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Research Document 2001/136 | **Document de recherche 2001/136**

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Assessment of the Canadian longspine thornyhead (*Sebastolobus altivelis*) for 2001

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Ce document est disponible sur l'Internet à:

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ISSN 1480-4883
Ottawa, 2001

ABSTRACT

A detailed compilation and analysis of the available data for longspine thornyheads (*Sebastolobus altivelis*) found in west coast Canadian waters is presented. This analysis was prompted by concerns over the rapid development of a new bottom trawl fishery directed at this species since 1996. An analysis of the available length frequency data from the commercial fishery showed that these distributions have been quite stationary over the four years of available data and between the traditional WCVI fishery and the new northern exploratory areas. Relative abundance indices estimated from CPUE data using general linear modelling methods showed a 25% decline in biomass over the five year history of the fishery. This level of change is consistent with previous population modelling for this species. This report suggests that current levels of fishing be allowed to continue for a further year while monitoring from the new independent biomass survey begun in 2001 and the current comprehensive level of fishery monitoring is continued. The report also notes that the most important additional research requirement for this species is to acquire an understanding of the growth rates and productivity of this species.

RÉSUMÉ

Ce rapport présente une compilation et une analyse détaillées des données disponibles sur le sébastolobe à longues épines (*Sebastolobus altivelis*) des eaux de la côte ouest canadienne. L'analyse a été réalisée pour donner suite aux préoccupations concernant le développement rapide d'une nouvelle pêche dirigée de cette espèce au chalut de fond depuis 1996. L'analyse des fréquences de longueurs des prises commerciales indique que ces distributions sont restées stables au cours des quatre années pour lesquelles des données sont disponibles et que les distributions sont semblables dans les lieux de pêche traditionnels de la côte ouest de l'île de Vancouver et dans les nouveaux secteurs de pêche exploratoire au nord. Les indices d'abondance relative estimés à partir des données de CPUE à l'aide de modèles linéaires généraux montrent que la biomasse a baissé de 25 % durant les cinq années de cette pêche. Cette baisse correspond aux résultats de la modélisation antérieure des populations du sébastolobe à longues épines. Ce rapport recommande de maintenir les captures à leurs niveaux actuels pour une autre année pendant la poursuite du nouveau relevé indépendant de la biomasse entamé en 2001 et de la surveillance exhaustive actuelle de la pêche. Selon le rapport, le plus important besoin en recherches supplémentaires sur cette espèce consiste à comprendre ses taux de croissance et sa productivité.

1.0 INTRODUCTION

The fishery for longspine thornyheads (*Sebastolobus altivelis*) has had a relatively short history on the Canadian west coast, with the documented fishery on this species beginning only in early 1996. Prior to that year, it is likely that this species was taken in small amounts coincidentally with its congener *Sebastolobus alascanus* (shortspine thornyheads), but the identification of thornyhead catch at the species level has not been available until the introduction of comprehensive observer coverage in early 1996. longspine thornyheads are abundant in the depth ranges from 600 to 1200 m (Wakefield 1990) and the fishery at these depths did not develop until after 1995 (Table 1). Prior to that year, small amounts of shortspine thornyheads are recorded as being caught deeper than 600 m, but it is only in 1995/96 that quantities of this species exceeded 100 t below that depth threshold for a complete fishing year (256 t in the "traditional area" and a further 49 t in the rest of the B.C. coast; Table 1; areas are defined in Figure 1). This catch would have consisted of mixed longspines and shortspines, and it is unlikely that the catch of longspines exceeded 200 t in that year.

Table 1. Percentage distribution of tows by standard (April-March) fishing year above and below 600 m in two areas of the B.C. as defined in Figure 1, based on tows with valid depth fields. Also shown is the total catch (in tonnes) of shortspine thornyheads (SST) above and below 600 m by standard fishing year in the same two areas.

	Traditional WCVI fishery				**Balance of B.C. coast**			
Fishing Year	**Number tows > 600 m**	**% tows > 600m**	**SST catch <= 600 m**	**SST catch > 600 m**	**Number tows > 600 m**	**% tows > 600m**	**SST catch <= 600 m**	**SST catch > 600 m**
1991/92	105	3%	52.2	19.6	4	0%	30.0	0.3
1992/93	229	3%	94.1	39.7	31	0%	83.3	2.0
1993/94	295	4%	117.2	81.0	67	0%	285.8	14.2
1994/95	213	3%	94.5	54.4	103	1%	619.8	36.7
1995/96	609	8%	139.7	256.1	169	1%	558.0	48.6
1996/97	2,594	29%	82.2	394.1	56	0%	378.7	12.1
1997/98	1,650	25%	69.4	247.6	87	1%	230.3	20.5
1998/99	1,906	28%	63.3	314.9	70	1%	182.3	25.4
1999/00	1,623	21%	69.2	428.8	495	4%	203.3	150.7
2000/01	885	18%	65.3	187.5	1,193	9%	197.4	293.6

The largest catches for this species have been taken in waters off the south-west coast of Vancouver Island, but the fishery is presently expanding northward to the northern sections of Vancouver Island, the west coast of the Queen Charlotte Islands and to Dixon Entrance through an exploratory fishing program implemented by DFO for the 2000/01 fishing year (Anonymous 2000) and which was continued into the 2001/02 fishing year (Anonymous 2001). A coastwide quota of 860 t was set for this species in 1997 at the same time as the introduction of "individual vessel quotas" which are used to manage all slope rockfish species (Schnute et al. 1999). This coastwide quota was reduced to 425 t on 1 April 2000. However, an additional 425 t of "exploratory" quota was allocated for longspines for those areas "north and west of a line drawn 230° true from the light located on Lookout Island located at 49°59'52.1" north latitude and 127°26'57.3" west longitude on the upper west coast of Vancouver Island" (Figure 1). This new regulation has maintained the same coastwide quota but has effectively halved the catch south of Nootka Sound where previously the majority of fishing has taken place.

The two *Sebastolobus* species overlap in distribution and appear morphologically similar. Both species of thornyheads have a long pelagic larval phase where they will be subject to considerable dispersion due to the prevailing ocean currents. Shortspines appear to settle at shallower depths and migrate to deeper depths (Jacobson and Vetter 1996) while longspines settle immediately at the deeper depths (Wakefield 1990). The effect of this behavioural difference is that shortspines are considerably larger than most longspines in the depths where they overlap. Jacobson and Vetter (1996) point out that both species have similar peak reproductive depths.

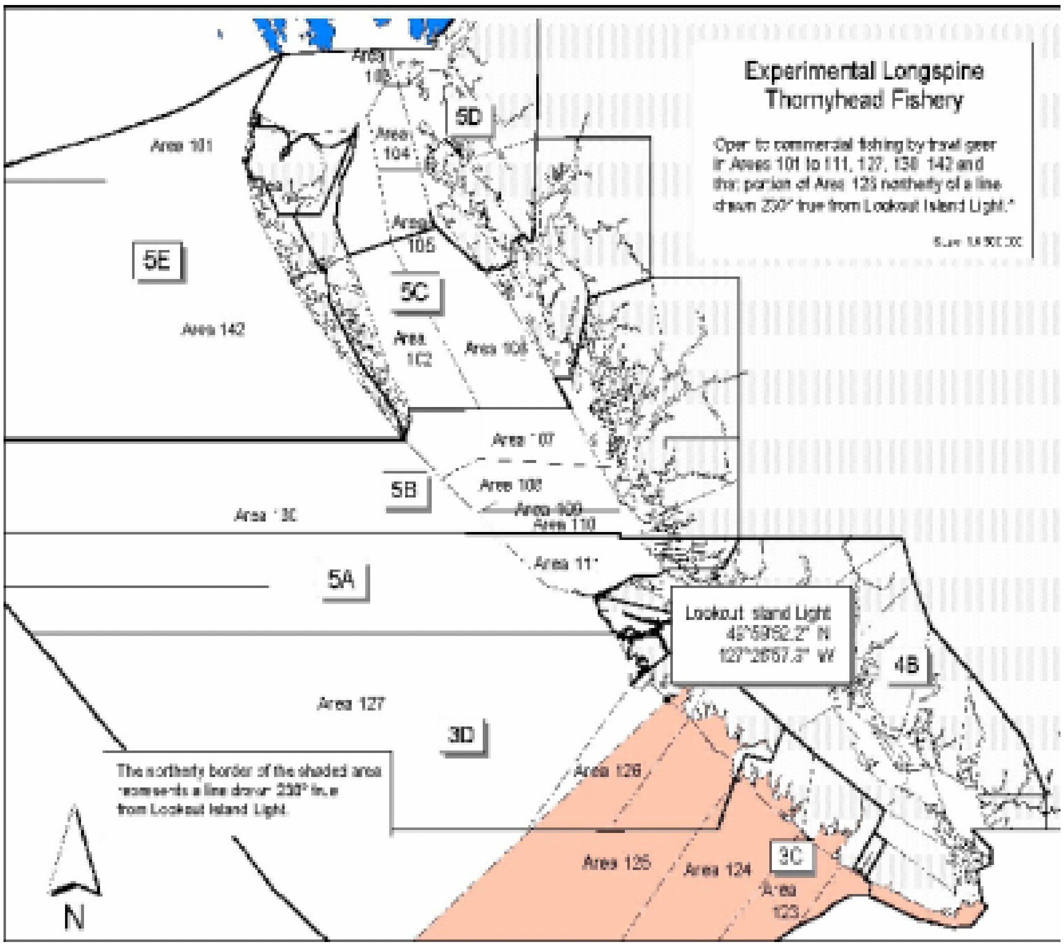

Figure 1. Map of the Pacific west coast of Canada showing the location of the “traditional” west coast Vancouver Island longspine thornyhead fishery (shaded area) and the exploratory longspine fishery (all areas to the north and west of the shaded area). Map taken from Anonymous (2000)

Neither thornyhead species is found in aggregated schools but instead both are distributed uniformly over soft sediments (Wakefield 1990). This distribution leads to relatively low catch rates in the fishery and commercial vessels typically tow for long periods (up to 16 hours) to catch a commercial amount of product.

Approximately 50 to 60% of both sexes have reached sexual maturity at 190 mm (Ianelli et al. 1994), which is also the retention size for this species in the commercial fishery. This size equates to approximately age 12 using the growth function provided in Kline (1996) and which was used by Starr & Haigh (2000) in their preliminary assessment of this species off the west coast of

Vancouver Island. The modal size in the commercial fishery is 240 mm, corresponding to age 20 (~100% mature) using the same growth and maturity functions.

Presently about 12 to 15 bottom trawl vessels specialise in taking the two *Sebastolobus* species in a fishery that extends from early spring to late autumn. The fish are sorted by size and the smaller fish are usually frozen whole at sea for export to Japan. The larger fish (primarily shortspine thornyheads) are headed and gutted before freezing. The tows are long (often 12 or more hours in length) and frequently double back on themselves so that a vessel tends to begin and end its tows in the same general location.

A report on the available stock assessment information for longspine thornyheads and a tentative assessment of the current stock status for this species off the west coast of Vancouver Island was prepared for the Groundfish Subcommittee of the Pacific Stock Assessment Review Committee (PSARC) in November 2000 (Starr & Haigh 2000). This paper concluded that the current stock status was indeterminate, given the strong uncertainties in the growth rates for this species. However, given the short history of the fishery on this population, the paper also concluded that current levels of fishing could be maintained, particularly with the current strategy of spreading the catch over the entire coast, pending the development of a monitoring tool for this stock.

A new random stratified trawl survey directed at longspine thornyheads was run in September 2001 and it is expected that this survey will be repeated in each of the next two years prior to a full evaluation of its results. The feasibility of such a survey was evaluated for the Groundfish Subcommittee of PSARC in 2000 (Starr & Schwarz 2000) and the September 2001 survey was based on the design proposed in that report.

This report is the second in a series commissioned by the Canadian Groundfish Research and Conservation Society in support of its commitment towards the sustainable use of the resource on which its members depend. The intent of this report is to update the information presented in Starr & Haigh (2000) and to report on the developing longspine fishery in the northern areas of the British Columbia coast.

2.0 DATA SOURCES

2.1 COMMERCIAL TRAWL DATA

The Department of Fisheries and Oceans has maintained records of groundfish catch and effort data from 1954 to 1995 using a combination of voluntary skipper interviews, vessel logbooks, landings records (sales slips or validation records) and observations at the waterfront. These data are archived in a database called GFCATCH (Leaman and Hamer 1985), the history of which has recently been described in detail by Rutherford (1999).

A mandatory at-sea observer program was implemented for most Option A and some Option B trawl vessels in early 1996. This includes about 90% of the entire British Columbia trawl fleet and every vessel which fishes for longspine thornyheads. The observers provide information on catch locations, bridge log data and species composition (by weight). The differentiation between the two thornyhead species would be very unreliable without the presence of observer coverage. Observers also collect biological data for selected species, including longspine thornyheads. A relational database, PacHarvest, was developed by the DFO Groundfish Section concerned with slope rockfish assessment (Schnute et al. 1999) which is located at the Pacific Biological Station, Nanaimo, B.C.

A detailed explanation of catch and effort data used in the general linear modelling section of this document is provided in Appendix A, including a description of the data selection and grooming procedures. There has been an important revision to the catch data reported from the PacHarvest database compared to the equivalent catch information reported in Starr & Haigh (2000). Tow by tow catches provided in this report have been scaled to the total landed catch for the trip by obtaining the proportion of the estimated catch of the tow relative to the total estimated catch for the trip (K. Rutherford pers. comm.). Previously only the estimated catch for the tow was reported and this modification in the database has resulted in some adjustment to the catch totals.

2.2 COMMERCIAL SAMPLING DATA

The current compulsory observer programme described in Section 2.1 also collects length and sex frequency information on longspines from selected tows. Recently the design for the selection of the tows to be sampled has been strengthened (R. Stanley *pers. comm.*) but information resulting from this improved design will not be available until next year. Length frequency data for longspine thornyheads from the commercial fishery are maintained in a database (GFBio) held by the Department of Fisheries and Oceans (DFO) at the Pacific Biological Station. The current description of this database, including available data fields, is available on the DFO website which is only accessible within the DFO internal local area network.

A description of the preparation of the commercial length frequency data for inclusion in this paper is provided in Appendix B.

3.0 BIOLOGICAL INFORMATION

The available biological information pertaining to longspine thornyheads is scarce and scattered. Most of the available information comes from research surveys conducted in the United States off the west coasts of California, Oregon and Washington and are detailed in Starr & Haigh (2000). Table 2 summarises what information is presently available for longspine thornyheads for commonly used biological parameters used in fisheries stock assessments and which were the values used by Starr & Haigh (2000) in their preliminary stock assessment.

Table 2. Summary of biological parameters for longspine thornyheads with their sources.

Parameter	Value	Source
M (natural mortality)	0.10	Ianelli et al 1994
Maximum age	45	Kline 1996
Maximum length	400 mm	Maximum in US survey data
Age at full maturity	23	Ianelli et al 1994
Age at 50% maturity	17	Ianelli et al 1994
Von Bertalanffy L_∞ (mm)	301	Kline 1996
Von Bertalanffy k	0.072	Kline 1996
Von Bertalanffy t_0	-1.90	Kline 1996
Length-weight a	4.85 E-06	Starr & Haigh (2000)
Length-weight b	3.163	Starr & Haigh (2000)

4.0 ANALYTICAL PROCEDURE USED FOR CATCH/EFFORT DATA

A stepwise multiple linear regression (where data are modelled assuming lognormal variability) was used to estimate trends in abundance from CPUE data derived from the commercial catch and effort database (see Appendix A for how these data were generated). This approach is commonly used to analyse fisheries catch and effort data and are described in Hilborn and Walters (1992) and Quinn and Deriso (1999).

Quinn and Deriso (1999) describe a general linear model based on the lognormal distribution:

$$U = U_r \prod_i \prod_j P_{ij}^{X_{ij}} e^{\varepsilon} \qquad \textbf{Eq.1}$$

where U is the observed CPUE, U_r is the reference CPUE, P_{ij} is a factor i at level j, and X_{ij} is a categorical variable which takes a value of 1 when factor P_{ij} is true and 0 when it is false. ε is a normal random variable with mean=0 and standard deviation σ.

Taking the logarithm of Eq.1 gives the following general form for one explanatory factor:

$$\ln U = \ln U_r + \sum_i \sum_j X_{ij} \ln P_{ij} + \varepsilon$$

or **Eq.2**

$$Y = \beta_0 + \sum_k \beta_k X_k + \varepsilon$$

where the subscript k in the second form of Eq.2 combines subscripts i and j in the first form, β_0 is the intercept of ln(CPUE) and β_k is the logged coefficient of the categorical variable for the factor under consideration.

The model described in Eq. 1and Eq. 2 is overparameterised and can take on an infinite number of solutions. . The approach used to overcome this problem in this analysis was to fix one of the β_k coefficients and to estimate the remainder of the coefficients relative to the fixed coefficient. Practically this is done in the regression model by dropping one coefficient (usually the first) and estimating the model with *k-1* coefficients. The dropped coefficient will be equal to zero (in log space).

Categorical variable coefficients obtained by dropping one factor will take on different values depending on which coefficients has been dropped. Following the suggestion of Francis (1999), these coefficients are transformed to “canonical” coefficient calculated relative to the geometric mean ($\bar{\beta}$)of the series:

$$\beta_k^0 = \beta_k / \bar{\beta} \qquad \textbf{Eq.3}$$

As the analysis is done in log space, this is equivalent to:

$$b_k^0 = e^{(\hat{\beta}_k - \overline{\beta})} \qquad \textbf{Eq.4}$$

where $\hat{\beta}_k$ is the coefficient calculated for each value of the predictor variable and $\overline{\beta}$ is the mean of those coefficients, including the dropped coefficient. When this procedure is applied to the annual abundance variable (‘year’ or ‘fishing year’), the resulting set of canonical indices is termed the “Standardised” CPUE index [Y_k^0] in this report.

The use of the canonical form allows the computation of standard errors for every coefficient, including the dropped coefficient (Appendix E). Ordinarily, the use of a fixed reference coefficient sets the standard error for that coefficient to zero and spreads the error associated with that coefficient to the other coefficients in the variable.

Eq. 2 can be extended to include as many factors as are thought to be reasonable, including interaction terms. A selection procedure has been developed (Vignaux 1993, Vignaux 1994; Francis 2001) to determine the relative importance of these factors in the model and to establish a stopping rule which will include only the most important factors. This procedure involves a forward stepwise fitting algorithm which generates a regression model iteratively, starting with the simplest model (one dependent and one independent variable).

The following general procedure was used to fit the models, given a data set with candidate predictor variables:

1. Calculate the regression with each predictor variable against the natural log of CPUE (kg/hr).

2. Generate the AIC (Akaike Information Criterion; Akaike 1974) for each regression based on the number of model degrees of freedom. Select the predictor variable that has the lowest AIC.

3. Repeat Steps 1 and 2, accumulating the number of selected predictor variables and increasing the model degrees of freedom, until the increase in residual deviance (=R^2) for the final iteration is less than 0.01.

The AIC is used for predictor selection to account for variables which may have equivalent explanatory power in terms of residual deviance but add fewer degrees of freedom to the model (Francis 2001).

A direct comparison of a number of alternative estimates of annual CPUE is made by standardising all available indices relative to the geometric mean of the index series. The simplest estimate of mean annual CPUE is:

$$R_j = \frac{\sum_{k=1}^{M_j} C_{jk}}{\sum_{k=1}^{M_j} E_{jk}} \qquad \textbf{Eq. 5}$$

where M_j is the number of records in the data set for year j, C_{jk} is the catch and E_{jk} is the effort associated with each record in the data set for year j. The series of annual abundance indices calculated in this manner is termed the "Arithmetic" CPUE index in this report and is the arithmetic mean of CPUE weighted by effort. This index can also be scaled relative to its geometric mean ($\bar{R}$) in the same manner as the canonical standardised index (Eq. 3):

$$R_j^0 = R_j \big/ \bar{R} \qquad \textbf{Eq.6}$$

Another simple index of annual abundance based on CPUE is:

$$U_j = e^{\left[\frac{\sum_{k=1}^{M_j} \ln\left(\frac{C_{jk}}{E_{jk}} \right)}{M_j} \right]} \qquad \textbf{Eq. 7}$$

where U_j is the annual geometric mean of the CPUE observations. The resulting series of indices is termed the "Unstandardised" CPUE index in this report as it is equivalent to a GLM where the only predictor variable is the year term. This index can also be scaled relative to its geometric mean ($\bar{U}$) in the same manner as the canonical standardised index (Eq. 3):

$$U_j^0 = U_j \big/ \bar{U} \qquad \textbf{Eq.8}$$

5.0 AREA DEFINITIONS FOR LONGSPINE THORNYHEADS

The current management plan for longspines defines two specific areas for longspines, a "traditional" area off the west coast of Vancouver Island and the balance of the BC coast (Figure 1). Starr & Haigh performed the CPUE analysis which was the basis for their preliminary stock assessment on all tows south of 50° N latitude. There are a suite of DFO management areas for groundfish, some of which are based on Pacific Marine Fisheries Commission (PFMC) statistical areas (Schnute et al. 1999; Schnute et al. 2000; Rutherford 1999), but these are not presently applied to the management of longspine thornyheads. The following two paragraphs describe a basis for rationalising the area definitions for longspine thornyheads for the purposes of presenting catch and effort summaries of the "traditional" and exploratory fishing grounds in this report.

Simple longspine CPUE was calculated for 5 km^2 grids (using Eq. 3) over the entire period of available data (February 1996 to March 2001) to determine areas of high and low longspine CPUE and how these patterns match with the present longspine catch regions (Figure 2). This map shows that longspine catch rates are reasonably uniform along the entire west coast of Vancouver Island, with few breaks in a continuous broad area of high CPUE (between 50 and 100 kg per hour towed) when moving in a north-west direction from south to north. The first obvious region of relatively low CPUE is approximately off Nootka Sound, where the CPUE pattern constricts to a very narrow "neck". The CPUE pattern then expands again into another smaller region of high catch rates after which there is a large region of no fishing at all off the Brooks Peninsula (Figure 2).

The "neck" in the CPUE pattern off Nootka Sound described in the previous paragraph is slightly to the north and west of the line used to define the demarcation between the "traditional" and "exploratory" fishery shown in Figure 1. The line shown in Figure 2 was the basis for separating all tows into "traditional" and "exploratory" areas in the PacHarvest database. Subdividing the existing "traditional" fishery lying to the south and east of this line will be difficult given the continuous pattern of high CPUE observed in Figure 2, but this may not be necessary as this could be a single biological stock.

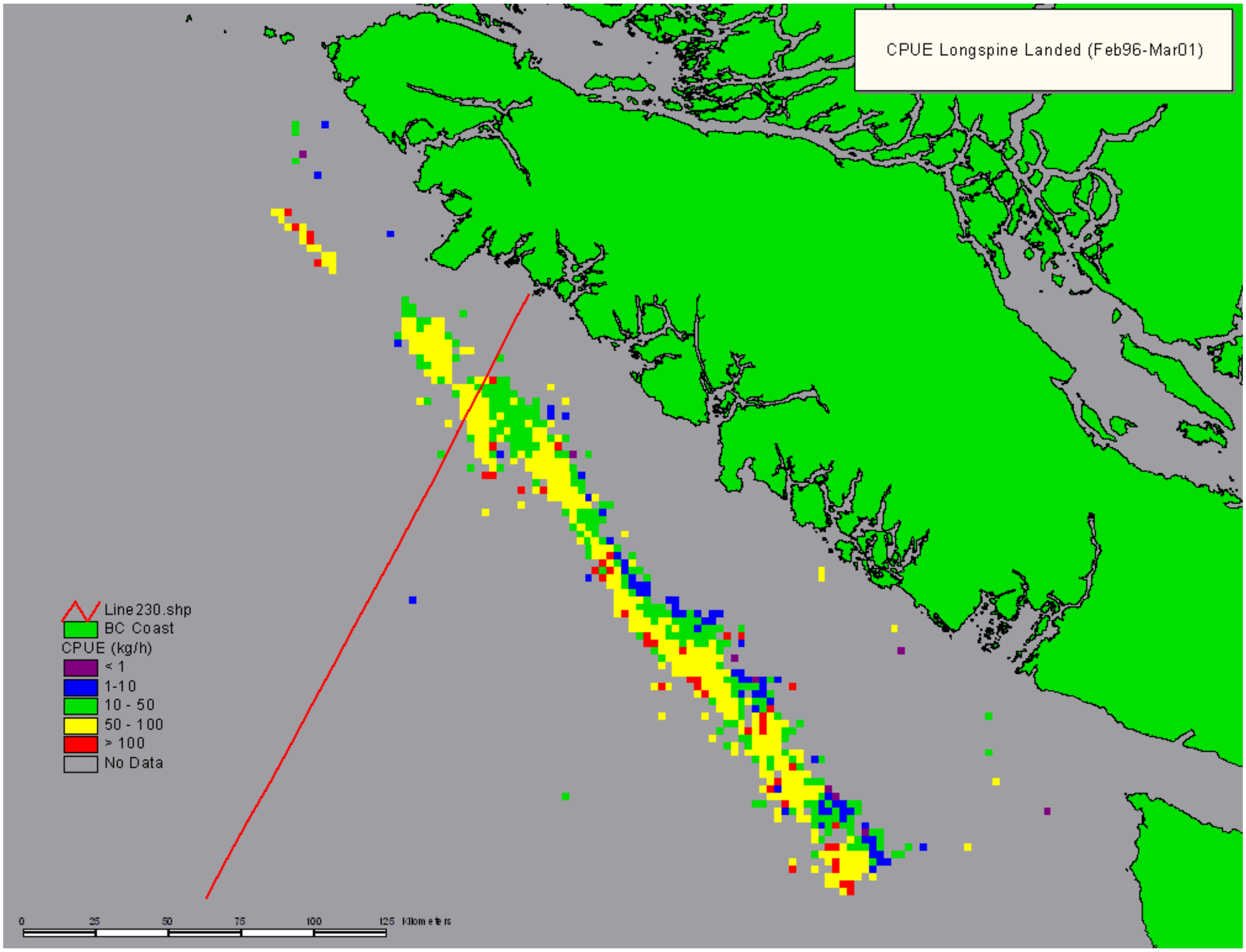

Figure 2. Distribution map of longspine CPUE for retained catch only (calculated for 5 km^2 grids using Eq. 3 and based on total catch and effort from February 1996 to March 2001). The "230 line" shown was used to divide tows in the PacHarvest database from the "traditional" Vancouver Island fishery to the south and east from the "exploratory" fishery to the north and west (Figure 1).

Three further large areas are proposed in this report to define the longspine exploratory fishery (Table 3). These area definitions are provided to differentiate among the new fisheries which are developing off Queen Charlotte Sound and the Queen Charlotte Islands from the slightly more developed fishery which exists immediately to the north and west of the "traditional" WCVI area.

Table 3. Definitions for the four areas used in this report for longspine catch and effort summaries.

Area Name	**Proposed Definition**
"Traditional" west coast Vancouver Island (WCVI)	All tows to the south and east of the 230° true line drawn from Lookout Island (Figure 1)
Northern Vancouver Island (NVI)	All tows to the north and west of the 230° true line drawn from Lookout Island (Figure 1) to Cape Scott and Triangle Islands
Outer Queen Charlotte Sound (QCS)	All tows between Cape Scott on Vancouver Island and Cape St. James at the southern tip of Moresby Island
West coast Queen Charlotte Islands (WCQCI)	All tows off the west coast of the Queen Charlotte Island and in Dixon Entrance

6.0 COMPARISON OF CATCH/EFFORT INFORMATION FROM THE "TRADITIONAL" LONGSPINE FISHERY AND THE EXPLORATORY AREAS

Annual summaries by standard (April to March) fishing year for each of the four areas defined in Table 3 show a declining pattern of catch in the "traditional" WCVI fishery and an equivalent increasing pattern in the exploratory areas, particularly in the Northern Vancouver Island area immediately to the north of the "traditional" area (Figure 3; Table 4). The intent of the management plan implemented in early 2000 was to encourage a northern movement of the fishery, but there is evidence that the shift had begun on a voluntary basis in 1999/00. In that fishing year, the data show a large increase in catch (to about 175 t) in the Northern VI area. Figure 2 shows that the only northern area on Vancouver Island which has had intensive longspine fishing activity is the area known as "Kyuquot" immediately to the north of the 230° degree line. Average catch rates in this region are as high as those experienced in the "traditional" areas (Figure 4;Table 4). Movement of the fishery into Queen Charlotte Sound and the west coast of the Queen Charlotte Islands occurred in 2000/01, with approximately 75 t of catch taken in the Outer QCS and 100 t in the WCQCI (Table 4). Catches in the Northern VI area increased another 50 t to 225 t in 2000/01.

Patterns in both types of effort (total hours fished and total tows) mirror the pattern in catch, with a strong increase in 1999/00 for the Northern VI area and in 2000/01 for all three exploratory areas (Figure 3; Table 4).

Catch per hour towed appears to have declined from the very high average catch rates seen in the first year of fishing in the "traditional" WCVI (Table 4). However, since that year, the change in catch per hour in this area has either levelled off or is declining slightly. Catch per tow on the other hand has increased steadily, likely reflecting the trend of every lengthening tows to catch this species (Figure 4). Catch per hour towed has increased dramatically in all three of the exploratory areas (Figure 4;Table 4), likely reflecting an increase in knowledge and understanding of these areas as the fisheries mature.

There is a suggestion in the data that the catch per hour towed is lower in the Outer QCS and the WCQCI fisheries. However, these fisheries are effectively completely new in 2000/01 and it is likely that CPUE will continue to rise as these areas become more fully developed. As well, it is known that the weather is poorer in these outer areas and it is likely that there is an interaction between catch rates and weather, with strong winds reducing the time of bottom contact, with a consequent decline in the estimate of catch per hour. Finally, the bottom topography may also affect catch rates, with less suitable grounds available for towing in the more northern areas.

Table 4. Annual summary statistics for the "traditional" longspine fishery and for the longspine exploratory areas as defined in Table 3. All years are standard fishing years (1 April – 31 March). Note that all effort measures are summed over all tows which either reported a catch or a discard of longspine thornyheads.

Standard Fishing Year	"Traditional" WCVI	Northern Vancouver Island	Outer Queen Charlotte Sound	West Coast Queen Charlotte Islands	Total Longspine Exploratory Areas	Total BC Coast
RETAINED CATCH (METRIC TONNES)						
1996/97	1,037.0	4.4	2.1	1.9	8.5	1,045.5
1997/98	475.4	0.5	6.9	1.4	8.8	484.2
1998/99	674.8	3.7	3.7	8.3	15.7	690.5
1999/00	574.8	177.1	0.5	14.7	192.4	767.2
2000/01	320.9	227.3	74.4	96.8	398.5	719.4
Total	3,087.9	413.0	87.6	123.1	623.8	3,711.8
DISCARD CATCH (METRIC TONNES)						
1996/97	105.3	1.0	1.1	0.2	2.3	107.6
1997/98	68.9	0.2	1.9	0.1	2.2	71.1
1998/99	111.6	0.3	2.1	0.2	2.5	114.1
1999/00	78.4	16.7	0.4	3.4	20.5	99.0
2000/01	40.1	48.4	6.7	19.4	74.5	114.7
Total	406.0	66.6	12.1	23.4	102.1	508.1
HOURS FISHED						
1996/97	13,099	148	249	155	552	13,650
1997/98	8,121	38	434	94	566	8,686
1998/99	11,046	55	164	445	663	11,709
1999/00	11,320	2,687	63	572	3,322	14,642
2000/01	6,068	3,834	1,531	2,242	7,607	13,675
Total	49,741	6,762	2,440	3,535	12,737	62,478
TOTAL TOWS						
1996/97	2,581	38	100	62	200	2,781
1997/98	1,633	18	127	32	177	1,810
1998/99	1,927	17	50	93	160	2,087
1999/00	1,575	377	22	141	540	2,115
2000/01	796	554	217	370	1,141	1,937
Total	8,535	1,004	516	708	2,228	10,763
RETAINED CATCH PER HOUR TOWED (KG/HR)						
1996/97	78.5	30.0	8.6	11.3	15.1	75.9
1997/98	58.4	14.0	15.7	14.7	15.4	55.6
1998/99	60.7	67.9	22.4	18.3	23.4	58.6
1999/00	50.6	65.5	8.4	25.8	57.5	52.2
2000/01	52.6	58.9	48.6	43.0	52.2	52.4
Total	61.7	60.7	35.9	34.6	48.7	59.1

Standard Fishing Year	"Traditional" WCVI	Northern Vancouver Island	Outer Queen Charlotte Sound	West Coast Queen Charlotte Islands	Total Longspine Exploratory Areas	Total BC Coast
DISCARD CATCH PER HOUR TOWED (KG/HR)						
1996/97	8.0	6.7	4.3	1.5	4.1	7.8
1997/98	8.5	5.5	4.3	1.2	3.9	8.2
1998/99	10.1	5.0	12.6	0.4	3.8	9.7
1999/00	6.9	6.1	5.7	6.0	6.1	6.7
2000/01	6.6	12.6	4.4	8.6	9.8	8.3
Total	8.1	9.8	5.0	6.6	8.0	8.1
RETAINED CATCH PER TOW (KG/TOW)						
1996/97	411	246	40	36	68	395
1997/98	309	106	64	53	64	288
1998/99	360	285	115	90	114	343
1999/00	379	475	31	111	368	376
2000/01	412	411	345	262	350	375
Total	374	429	206	180	301	359
DISCARD CATCH PER TOW (KG/TOW)						
1996/97	66	31	19	11	21	64
1997/98	60	13	19	9	17	56
1998/99	65	18	52	7	31	63
1999/00	57	47	21	35	43	53
2000/01	59	95	39	63	75	69
Total	62	71	31	50	57	61

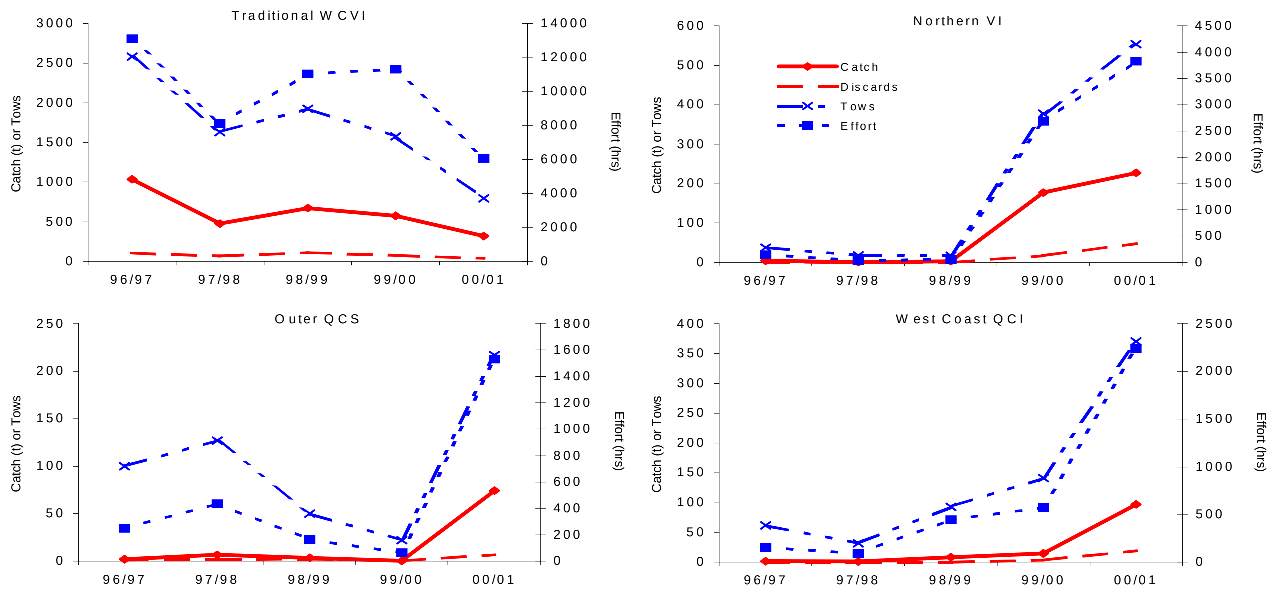

Figure 3 Annual (April-March) trends in retained catch ("catch"), discard catch ("discard"), total hours fished ("effort"), and total tows ("tows") in the four longspine areas as defined in Table 1. The legend is consistent across all graphs and only tows which recorded a retained or discarded longspine thornyhead are included.

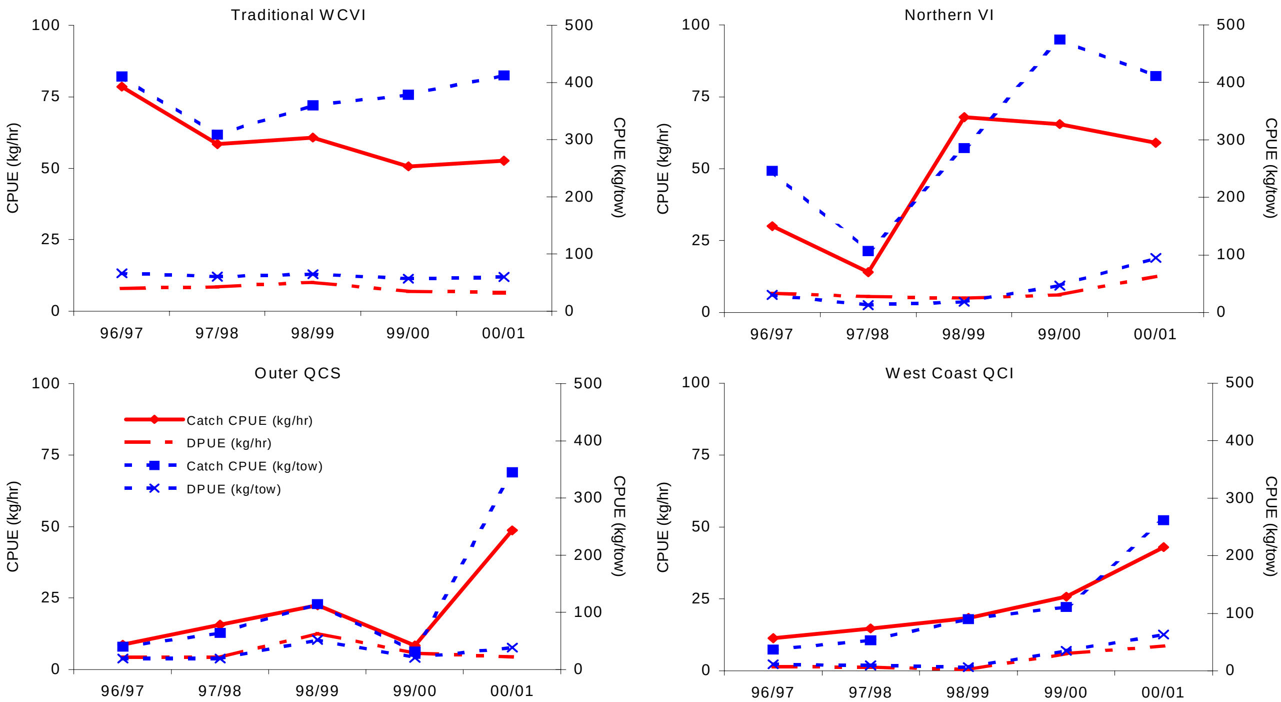

Figure 4. Annual (April-March) trends in retained catch per hour towed ["Catch CPUE (kg/hr)"], discard catch per hour towed ("DPUE (kg/hr)"), retained catch per tow ["Catch CPUE (kg/tow)"], and discard catch per tow ["DPUE (kg/tow)"] in the four longspine areas as defined in Table 4. The legend is consistent across all graphs and only tows which recorded a retained or discarded longspine thornyhead are included.

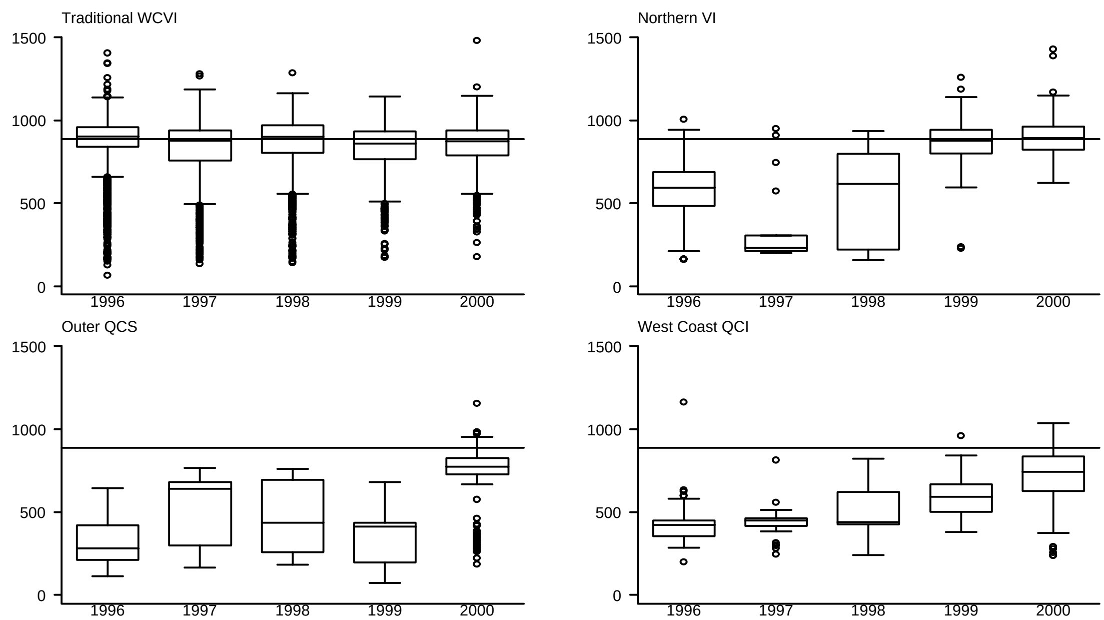

Figure 5. Distribution of depths for tows which either recorded a retained or discarded longspine thornyhead by standard fishing year and by the four longspine areas defined in Table 3. The horizontal line marks the median depth fished in the "traditional" WCVI longspine area in all four panels for comparison.

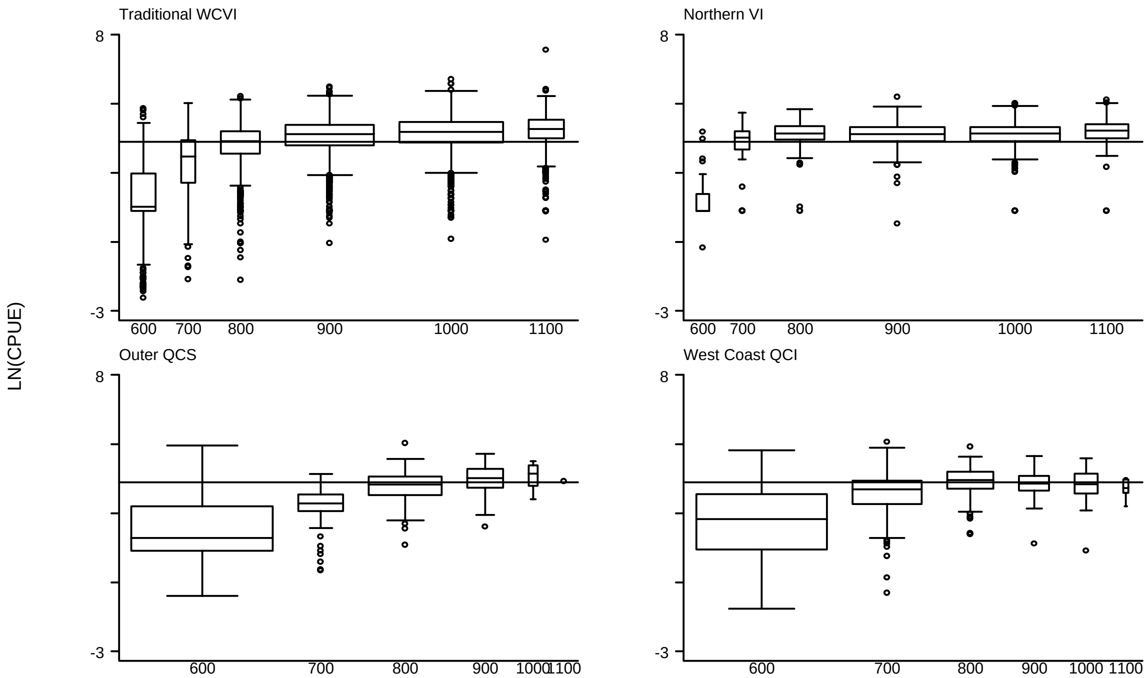

Figure 6. Distribution of ln(CPUE) by 100 m depth band (note that 600= 500-600 m band) and by the four longspine areas defined in Table 3 where ln(CPUE) is calculated as the retained catch divided by the hours towed for every tow that recorded a retained longspine catch in the dataset. The width of each box is proportional to the number of tows in that depth band within each longspine area. All tows below 600 m and above 1100 m have been pooled. The horizontal line marks the mean ln(CPUE) for the "traditional" WCVI longspine area in all four panels for comparison.

The distribution of depths fished by tows which recorded a catch or a discard of longspines has changed little in the five years of fishing in the "traditional" WCVI fishery (Figure 5). This reflects the developed nature of this fishery and the preferred depth range of this species. Tows in the years which preceded the development of the exploratory fisheries are distributed well below the preferred longspine depth range (Figure 5). The tows which caught longspines at these shallow depths may either reflect accidental bycatch or may be the result of observer inexperience in identifying this species. It is important to note that, once these fisheries became established (in 1999 for NVI and in 2000 for OQCS and WCQCI), the preferred depth ranges are very similar to those seen in the "traditional" WCVI fishery.

The distribution of log(CPUE) by depth is very predictable in all four areas, with uniformly increasing CPUE as depth increases (Figure 6). The large number of shallow tows in the OQCS and WCQCI fisheries which caught longspines may be, as suggested in the previous paragraph, due to species misidentification or small amounts of bycatch. Catch rates in all four areas are above average at depths greater than the 800-900 m band.

The information presented in this section shows that the new exploratory fisheries are comparable in terms of catch rates and depths fished to the more established traditional WCVI fishery once they become established as "mature" fisheries. The catch rates seen in the outer Queen Charlotte Sound and the west coast of the Queen Charlotte Islands will probably increase as these fisheries develop further.

7.0 COMPARISON OF LENGTH FREQUENCY DATA

Length frequency sampling of the longspine thornyhead fishery has been undertaken since the inception of the fishery, although extensive coverage did not begin until the 1998/99 fishing year (Table 5). The purpose of this sampling is to monitor any changes in the length frequencies in the catch taken by this fishery, both over time and between areas of the B.C. coast. It is not known if the population length structure will change significantly as the stock depletes, particularly if the distribution of lengths at age is broad (Hilborn and Walters 1992). However, this is one aspect of the fishery which is relatively easy to monitor and for which data have been collected. Given that an ageing protocol has yet to be developed for this species, it is reasonable to monitor these data to see if there are any detectable differences. Also it is likely that proportions by age in the catch will also be relatively uninformative as there is likely to be a considerable level of imprecision in the ageing procedure. Therefore, both methods are probably only sufficiently sensitive to detect major shifts in the population age or length structure.

The preparation of the length frequency data is described in Appendix B. This description includes the procedures used to scale the length frequency data to the catch (Appendix Table 5). Scaling to the catch was done to ensure that the available sample information was correctly weighted with respect to the amount of catch taken relative to each sample.

7.1 COVERAGE OF FISHERY

Catch-at-length samples have been obtained for longspine thornyheads from 19 different vessels during 206 trips in the five year history of the fishery to the end of March 2001 (Appendix Table 6). These vessels are mainly drawn from the 13 key vessels which target longspines (Appendix Table 1). Accordingly the sampled tows will largely represent the fishery as it was prosecuted in each of the sampled fishing years and will reflect over time any changes in fishing practises. It should be emphasised that this sampling procedure samples the catch rather than the underlying population.

There was a very large increase in the number of samples taken in the 2000/01 fishing year with the addition of 1,016 sampled tows to increase the total number of tows sampled from 386 to 1,402 in a single year (Appendix Table 7 and Appendix Table 8). The total number of longspines measured also increased by 34,500 from 59,600 to 97,100 measured (Appendix Table 7 and Appendix Table 9). However, while the number of samples collected in the northern fisheries increased substantially, the relative number of lengths measurements in these fisheries were not as high as in the traditional WCVI fishery.

Other measures also show how much sampling increased in the 2000/01 fishing year. For instance 78 trips of a possible 226 were sampled, but these trips represented nearly 100% of the total longspine catch (Table 5) which probably indicates that the remaining 148 trips are probably artefacts of the way that the data were qualified for the table and were not primarily directed at longspines. When the data are summarised by tow, it shows that 40% of the possible tows were sampled which represented over 50% of the longspine catch (Table 6). Another major change that occurred in this fishing year was the instruction to sample more frequently while on board the vessel. Previously only one or two tows would be sampled on a trip. But in 2000/01, many trips had over 10 tows sampled and one trip had 71 tows sampled (Table 7).

Table 5. Number of trips and the representative catch from those trips by standardised fishing year which have had at least one length sample taken during the trip compared to the total number of trips and catch taken by all tows at depths of 500 m or greater.

Fishing Year	Number trips with samples	% of trips with samples	Total trips	Total Catch of trips with samples	% catch of trips with samples	Total catch (t)
1996	1	0%	351	7.1	1%	1038.8
1997	11	4%	246	116.3	24%	479.9
1998	54	24%	221	409.4	59%	692.2
1999	62	25%	251	530.3	69%	771.4
2000	78	35%	226	698.0	95%	737.5
Total	206	16%	1295	1761.1	47%	3719.8

Table 6. Number of tows and the representative catch from those tows by standardised fishing year that were sampled for longspine thornyheads taken during the trip compared to the total number of trips and catch taken by all tows at depths of 500 m or greater.

Fishing Year	Number tows with samples	% of tows with samples	Total tows	Total Catch (t) of tows with samples	% catch of tows with samples	Total Catch (t)
1996	15	0%	3,217	4.6	0%	1038.8
1997	16	1%	2,216	8.7	2%	479.9
1998	127	5%	2,371	56.1	8%	692.2
1999	226	9%	2,596	91.7	12%	771.4
2000	1,011	39%	2,590	380.1	52%	737.5
Total	1,395	11%	12,990	541.2	15%	3719.8

Table 7. Frequency of the number of tows sampled per trip in each of the five standard fishing years.

Number tows sampled	1996-97	1997-98	1998-99	1999-2000	2000-01	Total
1		8	24	16	6	54
2		1	19	22	12	54
3		2	7	5	3	17
4			1	7	2	10
5				5	3	8
6				2	5	7
7					5	5
8			1	2	4	7
9					2	2
10					1	1
11					4	4
12					2	2
13					2	2
14				1	2	3
15	1		1		2	4
16					4	4
17			1		3	4
19					1	1
20+				2	15	17
Total	1	11	54	62	78	206

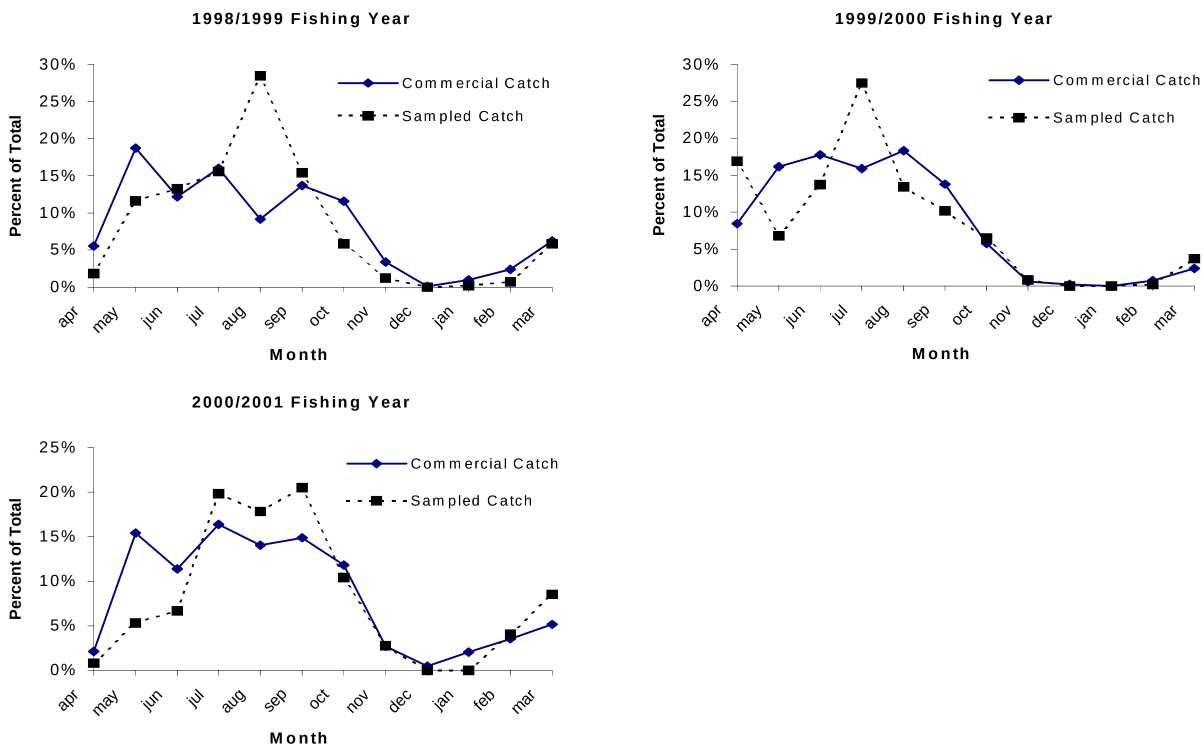

Figure 7. Distribution of sample coverage by month for the three most recent fishing years compared to the actual distribution of catch by month for the same periods.

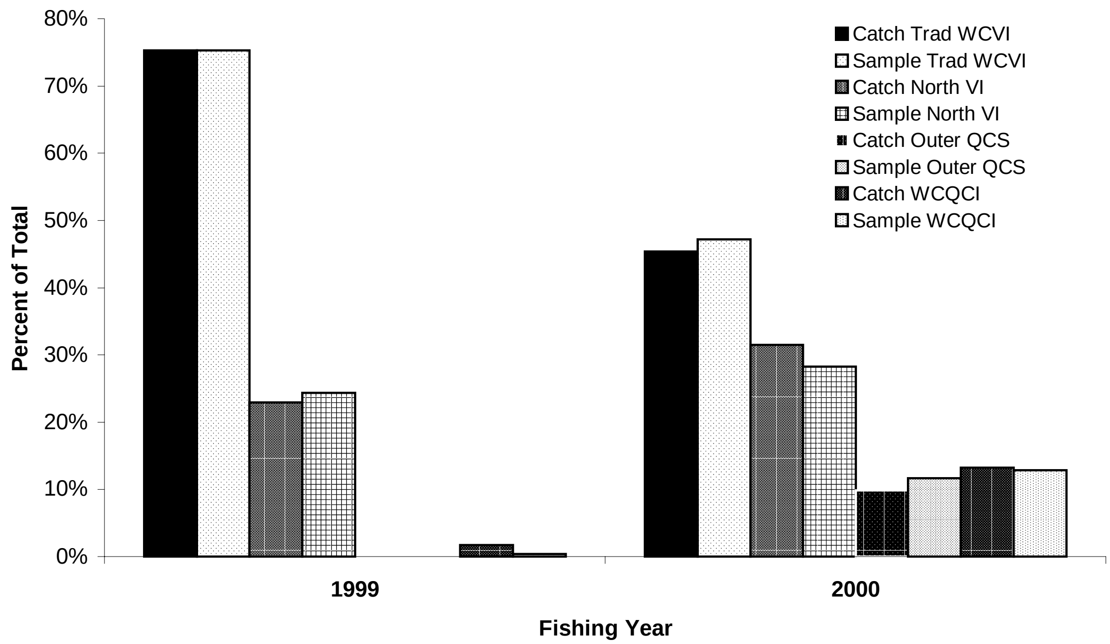

Figure 8. Distribution of sample coverage by the longspine exploratory areas defined in Table 3 for the two most recent fishing years compared to the actual distribution of catch by the same longspine areas.

The coverage of the sampling program can be evaluated by month (Figure 7) which shows the continuation of the tendency shown in earlier years of oversampling during the summer months (probably when it is easier to obtain good observers). The sample coverage by area seems very representative in 2000/01 (Figure 8). This is important to establish as this sampling program is an important research tool which is used to evaluate these developing fisheries. Finally, the distribution of samples by depth appears to be representative in all recent years (Figure 9).

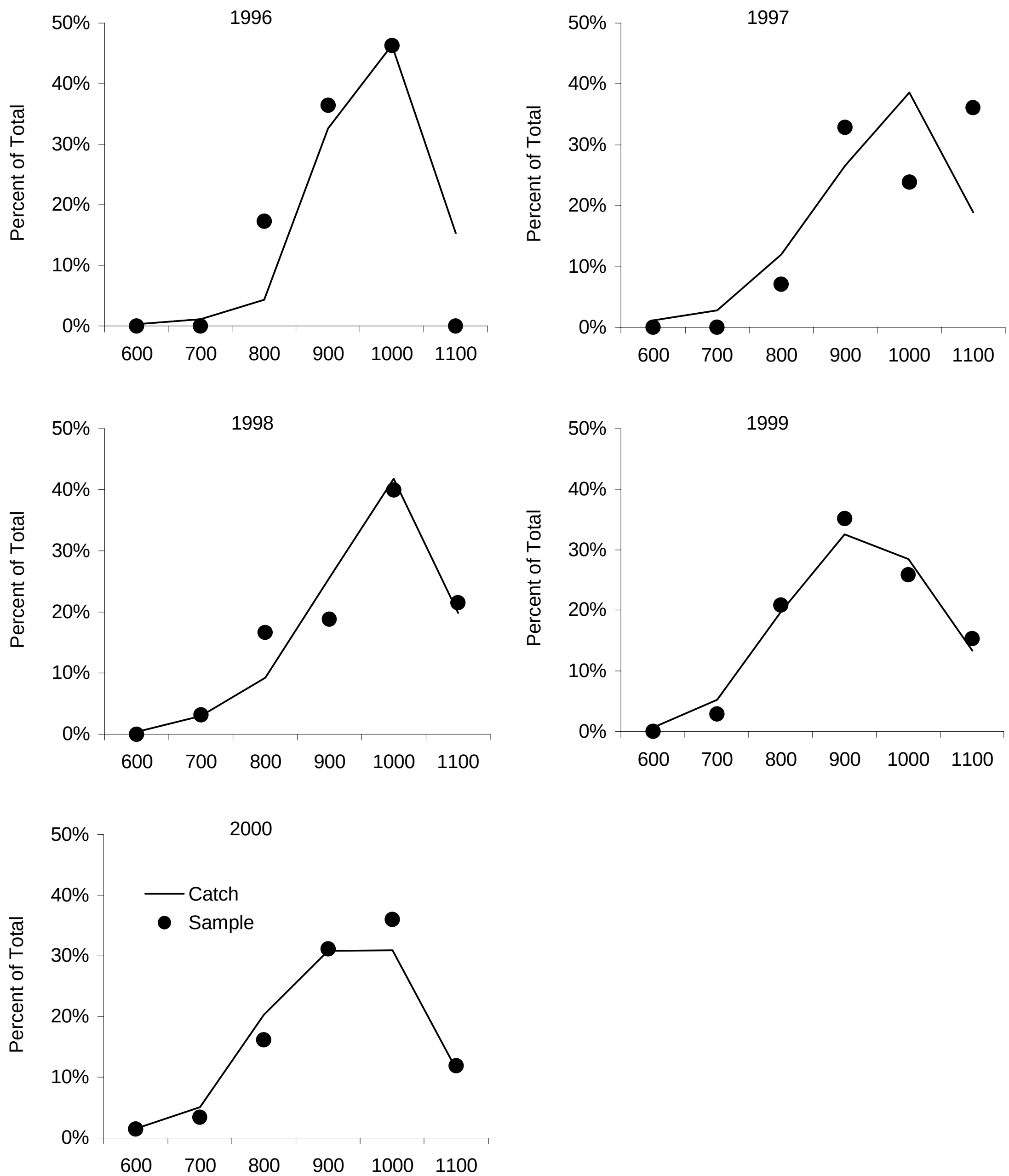

Figure 9. Distribution of sample coverage by 100 m depth bands for the five standardised fishing years compared to the actual distribution of catch by 100 m depth bands. Catch distribution is shown by the solid line and sample distribution is shown by the solid circles.

7.2 LENGTH FREQUENCY DISTRIBUTIONS BY SAMPLE CATEGORY

The mean, median and the distribution percentiles for the retained catch samples are very similar to those for the total catch samples, indicating that, on average, the biomass of discarded longspines is small relative to the biomass of the retained catch (Table 8). The equivalent distributions for the discard samples are much smaller than for the other samples, reflecting the small size of the effective commercial size limit (190 mm).

Table 8. Mean, standard deviation, 1%, 50% and 99% of the scaled (to tow catch) length distributions by standard fishing year and sample type.

Fishing Year	**Statistic**	**Sample Type**			**Total**
		Total catch	**Retained catch**	**Discard catch**	
1996/97	Mean		238		238
	Standard Deviation		26		26
	P1%		160		160
	Median		240		240
	P99%		290		290
1997/98	Mean	243	238	257	243
	Standard Deviation	35	25	19	33
	P1%	160	160	221	160
	Median	240	240	257	240
	P99%	350	290	310	340
1998/99	Mean	242	245	213	244
	Standard Deviation	32	28	24	29
	P1%	160	160	150	160
	Median	244	250	220	250
	P99%	320	310	260	310
1999/00	Mean	245	250	168	242
	Standard Deviation	27	25	24	31
	P1%	170	190	100	150
	Median	245	250	170	246
	P99%	300	310	230	302
2000/01	Mean	242	240	165	241
	Standard Deviation	29	26	22	30
	P1%	158	184	100	151
	Median	243	240	170	243
	P99%	304	305	210	304
Total	Mean	242	245	178	241
	Standard Deviation	29	27	35	30
	P1%	160	170	100	150
	Median	243	250	170	243
	P99%	305	305	276	305

Scaling of the samples to the catch by the sampled tow or by the sampled trip has almost no effect on the estimated distributions of longspines, regardless of the sample type investigated (total catch: Appendix Figure 2; retained catch: Appendix Figure 3; and discard catch: Appendix Figure 4). This lack of sensitivity to the sampling assumptions indicates that the length distribution is very uniform across areas. There does not appear to be any trend in length frequency over time for either the total catch or retained catch samples (Figure 10). The discard catch samples have decreased in size over the four year period of sampling (Figure 10), but this may either be an artefact of unrepresentative sampling for this catch category or a change in the discard practices over the sampling period.

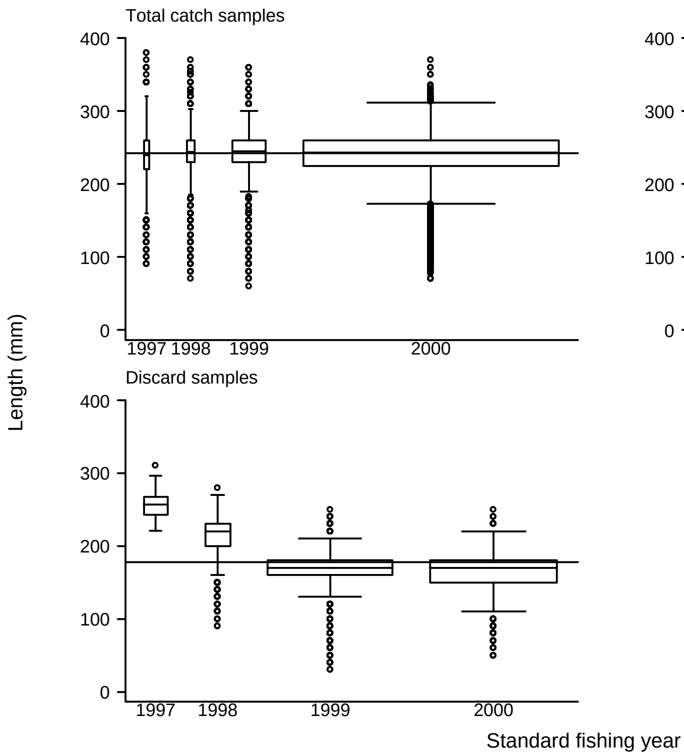

Figure 10. Box plots of the scaled (to the sample tow catches) length frequency distributions by sample type and standard fishing year. Horizontal line is the scaled mean length for each sample type across all fishing years and the width of the boxes is proportional to the sample size.

7.3 LENGTH FREQUENCY DISTRIBUTIONS BY LONGSPINE AREA

There is a suggestion in the summary statistics that the mean length from the Northern Vancouver Island longspine catching area may be slightly smaller than the traditional WCVI fishery or the two northern fisheries (Figure 11; Figure 12; and Table 9). However, the difference is slight and it is not known if these differences will be maintained over time. The discard samples from the west coast QCI are much smaller than from the other areas (Figure 12). This area should continue to be monitored to determine if this will be a consistent pattern over time as this is only the first year of length samples from this area.

Table 9. Mean, standard deviation, 1%, 50% and 99% of the scaled (to sample tow catch) length distributions by standard fishing year and longspine catching area defined in Table 3. Sample type "Total" and "Retained" have been combined in this summary, given the small differences seen in the mean statistics between these two categories in Table 8.

	Statistic	Traditional WCVI	Northern Vancouver Island	Outer Queen Charlotte Sound	West Coast Queen Charlotte I.	Total
1996	Mean	238				238
	Standard Deviation	26				26
	P1%	160				160
	Median	240				240
	P99%	290				290
1997	Mean	242				242
	Standard Deviation	33				33
	P1%	160				160
	Median	240				240
	P99%	340				340
1998	Mean	244				244
	Standard Deviation	29				29
	P1%	160				160
	Median	250				250
	P99%	310				310
1999	Mean	248	242			246
	Standard Deviation	26	26			26
	P1%	180	170			180
	Median	250	240			250
	P99%	310	300			310
2000	Mean	244	236	243	242	242
	Standard Deviation	28	28	31	30	29
	P1%	160	152	160	167	159
	Median	246	238	246	242	243
	P99%	305	300	305	309	304
Total	Mean	245	237	243	242	242
	Standard Deviation	28	28	31	30	29
	P1%	160	155	160	167	160
	Median	248	240	246	242	244
	P99%	310	300	305	309	305

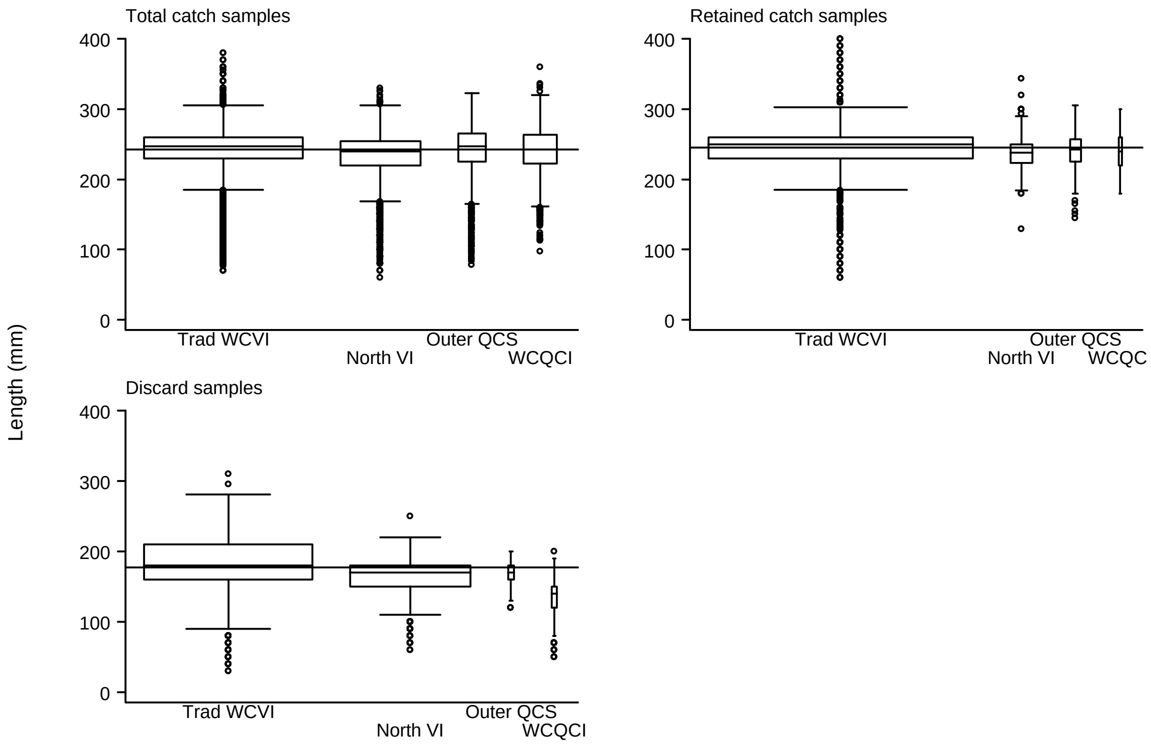

Figure 11. Box plots of the scaled (to the sample tow catches) length frequency distributions by sample type and longspine catching area defined in Table 3. Horizontal line is the scaled mean length for each sample type across all longspine catching areas and the width of the boxes is proportional to the sample size.

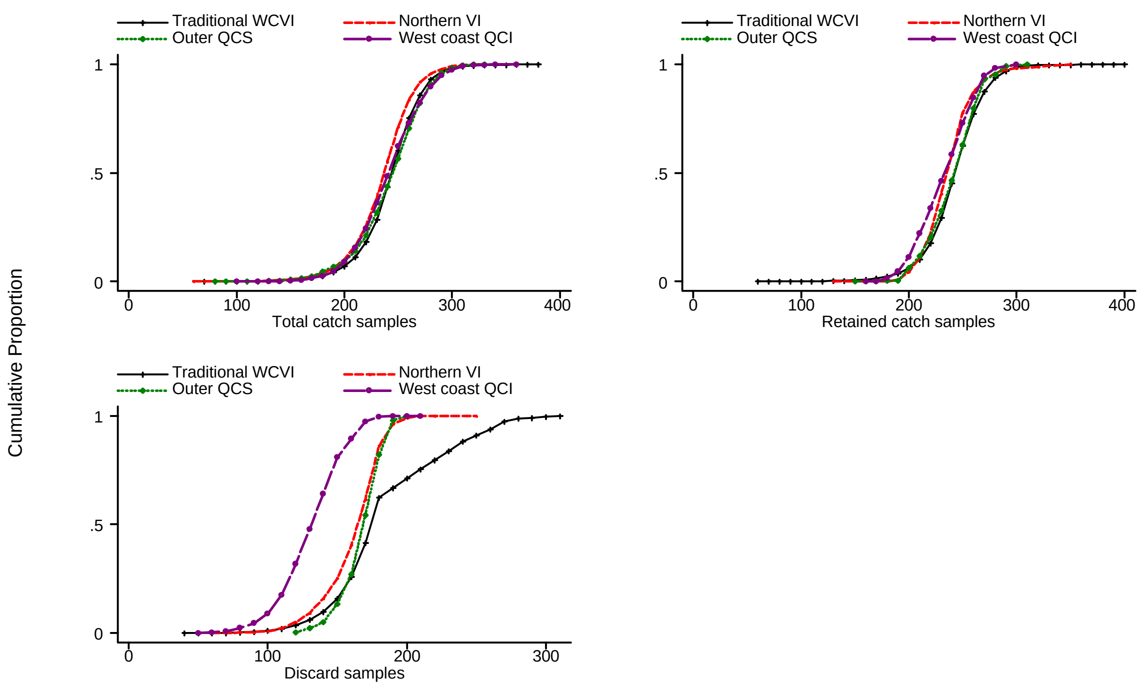

Figure 12. Cumulative frequency plots of the scaled (to the sample tow catches) length frequency distributions by sample type and longspine catching area defined in Table 3.

7.4 LENGTH FREQUENCY BY DEPTH

There does not appear to be much variation in the length distributions between the 100 m depth bands in any of the four longspines areas (Table 10; Figure 13). As seen in Table 9, there is a suggestion from Table 10 that the Northern Vancouver Island samples are smaller at depth compared to the "traditional" WCVI area, but this should be monitored over a longer time period of time to determine if the difference persists.

Table 10. Mean, standard deviation, 1%, 50% and 99% of the scaled (to sample tow catch) length distributions by 100 m depth band and longspine catching area defined in Table 3. Sample type "Total" and "Retained" have been combined in this summary, given the small differences seen in the mean statistics between these two categories in Table 8. Depth band intervals are the upper bound of each interval (700= 600-700 m) and the 600 m and 1100 m depth bands are pooled categories. Table totals will be the same as in Table 9.

	Statistic	Traditional WCVI	Northern Vancouver Island	Outer Queen Charlotte Sound	West Coast Queen Charlotte I.	Total
600	Mean	244		243	257	254
	Standard Deviation	31		27	31	31
	P1%	157		170	178	170
	Median	249		240	258	253
	P99%	298		298	318	318
700	Mean	253	230	240	252	249
	Standard Deviation	26	29	22	32	30
	P1%	173	150	178	171	170
	Median	253	231	239	253	250
	P99%	300	277	273	312	309
800	Mean	247	240	245	241	245
	Standard Deviation	28	27	31	31	29
	P1%	160	160	155	160	160
	Median	250	240	249	241	248
	P99%	310	296	305	309	304
900	Mean	245	237	243	234	242
	Standard Deviation	28	28	32	26	29
	P1%	166	154	160	167	160
	Median	250	239	246	234	244
	P99%	310	300	305	296	306
1000	Mean	244	237	238	239	242
	Standard Deviation	28	28	28	28	28
	P1%	160	155	170	175	160
	Median	245	240	240	240	242
	P99%	310	300	296	301	303
1100	Mean	243	235	240	237	239
	Standard Deviation	29	28	23	32	29
	P1%	150	154	183	159	151
	Median	244	237	246	241	240
	P99%	305	300	267	295	303

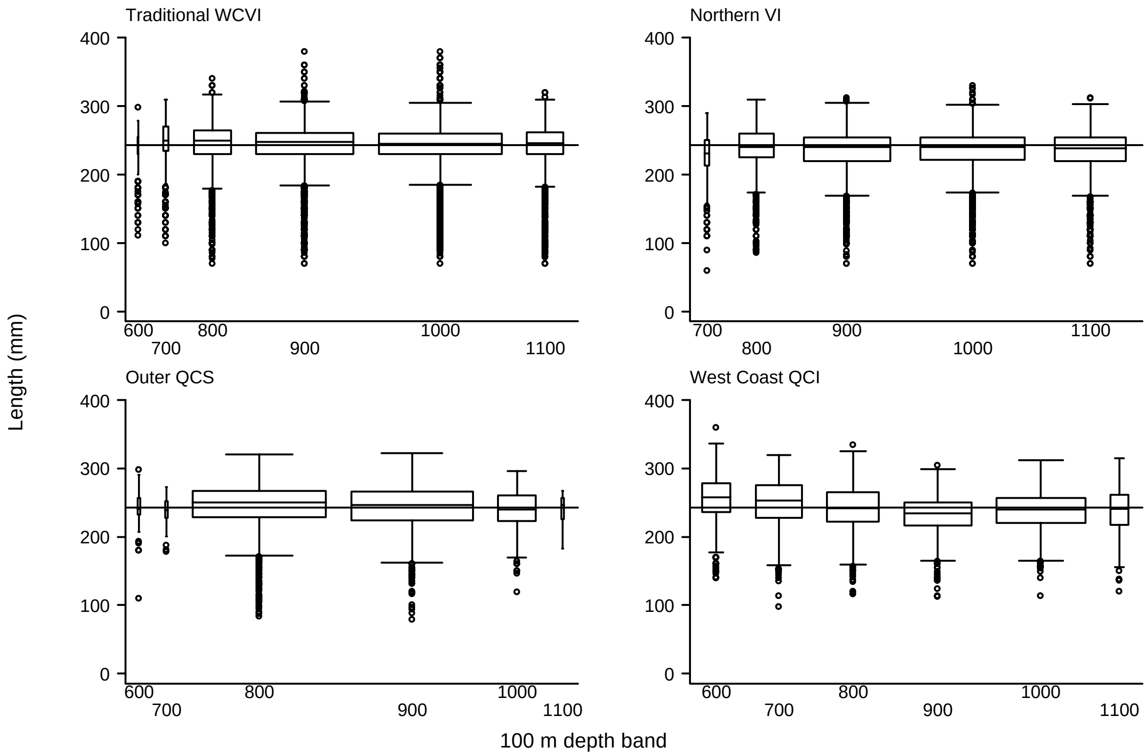

Figure 13. Box plots of the scaled (to the sample tow catches) length frequency distributions by depth for the total catch sample type only for each of the four longspine areas. Horizontal line is the scaled median length for all depths and areas and the width of the box is proportional to sample size. Depth band intervals are the upper bound of each interval (700= 600-700 m) and the 600 m and 1100 m depth bands are pooled categories.

7.5 LENGTH FREQUENCY BY SEX

Sampling information by sex has been poor until the most recent fishing year (Table 11) when approximately 18,000 of the 30,000 length samples taken in the total catch sample type in 2000/01 were examined for sex (Table 11 and Appendix Table 7). The total number of length samples examined for sex is only 20,000 of a total of 50,000 in the total catch sample category.

The sex ratios estimated in the most recent year appear to be slightly skewed to females (Table 11), with about 55% of the scaled sample population being female (excluding unknown sexes). Small longspines are difficult to sex reliably. As a result, the size distribution of this sex class tends to be smaller than for the fish identified as male or female (Figure 14). The size distribution for males is very similar to that for females, as is the size distribution of the sexes in the total and retained sample types (Figure 14).

Figure 14 shows that the mean length of the discarded fish with known sex is much larger than the mean length for that sample type category while the other sample types appear to have been sampled more representatively. This indicates that the samples which have been sexed from discard samples are not representative and is probably due to the fact that is not easy to reliably determine the sex of small longspines.

Table 11. Scaled (to catch by sampled tow) number of fish and sex ratios for those tows which were sampled for sex using total catch samples by fishing year and area sampled.

Fishing Year	Area	Unknown	Male	Female	Unknown	Male	Female
1997/98	WCVI	113	133	179	27%	31%	42%
1998/99	WCVI	2	296	113	0%	72%	27%
1999/00	NVI		25	28	0%	47%	53%
	WCVI	15	124	111	6%	50%	44%
	Total	15	149	139	5%	49%	46%
2000/01	NVI	607	1511	1910	15%	38%	47%
	OQCS	189	929	1114	8%	42%	50%
	QCI	414	1231	1495	13%	39%	48%
	WCVI	1002	2847	3643	13%	38%	49%
	Total	2212	6518	8162	13%	39%	48%
All years	Total	2342	7096	8593	13%	39%	48%

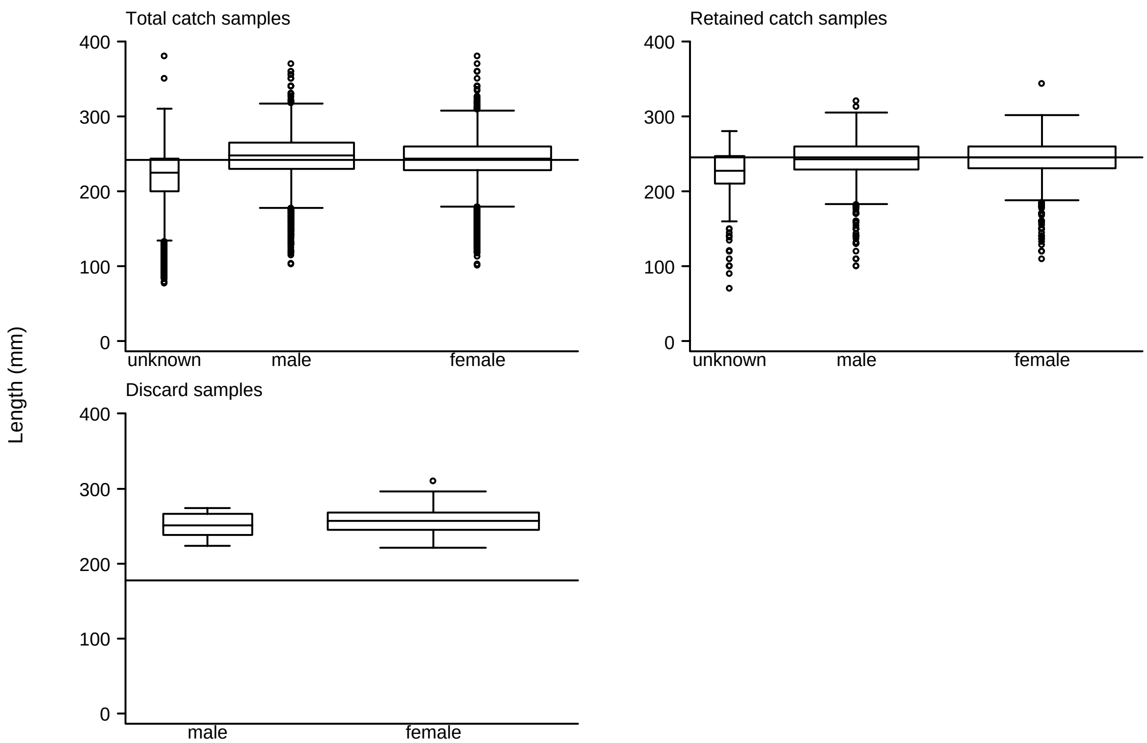

Figure 14. Box plots of the scaled (to the sample tow catches) length frequency distributions by sample type and by sex. Horizontal line is the scaled mean length for each sample type across all valid lengths, including lengths that have not been sexed and the width of the box is proportional to the sample size.

7.6 CONCLUSIONS FROM LENGTH FREQUENCY ANALYSIS

The available data indicate that there are only very small differences in the length distributions either by fishing year (Figure 10), by area (Figure 11 and Figure 12) or by depth (Figure 13). These observations indicate that the apparent population distribution has been very stable over the four years of available data in the traditional WCVI fishery and is very similar in all parts of the coast in the most recent fishing year and at all depths. The only consistent difference appears to be a suggestion from Table 9 and Table 10 that the samples from the Northern Vancouver Island area may be slightly smaller than from the "traditional" Vancouver Island fishery. This difference should be monitored over the next few years to determine if it persists. Also, the discard samples from the west coast of the Queen Charlotte Islands appears to be considerably smaller than the discard samples from the other three areas (Figure 12). This difference should also be monitored over the next few years to determine if it persists.

There are numerous hypotheses which could be made to provide an explanation for the observation of stability between areas and over the five years of fishing, including a low productivity, a low exploitation rate, poor recruitment, or a reservoir of unexploited fish with constant migration to the fished areas. However, such explanations would be speculative as there is no information presently available to select among the possible hypotheses.

Table 12. Estimates of the percent of the catch which is below the effective commercial size limit (190 mm) by fishing year based on the total catch sample distributions (Appendix Figure 2).

Fishing Year	By number in the sample	Unscaled sample	Scaled to catch in sampled tow	Scaled to catch in sampled trip
1997	6%	3%	4%	2%
1998	3%	2%	2%	2%
1999	3%	2%	1%	1%
2000	4%	2%	2%	3%

Table 13. Estimates of discard proportion taken from Table 4 by standard fishing year and longspine catching area.

Fishing Year	Traditional WCVI	Northern Vancouver Island	Outer Queen Charlotte Sound	West Coast Queen Charlotte I.	Total
1996/97	9%				9%
1997/98	13%				13%
1998/99	14%				14%
1999/00	12%	9%			11%
2000/01	11%	18%	8%	17%	14%

The length frequency data can be used to estimate the size of the discard catch relative to the total catch. These estimates are presented in Table 12, based on the distributions in the "total catch" samples presented in Appendix Figure 2. It is apparent that the estimated proportions are very small (1 to 4% by weight; 3 to 6% by numbers). An alternative estimate of the proportion of the catch discarded by weight can be taken directly from the estimates of catch and discard in Table 4 and are presented in Table 13 (9 to 18% by weight). These estimates are 3 to 4 times larger in percentage terms than those in Table 12, but these differences should be treated with caution as there is likely a considerable amount of error in both sets of estimates. However, given that the discard proportion is consistently estimated at a higher level when based on the catch data than when based on the length frequency data, it is plausible that either the total (unsorted) length samples are not capturing the smaller tail of the distribution very well or that the discard samples are consistently overestimated.

There is also some indication in Table 13 that discard rates are higher in the northern exploratory areas than in the "traditional" WCVI fishery. This tendency should be monitored as these fisheries progress in the next few years.

8.0 GLM Analysis of Catch/Effort Data

The most common reason to undertake analyses of fishery catch and effort data is to calculate an index of population abundance for the stock in question through a measure of relative catch per unit effort (CPUE). The underlying assumption in such an analysis is that variation in relative CPUE is proportional to the abundance of the underlying vulnerable fish population. As such a such an analysis usually extends over a considerable period of time, it is further assumed that changes in the dynamics of the fishery, including changes in the gear being fished and the application of learning are not changing systematically over the same time period (or at least that these changes are relatively minor compared to the changes in abundance).

Testing such assumptions is not easy and usually requires a fishery independent measure of abundance against which the CPUE-based abundance index can be gauged. No fishery independent indices of abundance are yet available for longspine thornyheads on the B.C. coast (although such an index is currently being developed). Therefore it is not known if the abundance indices calculated in this section are proportional to the abundance of longspine thornyheads. Scatter plots of catch and effort indicate that there is an increasing linear trend of catch with increasing effort (Figure 15). While this is not proof that CPUE and abundance are related, it suggests that some form of relationship does exist between these two measures. This paper will by default assume that such a relationship exists.

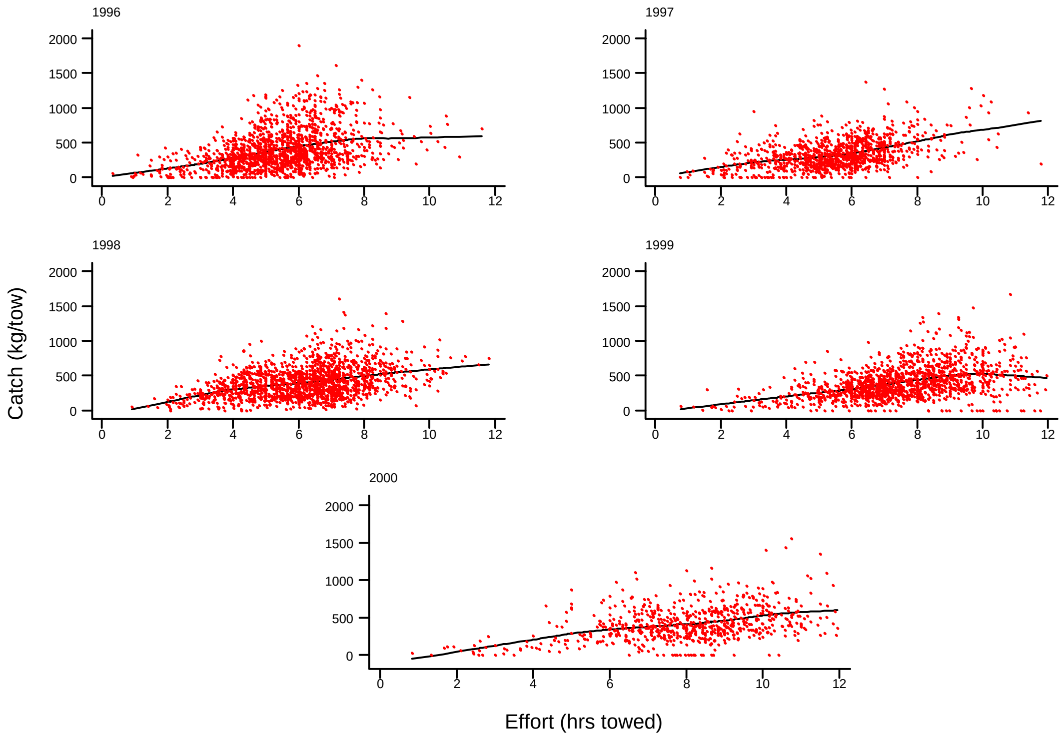

Figure 15. Scatter plots of catch per tow (kg) against the number of hours towed in the "traditional" Vancouver Island fishery by fishing year. A lowess line has been fitted to these data to show the underlying trend of the data.

8.1 SELECTION OF GLM VARIABLES AND MODELS

After making preliminary exploratory analyses, only one model was selected to be reported in detail (Table 14). This decision was dictated by the amount of data available, particularly given that the historical development of the fishery described in Section 6.0 which shows that the only area which has been consistently part of the fishery is the "traditional" WCVI fishery. Also the choice to only model the "traditional" area was made because this area has by far the largest share of the available data which means that any model conclusions would be mainly attributable to this area, making it sensible to confine the analysis to that area alone. Unfortunately, this model selection choice also means that a considerable amount of the more recent data cannot be used in the analysis (Table 4), given the movement of the fishery into new areas and the restriction of the southern fishery. Note that direct comparisons of the unstandardised catch rates between the four longspine areas defined in Table 3 can be made from Table 4.

Table 14. Model investigated using general linear modelling for longspine thornyheads and the time periods included in the modelling.

Area	**Time period**	**Data used** (see Appendix A)
"Traditional" west coast Vancouver Island longspine fishery (Table 3)	April 1996 – March 2001	All tows from 13 top vessels with declared mean depth greater than 700 m. Zero tows have LN(CPUE)=1 added.

The preliminary analyses reported in the previous paragraph showed that the model results were all relatively insensitive to assumptions about the depth intervals used, or the selection of vessels or of areas. This insensitivity is primarily attributable to the fact that the large majority of data comes from the traditional west coast Vancouver Island fishery and the catches were taken by a small number of core vessels. It was this observation that led to the decision to only report on one model.

As log(CPUE=0) is undefined, tows with zero catch either have to be dropped from the analysis or another distribution (other than lognormal) be used to characterise these tows. A binomial model is frequently used in analyses of fisheries catch and effort data to model the probability of a zero tow (e.g. Francis 2001). However, the number of zero tows in the data set are very low (Appendix Table 12) and there is no apparent annual trend. Some of the preliminary analyses showed that the available data did not allow a binomial model to be reliably estimated even when additional zero tows from more shallow depths were included in the analysis. Starr & Haigh (2000) added log(CPUE=1) to the zero tows and it was decided to continue with this decision. Nine of the positive tows in the data set have values lower than this number, but it has been found by experience that adding a very small number to the zero tows gives these tows an unreasonable amount of leverage. Therefore, it is better to add a value which is close to the smallest actual values in the dataset.

The GLM analysis reported by Starr & Haigh (2000) only used one area definition variable predictor. This analysis investigated a number of other area predictors, most of which were based on the Universal Transverse Mercator Grid system described by Schnute et al. (2000). All tows were assigned to unique grid blocks and these categorical variables were offered to the regression model as predictor variables along with the 0.1° latitude band used by Starr & Haigh (2000) and a large-scale area predictor based on the DFO minor statistical areas (Table 15). The model would then select the area categorical variable which had the best fit to the data, based on the selection criteria described in Section 4.0.

Table 15. Area categorical variables used in the longspine general linear modelling.

Variable	Description
5km	constant 5 km^2 grid blocks
10km	constant 10 km^2 grid blocks
25km	constant 25 km^2 grid blocks
40km	constant 40 km^2 grid blocks
Lat	0.1° latitude strips (WCVI models only)
Minor	DFO minor statistical areas

Details on the preparation of the data used in the final model, including the criteria used to select the data, are presented in Appendix A. The methodology used in the analysis is described in Section 4.0. A presentation of auxiliary information on the distribution of some of the data variables used in the regression model, including the distribution of tows and of log(CPUE) relative to key model predictors, is provided in Appendix F.

8.2 ANALYSIS OF THE TRADITIONAL WEST COAST VANCOUVER ISLAND FISHERY

The analysis of the traditional west coast of Vancouver Island fishery selected five predictor variables into the model, one of which was fishing year which is the variable used to index relative changes in stock abundance (Table 16). The predictor variable selected first by the model was the vessel categorical variable which explained about 10% of the total residual deviance. Fishing year was the last predictor introduced into the model as it has relatively low explanatory power. The only area predictor variable selected by the model was the 0.1° degree latitude band variable which was also selected in the model reported by Starr & Haigh (2000).

Table 16. Results for the traditional west coast Vancouver Island GLM regression model for longspine thornyheads, presented in the order of acceptance to the model. The variable selection process operated for five iterations before the stopping criterion described in Section 4.0 was invoked. Selected model predictor variables are indicated with a *. Table values are the proportion of the total residual deviance explained by each predictor variable at the specified model iteration.

Variable	1	2	3	4	5	6
Vessel*	0.0999					
Depth*	0.0469	0.1394				
0.1° latitude band*	0.0578	0.1367	0.1816			
Month*	0.0236	0.1286	0.1707	0.2084		
Fishing year*	0.0191	0.1144	0.1467	0.1945	**0.2242**	
10 km^2 grid	0.0522	0.1440	0.1825	0.1933	0.2190	0.2347
5 km^2 grid	0.0441	0.1292	0.1650	0.1905	0.2172	0.2328
Number species in tow	0.0022	0.1022	0.1432	0.1832	0.2104	0.2313
25 km^2 grid	0.0460	0.1355	0.1746	0.1906	0.2167	0.2310
40 km^2 grid	0.0226	0.1286	0.1737	0.1901	0.2151	0.2309
DFO minor stat area	0.0111	0.1106	0.1495	0.1845	0.2115	0.2276
Time of day set	0.0002	0.1002	0.1396	0.1818	0.2086	0.2244
Number of tows by vessel	0.0452	0.0999	0.1394	0.1816	0.2084	0.2242
Increase in proportion deviance explained	0.0000	0.0394	0.0422	0.0268	0.0157	0.0071

The total residual deviance explained by the model is 0.22 (Table 16), which is very similar to the value of 0.21 reported by Starr & Haigh (2000). The selected model variables are also the same as those reported last year, except that the order of acceptance was reversed between the depth and latitude predictors.

The plot of abundance indices shows a decline in estimated abundance from 1996/97 to 1999/00 and an possible levelling off in 2000/01 (Figure 16 and Figure 17). The total estimated drop in abundance is about 25% over the modelled time period (Table 17). This plot also shows that the standardised abundance index is very similar to the unstandardised simple indices plotted from the same data, indicating the standardisation procedure has not affected the underlying trend in the data. This may be due to an abundance distribution which is relatively independent of the fishery dynamics.

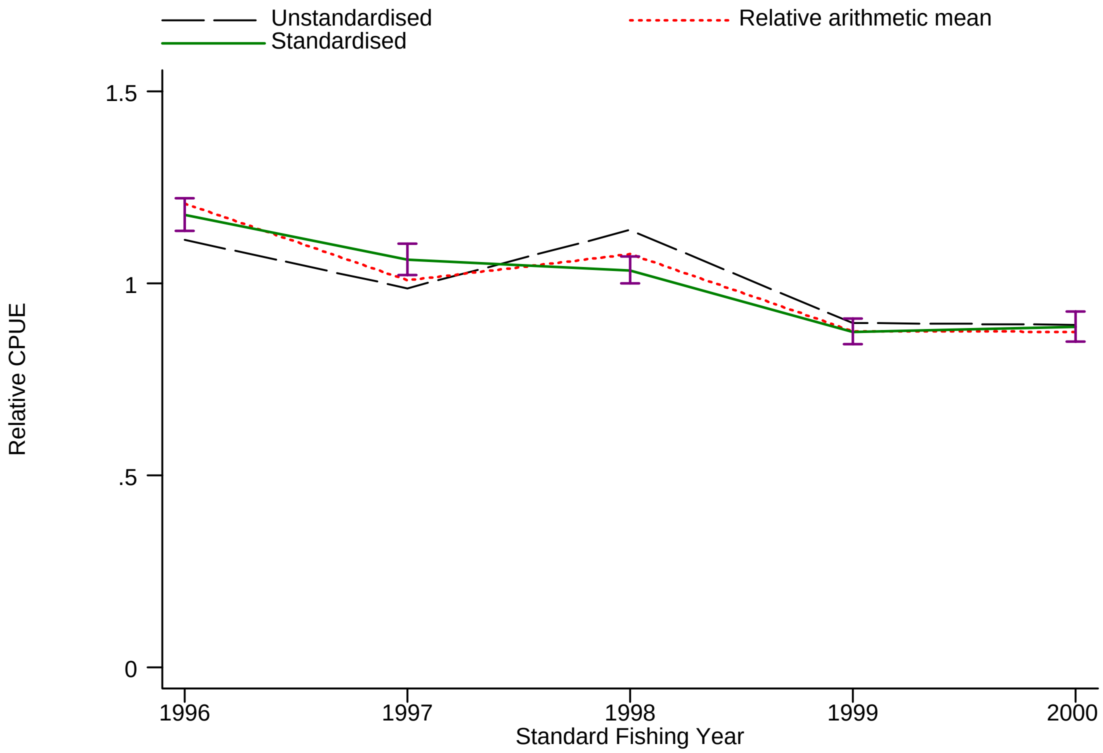

Figure 16. Plot of fishing year abundance estimates for traditional WCVI regression model with LN(CPUE=1) substituted for those records with zero longspine catch. Each annual index is normalised relative to the geometric mean of the indices in each set. Plotted lines: standardised index from the GLM (Eq. 3); unstandardised geometric mean of CPUE (Eq. 8); annual index of the arithmetic mean CPUE (Eq. 6).

Table 17. Estimates of relative abundance from the GLM regression model for the traditional WCVI longspine fishery. The abundance indices have been standardised relative to their geometric mean (Eq. 3) and the standard errors have been calculated as described in Appendix E.

Year	**Index**	**SE**	**Upper bound**	**Lower bound**
1996/97	1.178	0.018	1.222	1.136
1997/98	1.061	0.020	1.103	1.021
1998/99	1.033	0.017	1.069	0.999
1999/2000	0.873	0.019	0.907	0.841
2000/01	0.886	0.023	0.926	0.848

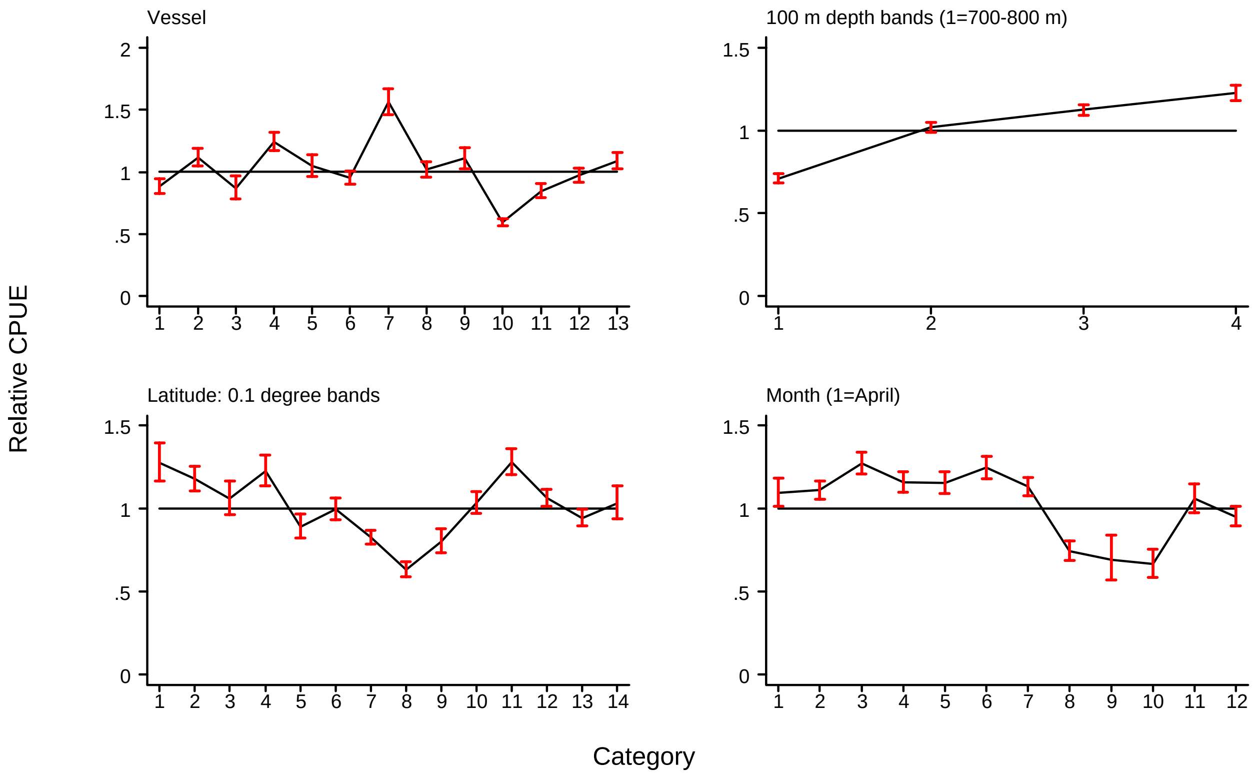

Figure 17. Coefficients for the traditional west coast Vancouver Island regression model with LN(CPUE=1) substituted for records where longspine catch is zero. All coefficients are plotted relative to their geometric mean (Eq. 3), the error bars are 2*SE and the horizontal line is plotted at a coefficient value of 1.0.

The plot of the coefficients for the 0.1° latitude band area variable shows that catch rates are high in the more southerly parts of Vancouver Island, followed by an area of low catch rates in the central section and at least one band of high catch rates in the north (Figure 17). As this analysis is confined to the "traditional" grounds, the areas of high catch rates in the northern Vancouver Island exploratory area are not included.

The depth coefficients show an increasing trend with increasing depth, but the contrast is not great, as the catchability only increases from about 0.7 to 1.2 in relative units (Figure 17). The month coefficients show a pattern similar to that reported by Starr & Haigh (2000), with low catch rates only in the winter months of November to January (Figure 17). Finally, the vessel coefficients show a similar amount of contrast as was shown in 2000, with the lowest and highest vessels showing a range of about 0.6 to 1.3 in relative catchability.

The residual diagnostics for this model show deviations from the normal assumption at both ends of the distribution. The model shows a tendency to overestimate the observations at both the lower and upper tails and has a bulge of underestimation in the centre of the distribution (Figure 18).

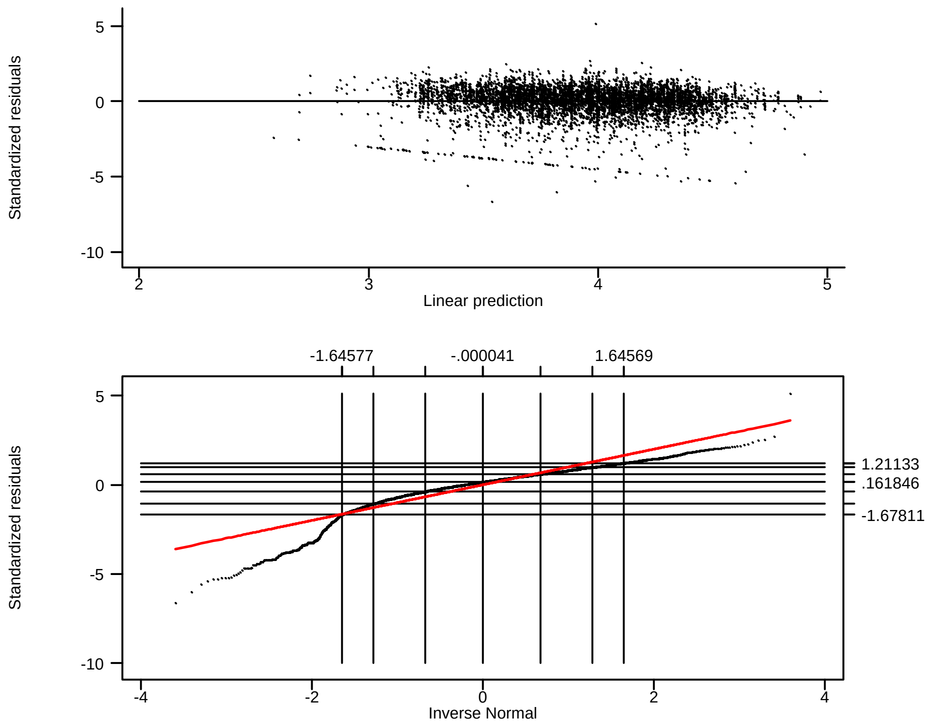

Figure 18. Standardised residuals for the traditional west coast Vancouver Island regression model with LN(CPUE)=1 substituted for records where longspine catch is zero and all model predictors are offered.

8.3 ANALYSIS OF INTERACTION EFFECTS IN THE TRADITIONAL WCVI MODEL

An analysis of the interaction effects for the five selected model predictor parameters was performed. This was done by creating categorical variables which described all possible interactions between each pair of predictor variables, for a total of 10 combinations of variable interactions. Each paired interaction term was then offered to the model after the five main effects model predictor variables were used. The same selection criteria provided in Section 4.0 form the basis for deciding that a variable is "significant" as traditional tests of model significance are almost always significant, given the relatively large number of observations in these models.

The results of the full interaction model based on the presentation of the entire suite of interaction terms to the model is provided in Table 18. Six of the ten possible interaction terms were accepted in the model based on the Section 4.0 selection criteria after the inclusion of all the main effect variables. The most important terms were generally the ones which included the vessel categorical variables, with the exception of a strong interaction between fishing year and month. This indicates that there may have been a change in the seasonal distribution of the catch over the period included in the dataset. Pairwise plots of the fishing year coefficients by month indicate that a number of the months show a strong decline in the relative CPUE for the 1999-2000 fishing year which is not apparent in the other months (Figure 20) which may be the primary source of the significant interaction in this pair of variables. Another possible source of interaction problems in this model could be the unbalanced nature of the data. Figure 22 shows that the fishery in the traditional area was more evenly distributed with respect to LN(CPUE) in the first year, but as the fishery matured and with the introduction of Individual Vessel Quotas, the vessels tended to concentrate in the summer months which have better weather and more favourable fishing conditions. And, as indicated in Section 6.0, half of the fishery has migrated to the exploratory area in the most recent fishing year. On the other hand, none the interaction terms which included the depth categorical variable was accepted into the regression. The interactions with the latitude band categorical variable appear to be less strong that those with month or fishing year (Table 18).

The full model including main effects and interaction effects explains over half of the residual deviance (Table 18). This is an improvement of 0.32 over the deviance explained by the main effects model only (0.22 of the deviance for the main effect variables alone; Table 16). The observations that a large amount of additional deviance is explained and the entry of many "significant" interaction terms after the main effects may indicate that a substantial amount of the explanatory power in models involving fisheries catch and effort data lies in the analysis of the interaction terms. However, it should be noted that the estimates of the main effects coefficients in the full interaction model appear to be altered relative to the estimates when only the main effects are included (compare Figure 19 with Figure 16 and Figure 17). For instance the fishing year trend line is very different in Figure 19 compared to the trend line shown in Figure 16. The large standard errors associated with the interaction model estimates indicate that they are very poorly determined and that the statistical properties of this analysis requires further investigation.

Table 18. Results for the interaction model applied to the traditional west coast Vancouver Island GLM regression model for longspine thornyheads, presented in the order of acceptance to the model after all the main effects variables have entered the model. The variable selection process operated for six iterations before the stopping criterion described in Section 4.0 was invoked. All selected interaction model predictor variables are indicated with a *. Table values are the proportion of the total residual deviance explained by each predictor variable at the specified model iteration. The final model including all the main effect variables explained 0.54 of the total deviance.

Variable or Interaction	**1**	**2**	**3**	**4**	**5**	**6**	**7**
VesselXMonth*	0.3310						
Fishing yearXMonth*	0.2909	0.3933					
VesselXFishing year*	0.3057	0.3914	0.4481				
VesselXLatitude*	0.3082	0.3995	0.4518	0.5015			
LatitudeXMonth*	0.2954	0.3852	0.4367	0.4822	0.5293		
Fishing yearXLatitude*	0.2715	0.3742	0.4193	0.4666	0.5161	**0.5438**	
MonthXDepth	0.2444	0.3457	0.4063	0.4580	0.5105	0.5365	0.5507
Fishing yearXDepth	0.2410	0.3410	0.3996	0.4531	0.5042	0.5312	0.5455
VesselXDepth	0.2533	0.3494	0.4094	0.4589	0.5081	0.5361	0.5510
LatitudeXDepth	0.2463	0.3452	0.4043	0.4582	0.5086	0.5358	0.5509
Increase in proportion deviance explained	0.1068	0.0624	0.0547	0.0535	0.0277	0.0146	0.0069

Model diagnostics for the full interaction model show deviations from the assumption of normality, which are similar to the deviations seen in the main effects model (Figure 23). Model deviations from normality are particularly noticeable for those tows with small catches, where the model appears to predict higher catches than observed.

Pairwise plots of the fishing year coefficients for every combination of the 0.1° latitude bands show that an apparent majority of the compared grids have similar fishing year coefficient patterns

(Figure 21), with some notable deviations in the 1999–2000 fishing year (e.g. grids 6 and 8 or grids 7 and 9 or grids 2 and 10). However, the overall impression is that the trends in the fishing year coefficients between grids are more similar than different, indicating that the selection process being used appears to be relatively sensitive to the observed differences.

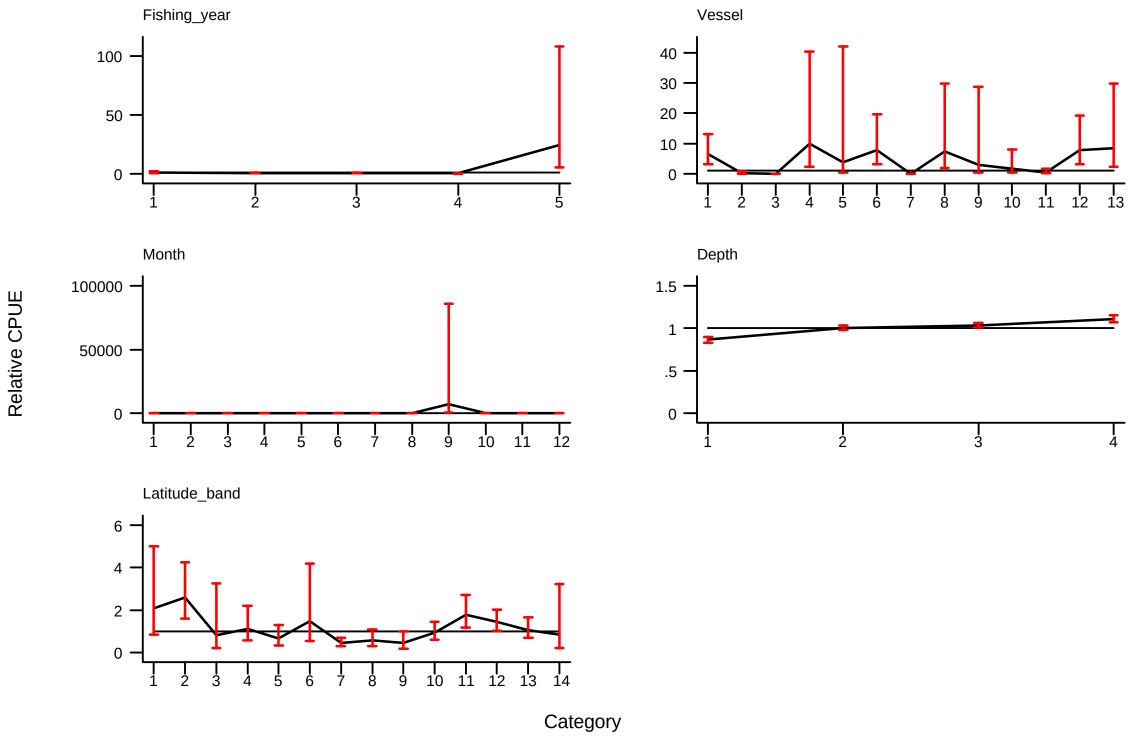

Figure 19. Plots of main effect categorical variables for the full interaction model including error bars (± 2 SEs).

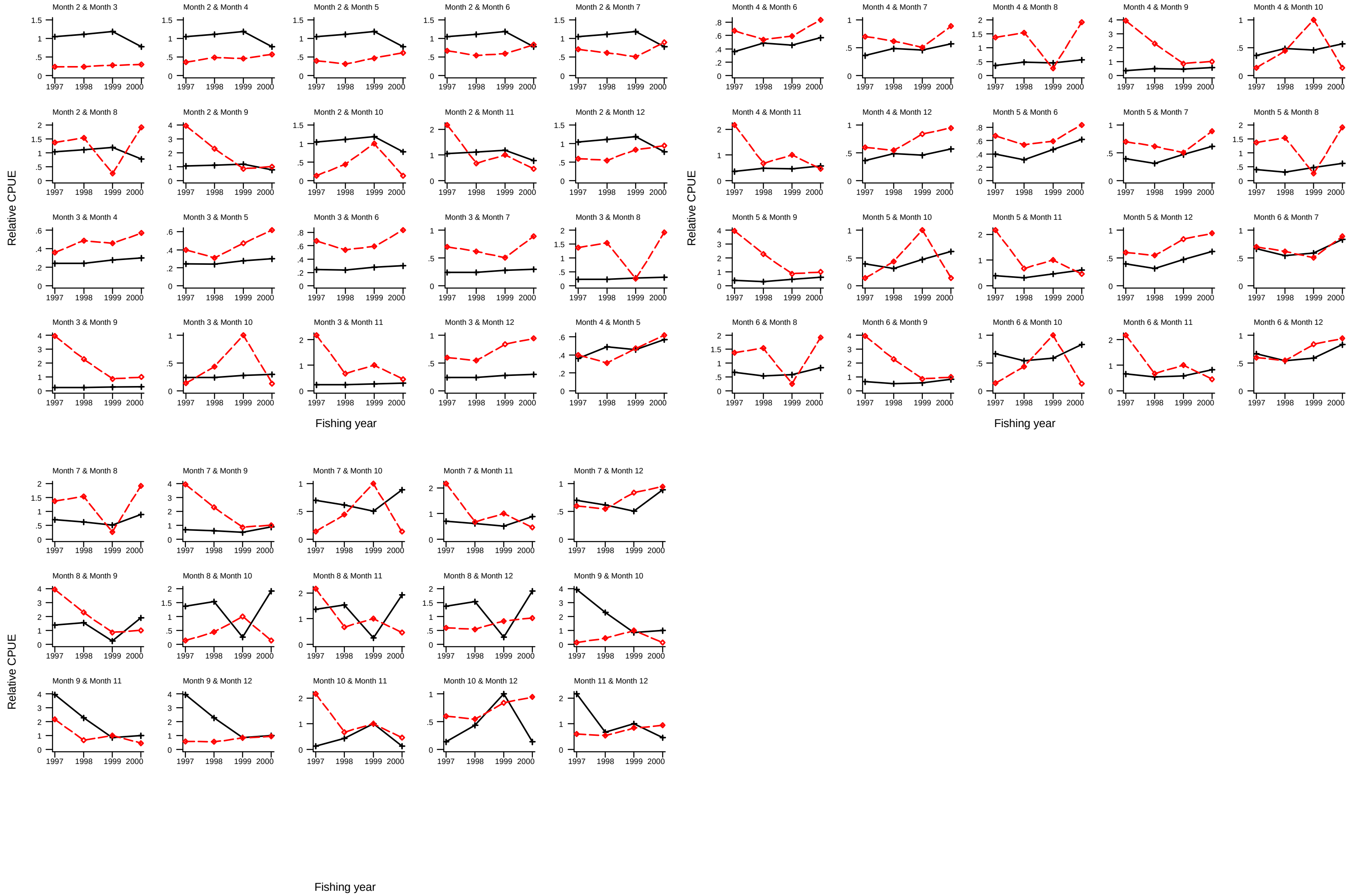

Figure 20. Interaction plots between fishing year and month (April=1) for all paired month combinations for each fishing year.

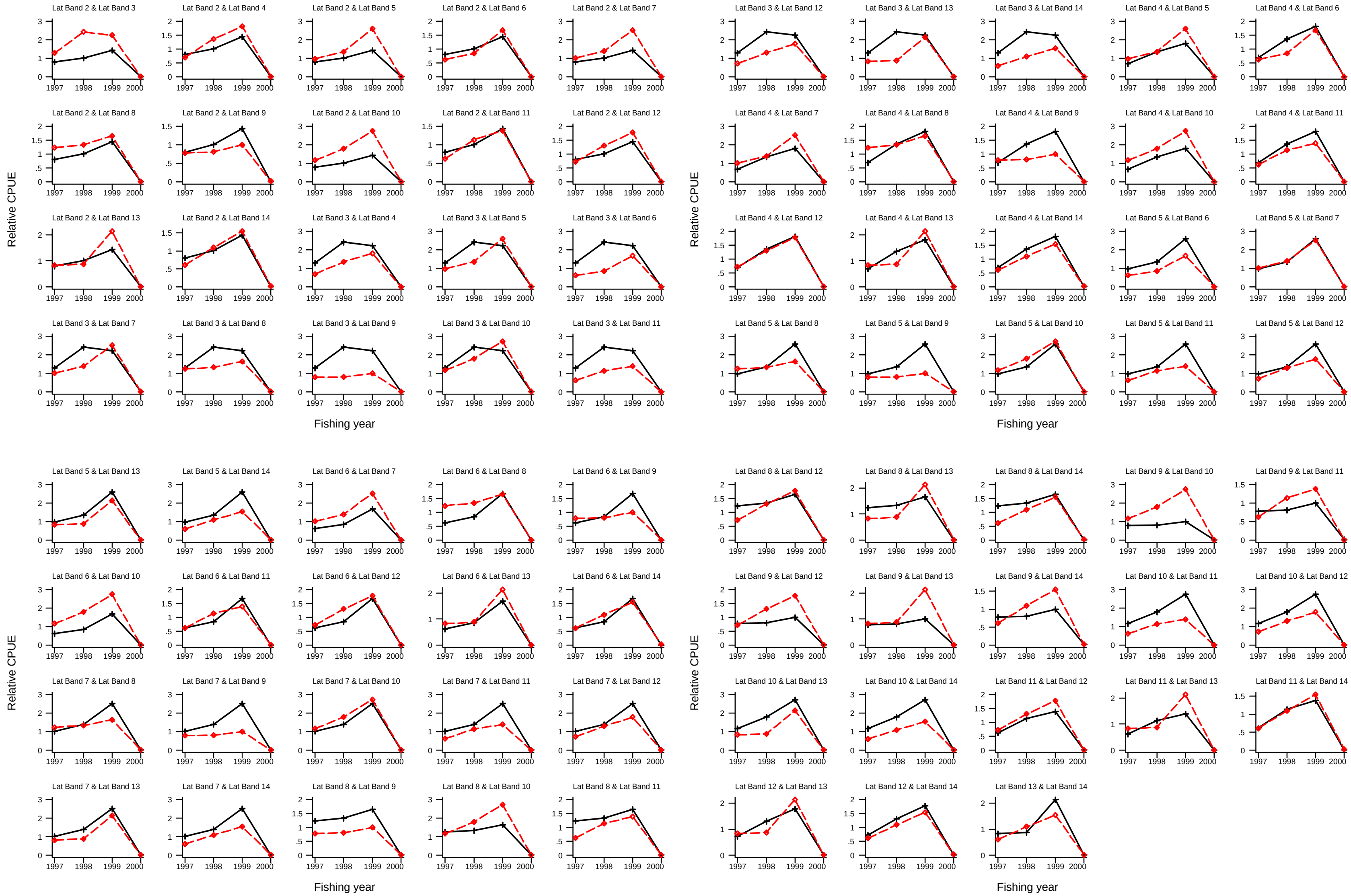

Figure 21. Interaction plots between fishing year and latitude band (Table 15) for all paired month combinations for each fishing year.

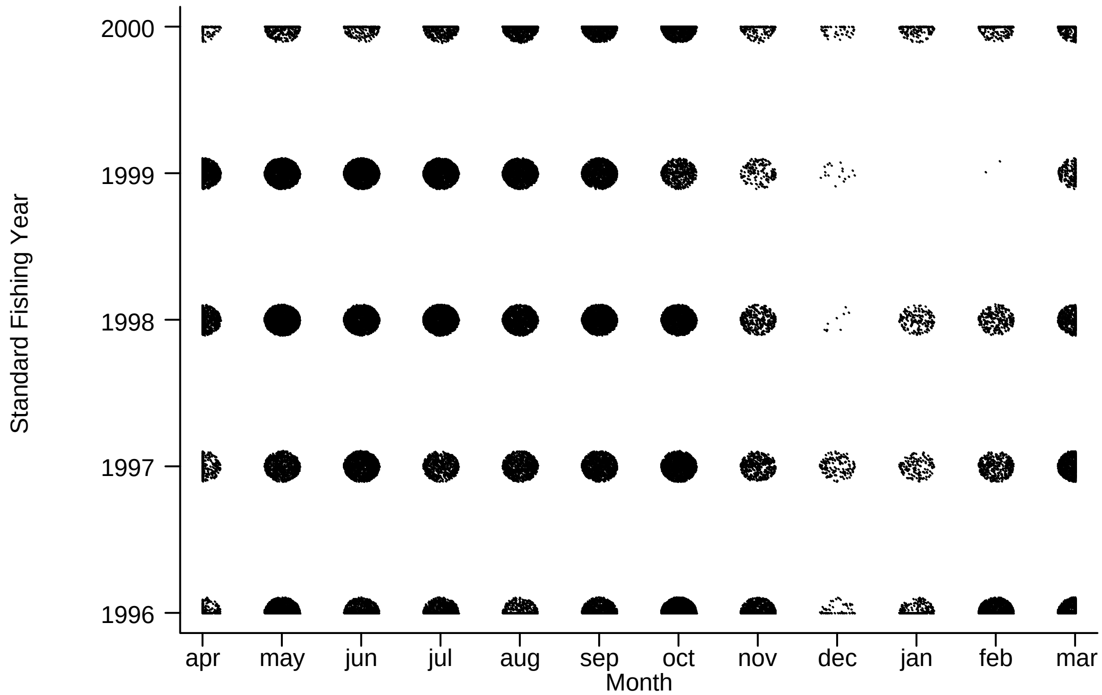

Figure 22. Density plots of the data intersections between standard fishing year and month. The points are jittered and the density is proportional to LN(CPUE) in each cell.

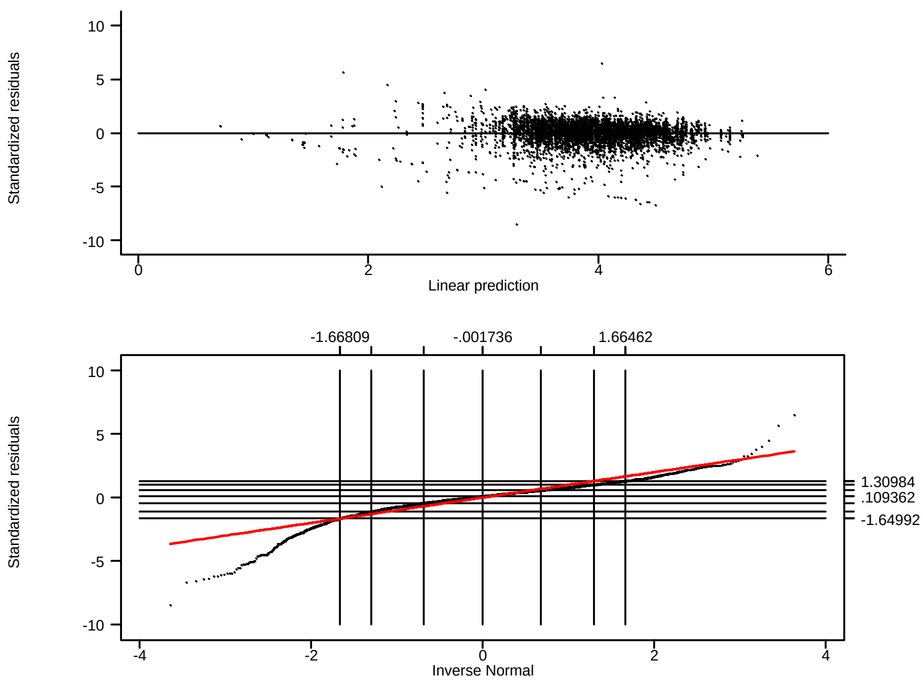

Figure 23. Standardised residuals for the interaction model performed on the traditional west coast Vancouver Island dataset with LN(CPUE)=1 substituted for records where longspine catch is zero and all model predictors are offered.

8.4 GLM SUMMARY

The high degree of interaction revealed by the analyses presented in Section 8.3 is troubling and casts doubt on the overall approach and analysis. However, Figure 16 shows that the estimated coefficients for the fishing year predictor variable (Eq. 3) are very similar to the trend shown in the arithmetic (Eq. 6) or geometric (Eq. 8) of the annual catch and effort data (for the main effects model only). While the observation of stability between the simple estimators of abundance and the complex model is frequent in these analyses, it does not always occur, indicating that these models can alter the estimates of presumed abundance trends. However, the interpretation of the model-based abundance trends is not as straightforward when there are strong interaction effects.

A detailed analysis of catch and effort data is frequently the best approach for gaining understanding about a fishery and the population being fished, particularly in situations where there are no other sources of data. However, the existence of significant interaction terms and the complexity of the process being modelled indicates that other sources for obtaining relative abundance indices are required if a stock is to be reliably monitored.

9.0 RECOMMENDATIONS AND YIELD OPTIONS

9.1 STOCK STATUS

Stock modelling results presented in Starr & Haigh (2000) concluded that the amount of information presently available for longspine thornyheads was insufficient to reliably assess this stock. This conclusion was mainly attributable to the short time period over which fishing has taken place and the difficulty of interpreting the available data. For instance, the preliminary modelling results indicated that the stock size could be either large or small, depending on the assumptions and which data sets were used. Consequently sustainable yields cannot be presently estimated with confidence.

It is thought that this species is not very productive, given its distribution in deep water and its apparent high maximum age. Experience in deepwater fisheries in other parts of the world suggest that caution should be used when fishing such a population. Population modelling results presented by Starr & Haigh (2000) indicated that the change in biomass over the four-year period was approximately equal to the total removals from the fishery. This observation was a function of the slow growth rates used in the modelling and the fact that most of the population was found in the flat section of the growth curve (as the population was made up primarily of older individuals). The existence of such a population structure implies that there will be a phase of "fishing down" as the population equilibrates to the lower abundance levels associated with higher yields. Populations at higher productivity levels are usually characterised by small fish and an expectation is that commercial CPUE will often be lower at the end of the "fishing down" phase than during the initial period of fishing.

9.2 TRADITIONAL WCVI FISHING AREA

The GLM analysis reported in Section 8.2 suggests that the relative CPUE in this area (south and east of the 230° degree line from Lookout Island) has declined on the order of 25% in the five year history of this fishery. This result is consistent with the stock modelling conclusion reached by Starr & Haigh (2000) that "…*current spawning biomass levels were in the range of 70 to 90% of* *the 1996 level after four years of fishing*". The present GLM analysis as well as the simple abundance estimators (Figure 16) also suggest that the decline in CPUE may have levelled off in the most recent year, given the substantial reduction in exploitation that was instituted in April 2000. It is significant that the largest decline in relative catch rate occurred in the first full year of the fishery when over 1,000 tonnes of catch was taken from this area which is about three times the catch in the most recent fishing year (Table 4).

The current catch limit for this fishery is 425 t, which is higher than the sum of the catches in the PacHarvest database for this area in 2000/01 (Table 4). Continuation of fishing at this level can be allowed for an additional year as long as catch rates and abundance are closely monitored because it will take several more years of monitoring with catches at their present level to determine the effect of these removal levels on biomass trends.

The lack of change in the length frequency distribution from 1996–97 to 2000–01 (Table 9) does not indicate that there has been no change in the population age structure as the population length structure may not change significantly as the stock depletes, particularly if the distribution of lengths at age is broad (Hilborn and Walters 1992).

9.3 EXPLORATORY AREAS

This paper has divided the northern longspine exploratory area into three sub-areas (Table 3) to make the description of the catch and effort summaries more understandable and comparable between areas and years. This division into areas is not intended to be a recommendation for management areas. Such decisions should be made through dialog between the fishermen, the managers and the scientists.

There is no suggestion in the information assembled in this paper that these new fisheries in the exploratory areas are substantially different from the existing fishery in the traditional WCVI area. Catch rates and length frequency distributions appear to be comparable, within the range of variability in the data and it is much too early to suggest that the current levels of catch in the exploratory areas are having a measurable effect on stock abundance.

Therefore, as with the "traditional" WCVI fishery, fishing can continue at current levels for another year along with the present level of monitoring so that the effect of the fishery on relative levels of biomass can be observed. It is presently much too early to comment on the appropriate levels of long-term harvest in these areas.

9.4 MANAGEMENT CARRYOVER POLICY OF 30%

DFO Management requested a comment in this assessment on the current "carryover policy of 30%". It is assumed that this phrase is a reference to a policy which allows fish which have been uncaught in any year to be harvested (up to a limit of 30% of the annual quota) in a subsequent year. It is also assumed that the carryover does not extend past a single year.

In principle, such a carryover policy should have no long term effect on a stock which is being fished at sustainable levels as the carryover policy should average to approximately the same levels of exploitation. Fish which have been forgone in any one year should be equally available in the following year. This is especially true for a relatively long-lived species (such as longspine thornyheads are thought to be) as natural mortality will be low. A carryover policy is less desirable on short-lived species with large fluctuations in recruitment or on highly variable migratory species. However, as longspines are thought to be relatively long-lived, a carryover policy should not pose any important additional risk to this species beyond the existing levels of harvest.

9.5 RESEARCH RECOMMENDATIONS

A new random stratified research survey targeted at this species was successfully completed in early October 2001. This survey is scheduled to be repeated for two more years, at which point its continuation will be assessed. This survey represents a major new initiative in groundfish research in western Canada and will provide substantial amounts of new information for the assessment of this species in the years to come.

Information presented in this report shows that sampling coverage in this fishery has been substantial. Table 6 shows that 40% of all tows representing over 50% of the catch were sampled in the 2000/01 fishery. Table 5 shows that nearly every trip that caught longspines had an observer on board. Figure 7, Figure 8, and Figure 9 show that the coverage of this fishery was nearly completely representative of all its major aspects, especially in recent years. This observation is particularly important if fishery information is being used to evaluate the effect of fishing on a stock. This level of sampling is a substantial commitment which will yield considerable amounts of useable stock assessment information in the future. The sampling protocol was considerably improved beginning in April 2001 which will only serve to increase the quality of the information being gathered. These combined research initiatives probably make the longspine thornyhead fishery among the best monitored groundfish fisheries in western Canada. The best recommendation at this point would be to continue the current level of research and monitoring and to review the quality and quantity of information as it becomes available.

Possibly the most important area of additional research for this species is the requirement for further investigation into growth rates to underpin estimates of long-term yield. Stock assessments for longspine thornyheads done for the Pacific Management Council (e.g. Ianelli et al. 1994) also emphasise the lack of information on this issue and other papers (e.g. Cailliet et al. 1996) underscore the uncertainty in the present ageing technology. It is thought that these fish are relatively old due to the great depths at which they live and the likely low productivity of the anoxic layer between 800 and 1100 m in depth (Jacobson & Vetter 1996). An unpublished M.Sc. thesis by Kline (1996) used radiometric techniques to independently age the two *Sebastolobus* species. The method measures levels of (^{210}Pb:^{226}Ra) disequilibria in otolith cores to estimate the age of the otolith. Results from this study estimated that the maximum age for *Sebastolobus altivelis* was 45 years. However, this method is extremely sensitive to contamination and errors in the ^{226}Ra measurements and the results should be considered provisional until confirmed. Adequate age and growth information are required before stock assessments can be done for this species with any degree of confidence.

Therefore, reliable estimates of growth and productivity a major missing elements for providing management advice for this species. Information on the productivity of this species, combined with observations of the effect of a series of monitored catches, are needed before estimates of long-term sustainable yield can be made. Research on longspine growth is an important requirement for developing a long-term management approach and the present lack of this information should be addressed.

ACKNOWLEDGEMENTS

I wish to acknowledge the support of the Canadian Research and Conservation Society for funding this groundfish research. I thank Rowan Haigh for contributing the map used in Figure 2. I also acknowledge the considerable help provided to me by Rowan Haigh and Brian Krishka by responding to my many queries on the various databases and by providing me data in a timely manner.

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APPENDIX A: GLM DATA PREPARATION

A.1 CATCH AND EFFORT DATA SOURCE

All catch and effort data were obtained from summary tables generated from the PacHarvest database held by the DFO at the Pacific Biological Station in September 2001. See Schnute *et al.* (2000) for a description of the PacHarvest database, including the available data fields. Data in the PacHarvest database commence in February 1996. Although there are detailed catch and effort data available prior to the initiation of the PacHarvest database (Rutherford 1999), only the PacHarvest data are available for the analysis of longspine thornyhead catch because it was not until mid-February 1996 that observers were placed on most vessels which caught this species. Catch estimates for this species are not considered reliable before the initiation of compulsory observer coverage.

A.2 GLM DATA PREPARATION AND GROOMING

Records satisfying the following conditions were used for the analysis of catch and effort in this report:

- Tow start date between 1 April 1996 and 31 March 2001
- Bottom trawl type
- Areas outside the Strait of Georgia (i.e. <> Major Area =4B)
- Fishing success code <=1 (code 0= unknown; code 1= useable) and a recorded catch or discard of at least one species of fish
- Valid depth field with a mean depth greater than 700 m (Appendix Figure 1). The depth field in the PacHarvest database is defined as the mean of the depths at the start and the end of the tow.
- Tows from vessels which had been in the fishery for at least four years (for discarded catch analysis) and five years (for landed catch analysis)
- Tows with valid latitude and longitude co-ordinates
- Tows with valid estimates of time towed
- Tows from the top 13 ranked vessels in terms of total tows over the five years with mean depths greater than 700 m (Appendix Table 1)

The locations of the selected tows have been translated into UTM (Universal Transverse Mercator) co-ordinates based on the latitude and longitude for each tow in the database. The UTM grid system and its application is described in detail in Schnute *et al.* (2000). This system was used to generate constant sized grid boxes of 5 km^2, 10 km^2, 25 km^2 and 40 km^2 which were each offered as predictor variables in the generalised linear analysis. Continuous variables (time of day set, number of species in tow and number of tows by vessel in data set) were entered into the model as third order polynomials.

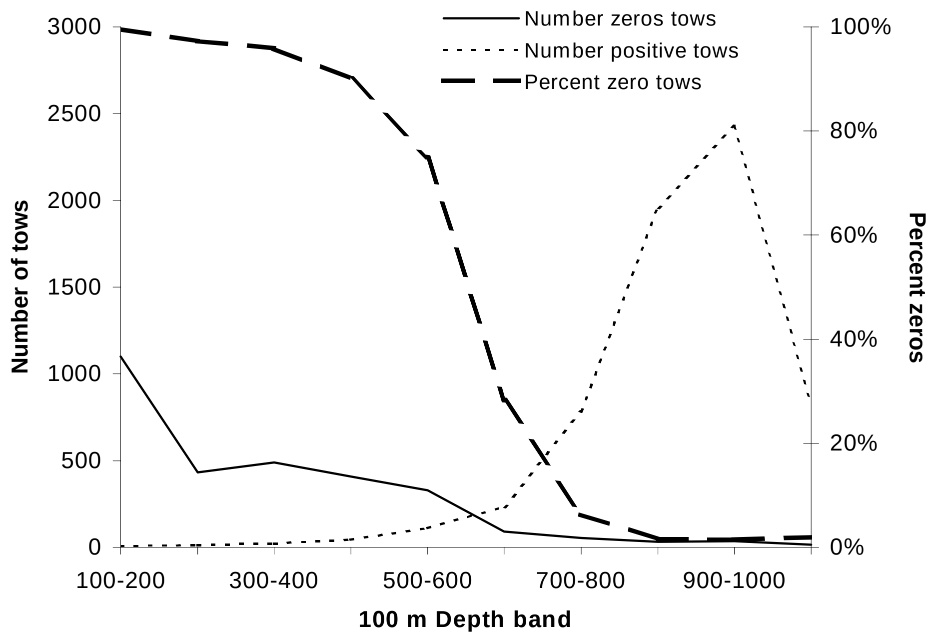
Vessel selection was restricted to the top 13 vessels which have all participated in the fishery nearly continuously since the 1996/97 fishing year (Appendix Table 1). The only possible exception to this criterion is vessel 13 which apparently dropped out of the fishery for the 1998/99 and 1999/00 seasons but has clearly re-entered the fishery in 2000/01. Vessels 14 and 15 have not participated recently in the fishery so they have been excluded as have all other vessels. The top 13 vessels account for 84% of the tows and of the longspine catch and for 87% of the hours fished over the five year period covered by this analysis.

Appendix Table 1. Number of tows for the entire BC coast with a mean depth of greater than 700 m by the 15 top-ranking vessels (in terms of total number of 700+ m tows) by standard fishing year for the period 1 April 1996 to 31 March 2001.

Vessel Rank	1996/97	1997/98	1998/99	1999/2000	2000/01	Total
1	150	213	244	254	185	1,046
2	166	52	195	183	151	747
3	154	123	133	154	147	711
4	106	129	142	184	135	696
5	44	112	157	169	185	667
6	136	151	153	100	97	637
7	94	60	132	153	190	629
8	186	52	71	134	98	541
9	90	51	122	122	77	462
10	128	47	91	83	98	447
11	140	35	64	74	58	371
12	41	7	47	99	100	294
13	51	43	8	1	118	221
14	116	75				191
15	66	54	56	1	2	179

Depth was entered into the model as a categorical variable in 100 m depth bands but choosing an appropriate depth range for an analysis involving a highly depth-stratified species is always problematic. Starr & Haigh (2000) confined their analysis to the depth range 700 m to 1100 m.

An examination of the distribution of all zero and positive tows for the 13 top vessels in the longspine fishery shows that the probability of a tow catching no longspines is strongly related to the mean depth of the tow (Appendix Figure 1). Approximately 30% of the tows in the 600-700 m band have no longspines and this value drops to 6% for the 700-800 m depth band and is negligible for the even deeper tows (Appendix Figure 1). The total number of tows over five years which caught longspines in the 600-700 m band is less than 300 while the number of positive tows in the next depth band is over 800 in the same period. Longspines clearly exist in the 600-700 m depth band but it is also clear that this is not a preferred fishing depth for this species and tows at this depth may not always be directed at longspines. In support of this contention, preliminary analyses using a wider depth range (from 500 m) which investigated whether there was an abundance effect derived from the change of the proportion zeros over time (binomial logit model) was inconclusive due to the lack of an apparent trend and the small amount of data. Therefore, for consistency with the previous analysis and given the possible difficulty of interpreting tows with no longspines in this depth band, it was decided to continue to restrict the analysis to depths greater than 700 m. Tows at depths greater than 1200 m were pooled in the 1100-1200 depth band where previously they had been discarded.



Appendix Figure 1. Distribution by 100 m depth bands of tows with zero and positive catch of longspine thornyheads in the "traditional" WCVI fishing grounds for all tows by the top 13 longspine vessels.

Fields or derived fields that were kept in the data set are described in Appendix Table 2. All variables in the final models were entered as categorical variables.

Appendix Table 2. Fields in the data set used to analyse longspine thornyhead catch and effort data

Field	**Description**
CPUE & LN(CPUE)	Kg/hour
Depth	Converted into 100m bands
Discarded catch	Kg
Effort	Tow time in hours
Latitude	In decimal degrees based on the mid-point of the tow
Locality	DFO locality area description (Rutherford 1999)
Longitude	In decimal degrees based on the mid-point of the tow
Minor Area	DFO minor area description (Rutherford 1999)
Month	From April 1996 to March 2001
Nspp	Number of species in tow
Retained catch	Kg
Standardised fishing year	01 April – 31 March
Time	Time of day when tow set
Tows	Total number tows by vessel in fishery
UTME	Universal Transverse Mercator Easting (Schnute et al 2000)
UTMN	Universal Transverse Mercator Northing (Schnute et al 2000)
Vessel	Coded

Appendix B: Preparation of Commercial Length Sampling Data

B.1 Sample data

Two types of data form the commercial length sampling data. One dataset provides the information about each sample and the other provides information about the individual fish sampled. The sample data include the tow and trip identifiers, the nature of the sample (whether it is random or stratified) and the sampling target (whether it is a sample of unsorted fish or it there has been sorting prior to sampling). It is this last category that makes these data difficult to analyse as many of the samples are sorted before the sampler has access to them and often the information on the data does not seem to reflect the actual sample. The category codes for the longspine length frequency data are provided in Appendix Table 3, along with how these codes were treated in the final analysis. Almost all the samples were identified as "random" (1394 of a total sample set of 1402).

The trip and fishing event identifiers allow the sample to be related to the commercial tow which caught the fish. The inclusion of these identifiers made the task of matching the sampling data to the fishery data much easier than in the previous year (Appendix 2; Starr & Haigh 2000). The sample information was linked to the tow, trip and area fished based on this information.

Appendix Table 3. Code description for category codes found in the GFBio database.

Category Code	Number samples	Description
1	838	Sample of unsorted catch
3	189	Sample of retained catch
4	128	Sample of discarded catch
34	247	Combined sample of retained and discarded catch
Total	1,402	

As reported previously (Starr & Haigh 2000), there were multiple samples for 76 of the tows sampled. These pairs of samples had various category codes (Appendix Table 4) but there was no consistent pattern except for the 40 tows with category code=1 which were clearly additional samples taken for sex and age and could be treated additively. Only 17 of the remaining 36 sampled pairs were combinations of retained (code=3) and discarded (code=4) and the other 19 were various combinations of the other codes. No attempt was made to link samples from the same tow but these samples were used individually where appropriate. The total number of fish available for analysis is nearly 100,000, about half of which are samples of the total unsorted catch (Appendix Table 7). The balance of the samples are stratified in some manner. There is also good coverage of the exploratory fishing areas , with over 300 samples taken in each area ,but relatively fewer length samples than in the traditional WCVI fishery (Appendix Table 8),

Appendix Table 4. Distribution of tows with multiple samples by category code.

Category Code	1st multiple sample	2nd multiple sample	Total
1	40	40	80
3	15	11	26
4	10	16	26
34	11	9	20
Total	76	76	152

A problem arose when scaling the sampled catch to the total catch because some samples seemed to be either unrepresentative or possibly miscoded. For instance, a few samples coded as "retained" or "total" had very low mean and maximum length. In some cases, when these samples were weighted by the catch associated with that tow, apparent anomalies in the scaled distributions appeared when compared to the equivalent unscaled distributions. These anomalous samples could be identified because their mean and maximum lengths were very low. When the lowest 2% of the distribution of maximum lengths among the samples were dropped from the analysis (25 samples), the apparent bias in the estimated length distributions disappeared.

B.2 SPECIMEN DATA

Only three fields are required in the specimen data for this analysis: length, sex (if available) and a sample identifier. This latter code allows the length or sex information to be linked back to the sampling information and to the fishery. Specimens with lengths greater than 400 mm were dropped (22 records) as this size was larger than the maximum seen in the data provided from the US research surveys (Starr & Haigh 2000). As this is research data

B.3 ANALYTICAL PROCEDURE FOLLOWED

Several scaling options were followed to prepare the length frequency data for presentation in this paper. These options were based on the interpretation of the category codes presented in Appendix Table 3 and the appropriate catch totals for scaling the samples (Appendix Table 5).

Appendix Table 5. Scaling options and procedures followed in preparing longspine length frequency data for presentation in this report.

Options	No Scaling	Scaling based on catch in tow	Scaling based on catch for trip
Total catch	Samples with category codes 1 or 34 were summed to obtain resulting distributions	Tows with sample categories 1 or 34 were scaled to the combined retained and discarded catch for the sampled tow	Sample categories 1 or 34 were totalled for the entire trip and scaled to the combined retained and discarded catch for the entire trip
Retained catch	Samples with category code 3 were summed to obtain resulting distributions	Tows with sample category 3 were scaled to the retained catch for the sampled tow	Sampled fish from category 3 were summed for the entire trip and scaled to the retained catch for the sampled trip
Discard catch	Samples with category code 4 were summed to obtain resulting distributions	Tows with sample category 4 were scaled to the discarded catch for the sampled tow	Sampled fish from category 4 were summed for the entire trip and scaled to the discarded catch for the sampled trip

APPENDIX C: SAMPLING INFORMATION ASSOCIATED WITH THE COMMERCIAL LENGTH SAMPLING DATA

The following tables are provided to detail the amount of commercial length sampling which has been done on longspine thornyheads by standard fishing year and longspine fishing area (Table 3).

Appendix Table 6. Number of sampled trips by standardised fishing year (1 April – 31 March) by participating vessel. Data for the 1996-97 fishing year have not been presented to preserve confidentiality

Vessel Name	**1997-98**	**1998-99**	**1999-2000**	**2000-01**	**Total**
CALEDONIAN			1	1	
CAPE MORIEN		10	10	13	33
CARMANAH I		1	3	5	9
CHALLENGER			1		1
E.J. SAFARIK	1	4	4	9	18
FREE ENTERPRISE #1		3	1	2	6
FROSTI		6	4	4	15
HOPE BAY		4			4
JEANNA MARIE	2	6	6	3	17
KNIGHT DRAGON	1	3		2	6
MISS TATUM		3			3
NEMESIS		2	5	4	11
NOOTKA MARINER	1			5	6
OCEAN REBEL		2	7	9	18
OCEAN SELECTOR	1	2	5	5	13
PACIFIC VIKING		4	8	7	19
VIKING MOON	1	3	5	4	13
VIKING SKY	2				2
VIKING STORM	2	1	3	5	11
	11	54	62	78	206[1]

[1] Includes one trip sampled in 1996-97

Appendix Table 7. Number of samples and length measurements classified by the number of samples taken per tow and by the sample type category for all samples taken between February 1996 and 1 April 2001.

	Number of Samples/Tow					
	1 Sample/Tow		**2 Samples/Tow**		**Total**	
Sample Type	**Samples**	**Lengths**	**Samples**	**Lengths**	**Samples**	**Lengths**
Total Catch	985	42,820	100	10,098	1085	52,918
Retained Catch	163	20,496	26	4,354	189	24,850
Discarded Catch	102	15,482	26	3,845	128	19,327
Total	1250	78,798	152	18,297	1402	97,095

Appendix Table 8. Distribution of samples by longspine area defined in Table 3 by standard fishing year classified by the sample type category for all samples taken between February 1996 and 31 March 2001.

Fishing Year	Total Catch	Retained Catch	Discarded Catch	Total
TRADITIONAL WCVI				
1996/97		15		15
1997/98	11	4	1	16
1998/99	32	80	15	127
1999/00	68	48	63	179
2000/01	355	9	7	371
Total	466	156	86	708
OUTER QC SOUND				
1996/97				
1997/98				
1998/99				
1999/00				
2000/01	112	17	2	131
Total	112	17	2	131

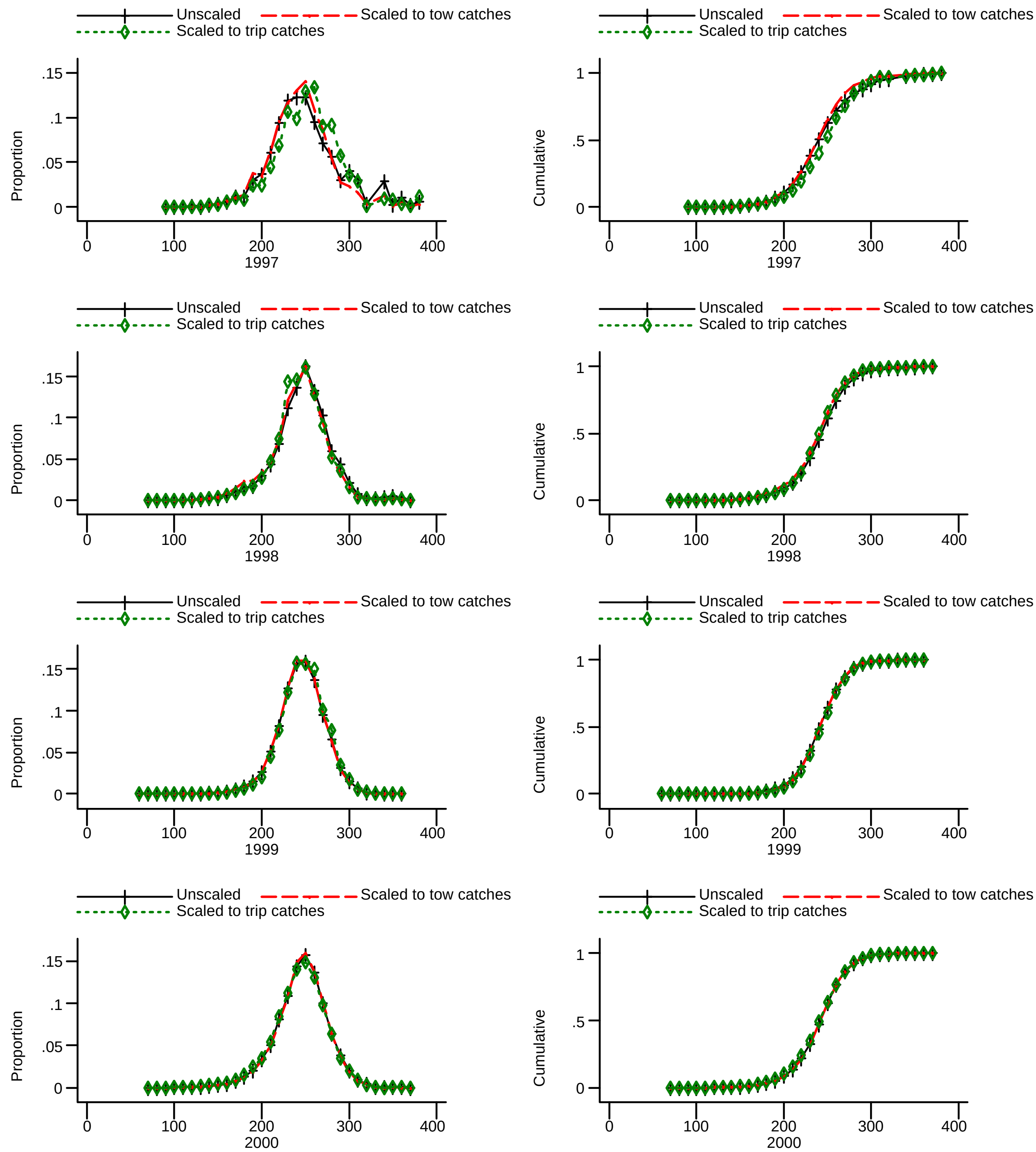
Fishing Year	Total Catch	Retained Catch	Discarded Catch	Total
NORTHERN VI				
1996/97				
1997/98				
1998/99				
1999/00	33	3	7	43
2000/01	259	11	24	294
Total	292	14	31	337
WEST COAST QCI				
1996/97				
1997/98				
1998/99				
1999/00	2		4	6
2000/01	213	2	5	220
Total	215	2	9	226

Appendix Table 9. Distribution of number of length measurements by longspine area defined in Table 3 by standard fishing year classified by the sample type category for all samples taken between February 1996 and 31 March 2001.

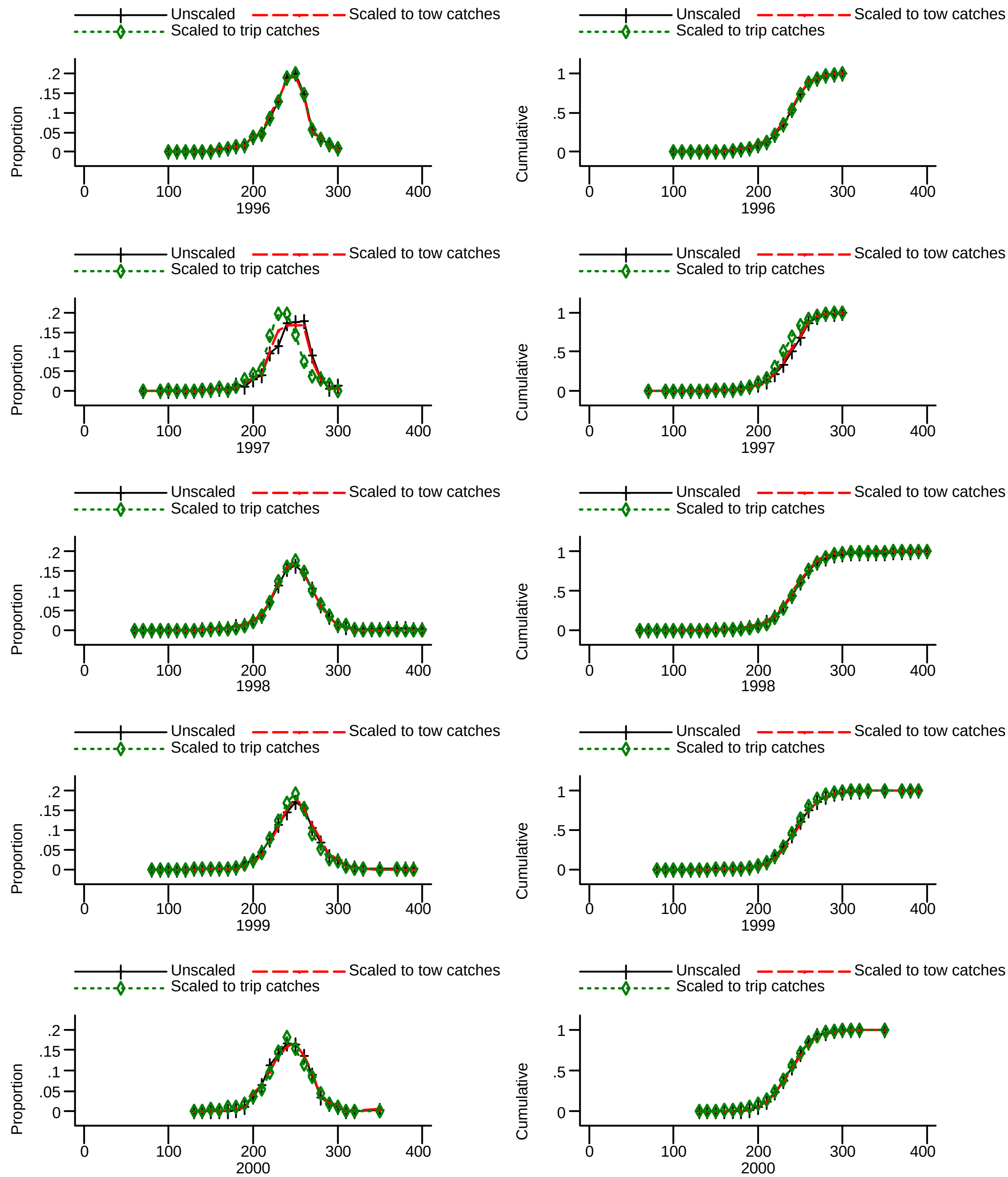
Fishing Year	Total Catch	Retained Catch	Discarded Catch	Total
TRADITIONAL WCVI				
1996/97		1,490		1,490
1997/98	1,563	342	62	1,967
1998/99	5,018	13935	2,678	21,631
1999/00	9,417	7,441	10,025	26,883
2000/01	14,911	293	820	16,024
Total	30,909	23,501	13,585	67,995
OUTER QC SOUND				
1996/97				
1997/98				
1998/99				
1999/00				
2000/01	2,562	210	182	2,954
Total	2,562	210	182	2,954

Fishing Year	Total Catch	Retained Catch	Discarded Catch	Total
NORTHERN VI				
1996/97				
1997/98				
1998/99				
1999/00	5,492	345	1,091	6,928
2000/01	8,846	520	3,354	12,720
Total	14338	865	4,445	19,648
WEST COAST QCI				
1996/97				
1997/98				
1998/99				
1999/00	362		364	726
2000/01	4,747	274	751	5,772
Total	5,109	274	1,115	6,498

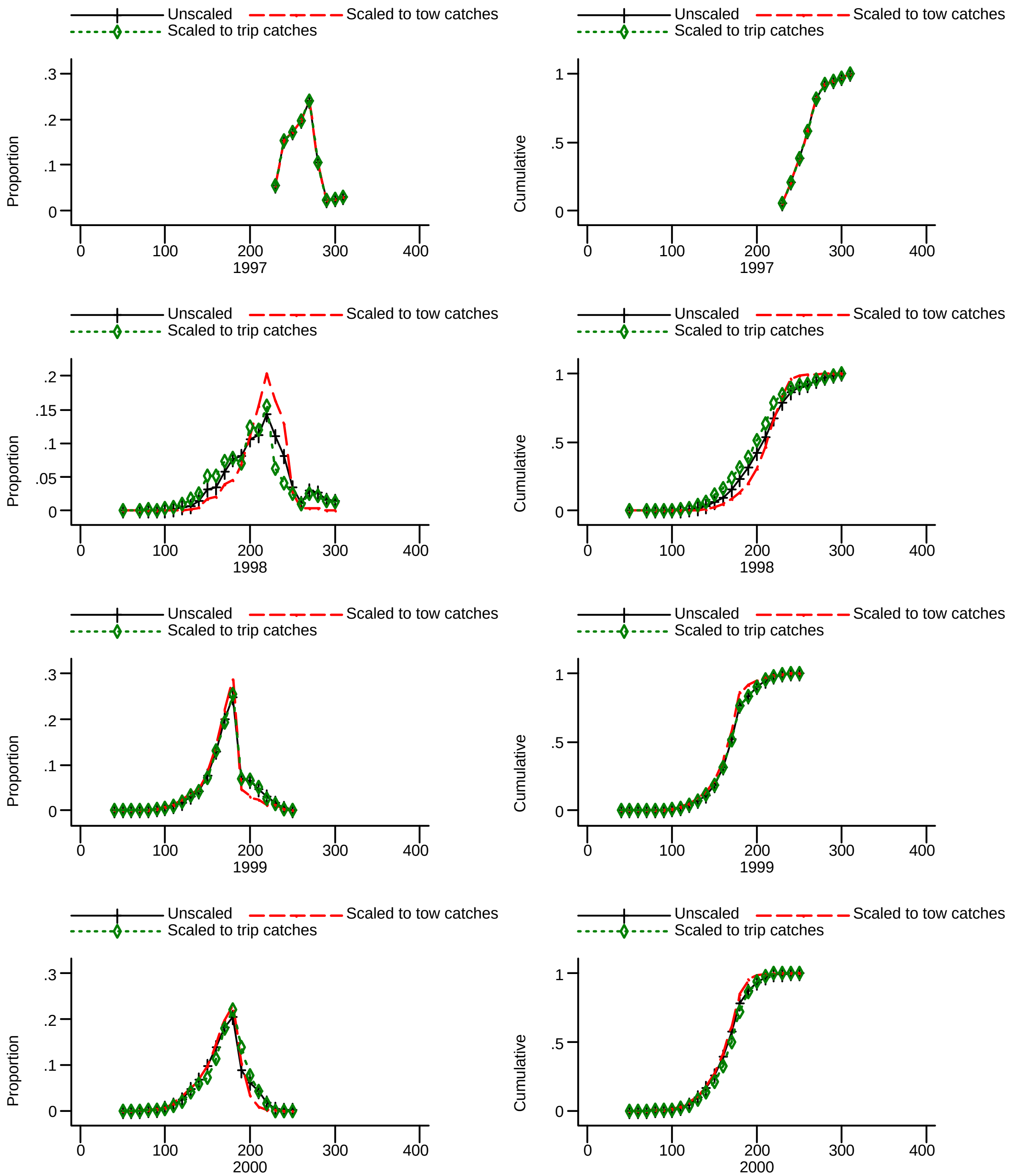
Appendix D: Longspine Length Frequency Distributions by Fishing Year, Sample Type and Scaling Option



Appendix Figure 2. Proportional and cumulative distribution of longspine thornyhead catch by fishing year for total catch samples only. Three scaling options are presented: a) unscaled, b) scaled to the catches for the sampled tow only and c) scaled to the total catches for the entire trip that was sampled.



Appendix Figure 3. Proportional and cumulative distribution of longspine thornyhead catch by fishing year for the retained catch samples only. Three scaling options are presented: a) unscaled, b) scaled to the catches for the sampled tow only and c) scaled to the total catches for the entire trip that was sampled.



Appendix Figure 4. Proportional and cumulative distribution of longspine thornyhead catch by fishing year for the discard catch samples only. Three scaling options are presented: a) unscaled, b) scaled to the catches for the sampled tow only and c) scaled to the total catches for the entire trip that was sampled.

APPENDIX E: CALCULATING STANDARD ERRORS FOR CPUE

BY CHRIS FRANCIS, 7 JUNE 2001

This note describes how to calculate standard errors (*s.e.*s) for standardised CPUE indices following the suggestion of Francis (1999). These *s.e.*s relate to what Francis (1999) called the *canonical form* for CPUE indices (in which there is no reference year).

These *s.e.*s have two advantages over those calculated by the method that has been used by most people at NIWA. First, an *s.e.* is calculated for every year (i.e., we don't have an *s.e.* of 0 for the reference year). Second, the *s.e.*s are not inflated by the uncertainty associated with the reference year (see fig. 2 of Francis 1999, which shows that the *s.e.*s can vary a lot with the choice of reference year, and that they are always much smaller when there is no reference year).

In the procedure described here, I am assuming that you have carried out a CPUE standardisation in the conventional way (i.e., with a reference year) and are able to obtain, from whatever software you are using, the estimated covariance matrix for your year coefficients. By the year coefficients, I mean the vector of regression coefficients associated with each year. If there are n years in your data set this vector will have length n-1 (because the reference year is excluded). Note that these year coefficients are in log space; to get year effects (in natural space) you need to exponentiate the year coefficients. Suppose that the reference year you have chosen is the rth of your n years (very often r = 1) and that **V** is the estimated covariance matrix for the year coefficients (so **V** is an (n-1) x (n-1) matrix).

You need to construct an n x (n-1) matrix **Q,** whose ijth element is given by

$$Q_{ij} = \begin{cases} (n-1)/n & \text{if } i < r \text{ and } i = j \\ (n-1)/n & \text{if } i > r \text{ and } i = j+1 \\ -1/n & \text{otherwise} \end{cases}$$

If you are working in S or Splus, you can create **Q** using the following two commands

```
Q<–matrix(-1/n,n,n-1)
Q[-r,]<–Q[-r,]+diag(rep(1,n-1))
```

Now calculate matrix $\mathbf{V}^0$ = (**Q** * **V**) * **Q**', where * represents matrix multiplication and **Q**' is the matrix transpose of **Q**. In S or Splus, V0<–(Q %*% V) %*% t(Q).

$\mathbf{V}^0$ is the covariance matrix that you want. That is, the *s.e.* for the ith year coefficient is $\sqrt{V_{ii}^0}$. (Note that $\mathbf{V}^0$ is an n x n matrix so this provide *s.e.*s for all n years, including the reference year).

APPENDIX F: DATA SUMMARIES SUPPORTING THE GLM ANALYSIS

The following tables and graphs summarise the data available in each dataset used for the GLM models presented in Sections 5.6 and 5.7. The data summary consists of two tables and two graphs:

- 1st table: distribution of vessels, tows, catch, and effort by vessel category;
- 2nd table: distribution of tows by standard fishing year and DFO minor statistical area;
- 1st graph: box plots of the distribution of data for key variables by standard fishing year;
- 2nd graph: box plots of the distribution of LN(CPUE) for key predictor variables used in the models.

Note that for all graphs and tables, the data have been restricted to tows set in depths greater than 700 m and that the graphs and the 2nd table are restricted to the top 13 vessels category as well.

F.1 WCVI ANALYSIS SUMMARY STATISTICS

Appendix Table 10. Number of vessels in the traditional WCVI dataset grouped into two categories: the top 13 vessels (Appendix Table 1) and the remaining vessels. The number of tows, the total catch in kg and the total effort in hours are presented for each vessel category. These latter three totals are also expressed in percent, indicating the amount of data present in the dataset for each vessel category.

Vessel category	Number of vessels	Tows		Catch		Effort	
		Total	Percent	Total	Percent	Total	Percent
Top 13	13	6,119	81%	2,410,294	81%	39,320	85%
Other	28	1,446	19%	556,503	19%	6,907	15%
Total	41	7,565		2,966,797		46,226	

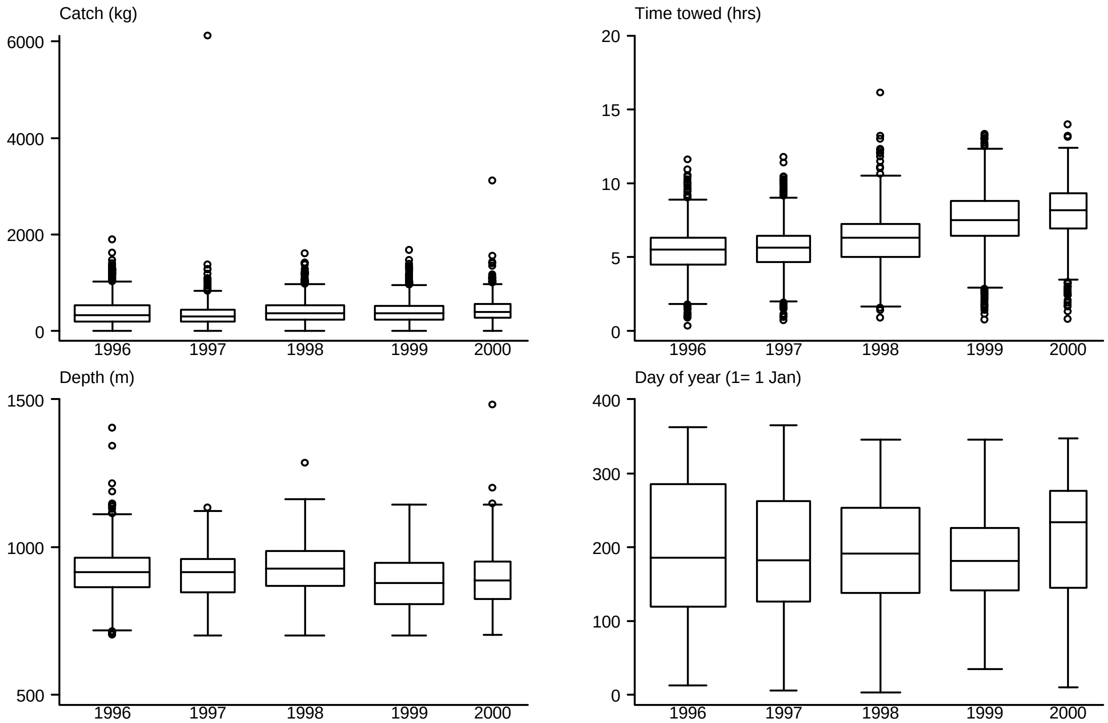
Appendix Table 11. Number of tows in the traditional WCVI dataset by standard fishing year and DFO minor statistical area (arranged from south to north). The dataset has been limited to the top 13 vessels, to tows set at greater than 700 m in depth and includes tows with zero declared catch.

Fishing Year	DFO Minor Statistical Area				Total[1]
	23	24	25	26	
1996/97	129	683	324	340	1,476
1997/98	242	390	242	177	1,053
1998/99	540	309	504	182	1,535
1999/2000	192	174	582	397	1,345
2000/01	190	59	234	227	710
Total	1,293	1,615	1,886	1,323	6,119

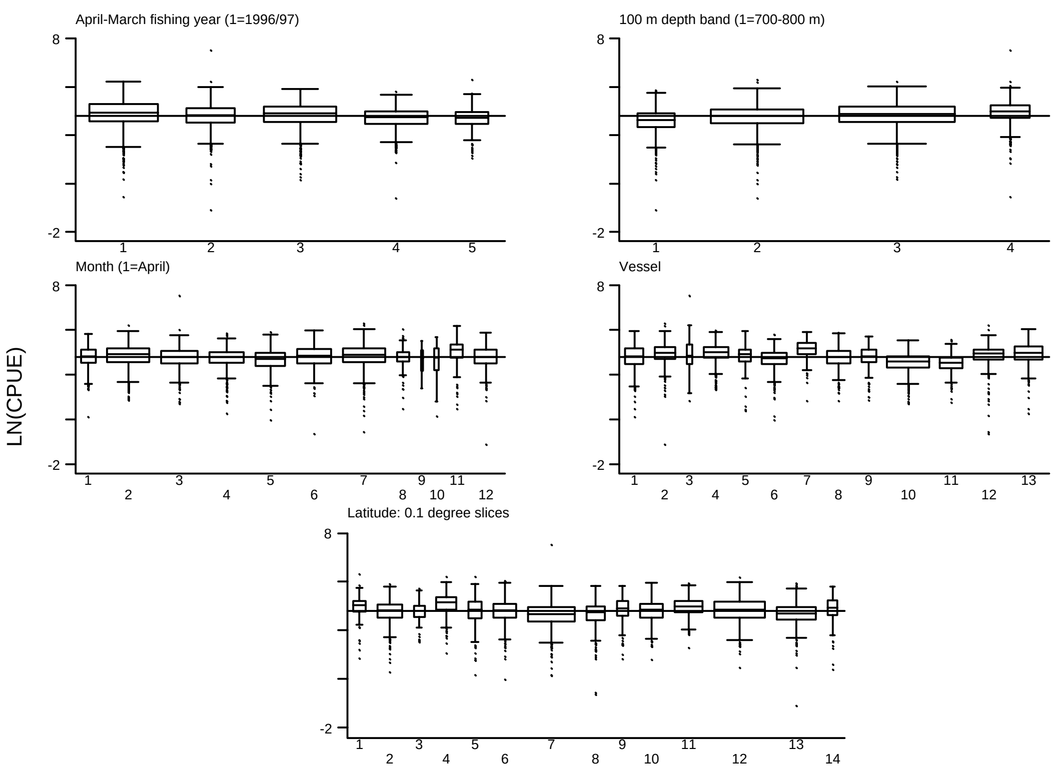
[1] One unknown tow and one tow in Area 21 included in the Total.

Appendix Table 12. Number of tows and distribution of tows in the traditional WCVI dataset with no indicated catch of LST by fishing year in the dataset for the "Top 13" vessels and for tows set at greater than 700 m in depth..

Year	Zero tows	Positive tows	Total tows	% Zero	% Positive
1996	41	1,435	1,476	3%	97%
1997	32	1,021	1,053	3%	97%
1998	4	1,531	1,535	0%	100%
1999	35	1,310	1,345	3%	97%
2000	24	686	710	3%	97%
Total	136	5,983	6,119	2%	98%



Appendix Figure 5. Distribution of catch, hours fished, depth and day of year for the traditional west coast Vancouver Island GLM model by standard fishing year. The width of the boxes is proportional to the number of tows.



Appendix Figure 6. Box plots of LN(CPUE) for each categorical variable which entered into the traditional west coast Vancouver Island GLM model. The width of the boxes is proportional to the number of tows in that category and the mean LN(CPUE) is plotted as a horizontal line. Tows with no catch have missing values for LN(CPUE).