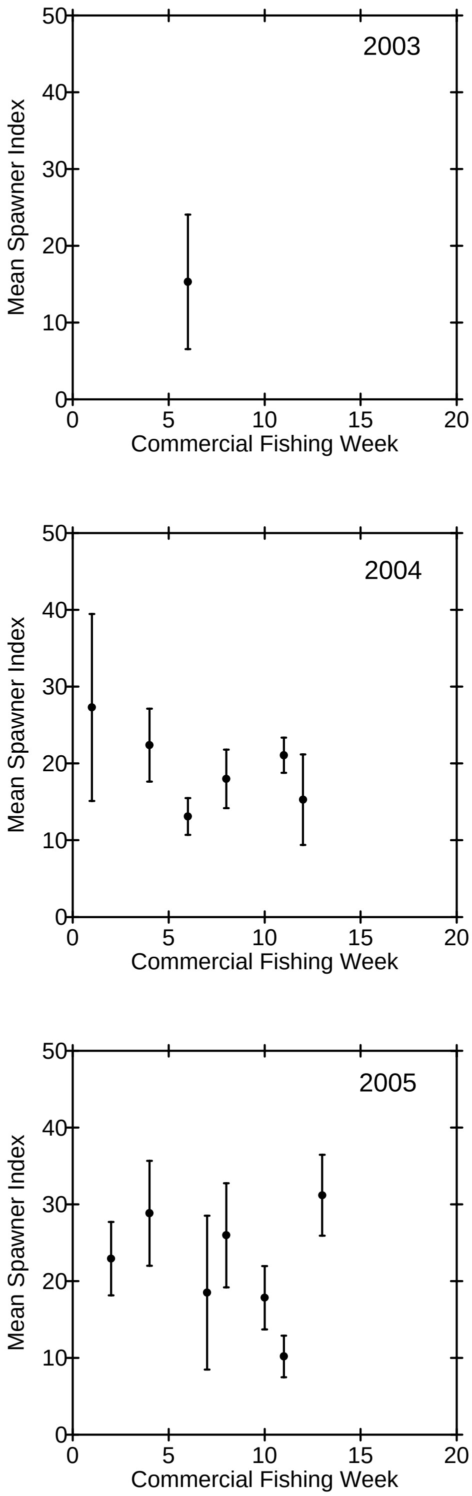


Figure 8. Variation in Mean Spawner Index obtained from the Prince Rupert commercial humpback shrimp trap fishery, 2003 to 2005. Refere to Table 4 for details on trap type and location of weekly samples. Error bars designate +/- 1 Standard Error.

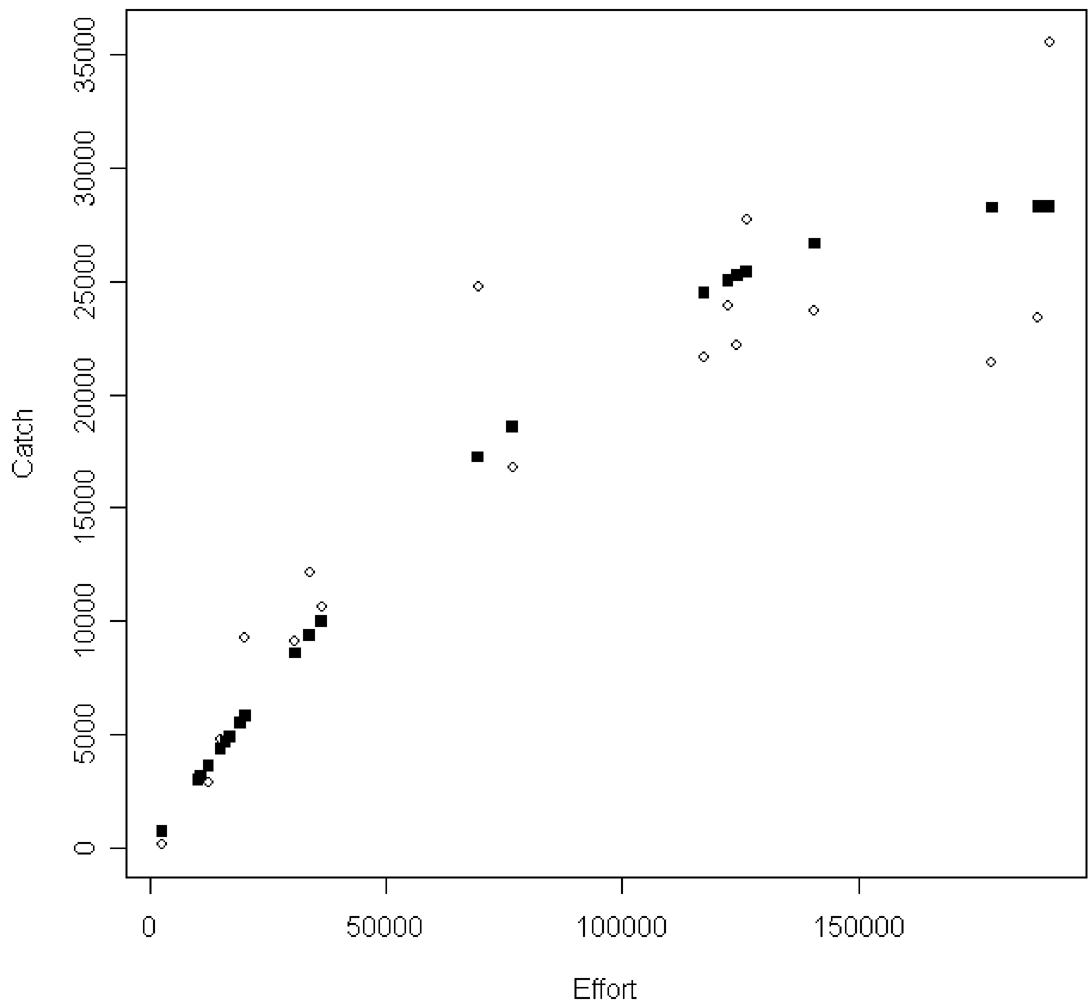


Figure 9. Yield-effort relationship determined from Prince Rupert Harbour commercial humpback shrimp trap fishery data. Y- axis is humpback shrimp catch (kg) and x-axis is effort (# trap sets). Open circles designate observed data, closed squares designate model output.

Appendix 1. Trap type codes and trap descriptions

Trap code	Description
A1	Cone nesting, 3 ring stainless steel frame, 22.5 mm nylon web, 117 L volume
A2	Cone nesting, 3 ring stainless steel frame, 38.1 mm nylon web, 117 L volume
A7	Cone nesting, 3 ring stainless steel frame, 38.1 nylon web, 100 L volume
C2	Large cone nesting, 3 ring steel frame, 38.1 mm mesh, 170 L volume
L5	16" x 20" x10" high wire mesh trap, 1/2" x 1/2" wire mesh throughout except for 1"x1" wire mesh panels on bottom and sides
L7	16" x 20" x 10" high wire mesh trap, 1/2" x 1/2" wire mesh and 1"x1" wire mesh panels on bottom and sides and 1" X 1" tunnels
M7	24" x 24" x 12" high wire mesh trap, 1/2" x 1/2" wire mesh and 1"x1"wire mesh panels on bottom and sides and 1" X 1" tunnels

Appendix 2. Data collection form used for the Prince Rupert humpback shrimp fishery.

C O M M E R C I A L T R A P C. P. U. E.

commercial vessel name ______ **VRN** [ ] **Date** [ ] year month day **Set No.** [ ]

observer name ______ code no. [ ] **Nearest Chart Ref.** ______ area sub-ar. locality

observer vessel name ______ code no. [ ] **Lat.deg** ______ **Lat.min.** ______ **Long.deg** ______ **Long.min.** ______

(RECORD MINUTES AS DECIMANL MINUTES: EG. 30 SEC. = .5 MIN)

Sample wt. [ ] **kg.** **Species** [ ] **Depth** [ ] minimum [ ] maximum ☐ fathoms ☐ meters

Time: **Set** [ ] hour day **Haul** [ ] hour day **Duration** [ ] hours

TRAP TYPE	Bait	Sylon infected	imm. male 0	male 1	transitional 2	female 3	egged female 4	spent female 5	Use

Sample weight (kg.) by sex

Sy=	
0 =	
1 =	
2 =	
3 =	
4 =	
5 =	
T =	

Days in this location ______

No. previous yrs. this location ______

Was rockfish bycatch recorded?

Yes__ No__

Rockfish Bycatch *

Sp. code	#	wt. (kg)

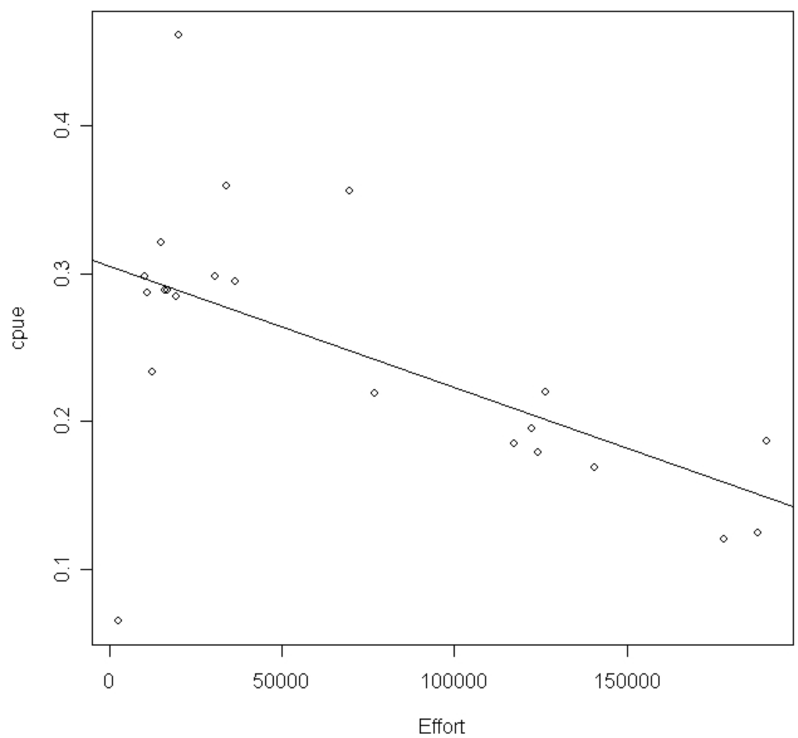
* All traps in string to be inspected for bycatch

revised Apr/2004

Sampled every [ ] of [ ] traps in string = [ ] traps sampled

Remarks: ______

Appendix 3. Regression parameters determined for the surplus production model.




```
lm(formula = cpue ~ Effort)

Residuals:
     Min        1Q    Median        3Q       Max
-0.238554 -0.023923 -0.003988  0.018802  0.173008

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  3.053e-01  2.437e-02   12.53 6.35e-11 ***
Effort      -8.241e-07  2.559e-07   -3.22  0.00430 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.07646 on 20 degrees of freedom
Multiple R-Squared: 0.3414,     Adjusted R-squared: 0.3085
F-statistic: 10.37 on 1 and 20 DF,  p-value: 0.004295
```