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A review of longspine thornyhead *Sebastolobus altivelis* along the Pacific coast of Canada: biology, distribution, and abundance trends

Examen du sébastolobe à longues épines (*Sebastolobus altivelis*) dans les eaux de la côte canadienne du Pacifique : biologie, répartition et tendances en matière d'abondance

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Abstract

This paper reviews the current data on the biology, distribution, and abundance trends for longspine thornyhead *Sebastolobus altivelis*. The information contained herein is primarily for use in a COSEWIC status report on this species. It is not meant to be a comprehensive stock assessment. This species has a mean weight of 114 g/fish. Allometric growth shows no difference between the sexes; information on size-at-age is sparse. The oldest fish aged was 71 years. With an estimated age-of-50%-maturity at 20 years, and an assumed natural mortality rate of 0.10, generation time is roughly 30 years. According to survey and commercial trawl records, longspine thornyhead occur at depths between 500 m and 1600 m. Using this interval, a bathymetric analysis estimates the potential extent of occurrence at 17,775 km^2 and the area of occupancy at 9,914 km^2. However, based on trawl observations alone, the area of occupancy could easily equal 11,700 km^2. Within its habitat, the two predominant concurrent species are shortspine thornyhead *Sebastolobus alascanus* and sablefish *Anoplopoma fimbria*. Total removal of longspine thornyhead from BC coastal waters by the commercial fleet from 1996 to 2005 equals approximately 57 million fish. The only available survey for indexing longspine thornyhead populations is that conducted off the WCVI in 2001-2003. The trend from this survey is flat. The commercial trawl CPUE indices show a declining trends in all areas of the coast: -8% y^{-1} for the WCVI region from 1996 to 2004, -9% y^{-1} for the Tidemarks region from 2000 to 2004, and -23% y^{-1} for the Rennell region from 2000 to 2004.

Résumé

Le document passe en revue les données actuelles sur la biologie, la répartition et les tendances en matière d'abondance du sébastolobe à longues épines, *Sebastolobus altivelis*. L'information qu'il contient est destinée principalement à un rapport du COSEPAC sur la situation de l'espèce. Il ne vise pas à faire une évaluation complète du stock. Cette espèce à un poids moyen de 114 g/poisson. L'allométrie de croissance n'affiche aucune différence entre les sexes; l'information sur la taille selon l'âge est limitée. Le poisson le plus vieux avait 71 ans. Avec un âge estimatif à maturité pour 50 % de 20 ans et un taux de mortalité naturelle présumé de 0,10, la durée de génération est d'à peu près 30 ans. Selon les registres de relevé et de la pêche commerciale au chalut, le sébastolobe à longues épines vit à des profondeurs variant entre 500 m et 1 600 m. À partir de cet intervalle, une analyse bathymétrique estime l'étendue possible de sa présence à 17 775 km^2 et son aire de répartition à 9 914 km^2. Toutefois, selon les observations au chalut seulement, l'aire de répartition pourrait facilement s'étendre à 11 700 km^2. Dans cet habitat, les deux espèces concurrentes dominantes sont le sébastolobe à courtes épines, *Sebastolobus alascanus*, et la morue charbonnière, *Anoplopoma fimbria*. Le total des prélèvements de sébastolobe à longues épines des eaux côtières de la C.-B. par les pêcheurs commerciaux de 1996 à 2005 équivaut à environ 57 millions de poissons. Le seul relevé qui permette de calculer des indices du sébastolobe à longues épines est celui qui a été réalisé sur la côte ouest de l'île de Vancouver, de 2001 à 2003. La tendance illustrée par ce relevé est plane. Les indices des CPUE de la pêche commerciale au chalut révèlent des tendances à la baisse dans tous les secteurs de la côte : -8 % y^{-1} pour le secteur de la côte ouest de l'île de Vancouver de 1996 à 2004, -9 % y^{-1} pour le secteur de Tidemarks de 2000 à 2004 et -23 % y^{-1} pour le secteur de Rennell, de 2000 à 2004.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Introduction

This paper reviews the current data on the biology, distribution, and abundance trends for longspine thornyhead *Sebastolobus altivelis*. The information contained herein is primarily for use in a COSEWIC status report on this species (Appendix 1). It is not meant to be a comprehensive stock assessment.

In spring, females release fertilized eggs in a gelatinous matrix which floats to the surface. Here, the eggs hatch and the larvae and early stage juveniles remain in the upper 200 m for 6 months. As the juveniles mature they get progressively deeper, generally remaining in the mesopelagic zone (~600 m) for one year. Eventually, young fish settle directly into adult territory at 600-1,200 m. Juveniles eat euphausiids, adults target brittle stars. Longspine thornyheads are adapted to live in deep water where oxygen is low and pressure is high. Sexual maturity is reached by length 150 mm which corresponds to a modelled age of 4 years.

The bulk of the longspine thornyhead population lives in the DFO management region “WCVI”, with two smaller known populations in the “Tidemarks” and “Rennell” regions. These populations may be continuous. Commercial trawl indices suggest annual rates of decline of 8%, 9%, and 23% in these three regions, respectively. The total observed decline for the west coast Vancouver Island (WCVI) populations is estimated to be around 50% over nine years of fishing.

2. Analytical Methods

2.1. Length-weight growth model

Length-weight relationships typically follow allometric growth (Quinn and Deriso 1999, p.130), and models assume multiplicative error when the variability in growth increases as a function of length. Suppose that a set of data $\{L_i, W_i\}$ for fish $i = 1, \ldots, n$ exists. Then the typical growth model is

$$W_i = \alpha L_i^{\beta} e^{\sigma \varepsilon_i} , \qquad (1)$$

where W_i = weight of fish i;
L_i = length of fish i;
α = scaling factor;
β = exponential factor;
σ = standard deviation of lognormal error;
ε_i = standard normal random variable i.

The logarithmic form

$$\ln W_i = \ln \alpha + \beta \ln L_i + \sigma \varepsilon_i \qquad (2)$$

yields the negative log likelihood:

$$\ell(\alpha, \beta, \sigma) = n \log \sigma + \frac{1}{2\sigma^2} \sum_{i=1}^{n} \left(\ln W_i - \ln \alpha - \beta \ln L_i \right)^2 . \qquad (3)$$

2.2. Length-age growth model

Growth rates of fish tend to slow down as they get older (Quinn and Deriso 1999, p.135), hence a length-age growth model yields a concave curve approaching an upper asymptote. Typically, growth curves follow an S-shape with a leading convex curve; however, the region of growth at young ages usually lacks data so that models do not represent juvenile growth well. The von Bertalanffy equation (4) adequately describes the concave section of a growth curve. Suppose that a set of data $\{L_i, t_i\}$ for fish $i = 1, \ldots, n$ exists. Then the growth model with multiplicative error is

$$L_i = L_\infty \left[1 - e^{-K(t_i - t_0)}\right] e^{\sigma\varepsilon_i} , \qquad (4)$$

where L_i = length of fish i;
t_i = age of the fish i;
L_∞ = horizontal asymptote describing the theoretical maximum length;
K = parameter that governs the speed with which the curve reaches L_∞;
t_0 = theoretical age when the fish is length 0;
σ = standard deviation of lognormal error;
ε_i = standard normal random variable i.

The logarithmic form is

$$\ln L_i = \ln L_\infty + \ln\left[1 - e^{-K(t_i - t_0)}\right] + \sigma\varepsilon_i ,$$

and the negative log likelihood is

$$\ell\left(L_\infty, K, t_0, \sigma\right) = n \log\sigma + \frac{1}{2\sigma^2} \sum_{i=1}^{n} \left[\ln L_i - \ln L_\infty - \ln\left(1 - e^{-K(t_i - t_0)}\right)\right]^2 . \qquad (5)$$

2.3. Generation Time

Generation time, assumed to be the average age of parents in the population, takes the form:

$$t_{gen} = k + \frac{1}{e^M - 1} , \qquad (6)$$

where k = age at 50% maturity;
M = instantaneous rate of natural mortality.

A crude approximation to generation time is frequently adopted:

$$t_{gen} = k + \frac{1}{M} , \qquad (7)$$

which approaches (6) as $M \to 0$.

2.4. Swept-area biomass calculations

Catch and effort data for strata i in year y yield catch per unit effort (CPUE) values U_{yi}. Given a set of data $\{C_{yij}, E_{yij}\}$ for tows $j = 1, \ldots, n_{yi}$,

$$U_{yi} = \frac{1}{n_{yi}} \sum_{j=1}^{n_{yi}} \frac{C_{yij}}{E_{yij}}, \tag{8}$$

where C_{yij} = catch (kg) in tow j, stratum i, year y;
E_{yij} = effort (h) in tow j, stratum i, year y;
n_{yi} = number of tows in stratum i, year y.

CPUE values U_{yi} convert to CPUE densities δ_{yi} (kg/km^2) using:

$$\delta_{yi} = \frac{1}{vw} U_{yi}, \tag{9}$$

where v = average vessel speed (km/h);
w = average net width (m).

Alternatively, if vessel information exists for every tow, CPUE density can be expressed

$$\delta_{yi} = \frac{1}{n_{yi}} \sum_{j=1}^{n_{yi}} \frac{C_{yij}}{D_{yij} w_{yij}}, \tag{10}$$

where C_{yij} = catch weight (kg) for tow j, stratum i, year y;
D_{yij} = distance travelled (km) for tow j, stratum i, year y;
w_{yij} = net opening (km) for tow j, stratum i, year y;
n_{yi} = number of tows in stratum i, year y.

The annual biomass estimate is then the sum of the product of CPUE densities and bottom areas across m strata:

$$B_y = \sum_{i=1}^{m} \delta_{yi} A_i = \sum_{i=1}^{m} B_{yi}, \tag{11}$$

where δ_{yi} = mean CPUE density (kg/km^2) for stratum i, year y;
A_i = area (km^2) of stratum i;
B_{yi} = biomass (kg) for stratum i, year y;
m = number of strata.

The variance of the survey biomass estimate V_y (kg^2) follows:

$$V_y = \sum_{i=1}^{m} \frac{\sigma_{yi}^2 A_i^2}{n_{yi}} = \sum_{i=1}^{m} V_{yi}, \tag{12}$$

where σ^2_{yi} = variance of CPUE density (kg^2/km^4) for stratum i, year y;

V_{yi} = variance of the biomass estimate (kg^2) for stratum i, year y.

The CV of the annual biomass estimates is

$$CV_y = \frac{\sqrt{V_y}}{B_y}. \tag{13}$$

2.5. General linear models (GLM) for CPUE data

Quinn and Deriso (1999, p.19) describe a general linear model based on the lognormal distribution:

$$U_{ijk} = U_0 \prod_i \prod_j P_{ij}^{X_{ij}} e^{\varepsilon_{ijk}}, \tag{14}$$

where U_{ijk} = the observed CPUE for tow k at the j^{th} level of factor i;

U_0 = the reference CPUE;

P_{ij} = coefficient for factor i at level j;

X_{ij} = 1 when the j^{th} level of the factor i contains data, and 0 when it does not;

ε_{ijk} = random deviate for observation k with mean=0 and standard deviation σ.

Taking the logarithm of (14) yields an additive linear regression model with p factors and $n_{i=1,\ldots,p}$ levels:

$$\ln U_{ijk} = \ln U_0 + \sum_{i=1}^{p} \sum_{j=1}^{n_i-1} X_{ij} \ln P_{ij} + \varepsilon_{ijk} \quad \text{or} \quad Y_{ijk} = \beta_0 + \sum_{i=1}^{p} \sum_{j=1}^{n_i-1} \beta_{ij} X_{ij} + \varepsilon_{ijk}. \tag{15}$$

where Y_{ijk} = $\ln U_{ijk}$;

β_0 = the model intercept $\ln U_0$;

β_{ij} = the logged coefficient P_{ij} of factor i at level j.

As the model described by (14) and ((15) is over-parameterised, constraints must be imposed to allow estimation of model parameters. A common solution sets one coefficient for each factor to zero, usually the first, where the remaining $n_i - 1$ coefficients of each factor i represent incremental effects relative to the reference level.

The estimated factor coefficients are not unique: coefficients obtained by fixing a factor level will differ with the choice of reference level. However, the relative differences among the estimated coefficients will not be affected by the choice of constraint. Following the suggestion of Francis (1999), coefficients for factor i were transformed to "canonical" coefficients over all levels j calculated relative to their geometric mean $\bar{\beta} = \sqrt[n]{\prod_{j=1}^{n} \beta_j}$ (including the level where $\beta_j = 0$), so that

$$\beta'_j = \frac{\beta_j}{\bar{\beta}}. \qquad (16)$$

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

$$b'_j = e^{\left(\beta_j - \bar{\beta}\right)}. \qquad (17)$$

The use of the canonical form allows the computation of standard errors for every coefficient, including the fixed coefficient (Francis 1999). 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.

A range of factors P_{ij} are available in the data which may be used to account for variability in the observed CPUE. These include factors such as the date of capture (usually year and month), the capturing vessel, and the depth and location of capture. The year of capture is usually given special significance in these analyses: variations between years in this factor are interpreted as relative changes in the annual abundance of the fish species which is the subject of the analysis. The resulting series of ‘year’ or ‘fishing year’ canonical coefficients is termed the “Standardised” annual CPUE index Y'_j in this report.

A selection procedure (Vignaux 1993, Vignaux 1994; Francis 2001) was applied to determine the relative importance of these factors in the model. The procedure involves a forward stepwise fitting algorithm which generates regression models iteratively, starting with the simplest model (one dependent and one independent variable) and building in complexity subject to a stopping rule designed to include only the most important factors.

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

- Calculate the regression with each predictive factor (variable) against the natural log of CPUE (kg/h).
- Generate the Akaike Information Criterion (AIC) (Akaike 1974) for each regression based on the number of model degrees of freedom. Select the predictor variable that has the lowest AIC. The AIC is used for model selection to account for variables which may have equivalent explanatory power in terms of residual deviance but require fewer degrees of freedom for the model (Francis 2001).
- 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 (as measured by R^2) for the final iteration is less than 0.01. The selection of 0.01 as the threshold is arbitrary but adding factors which explain small amounts of the total variance has little effect on the year coefficients and other coefficients of interest.

Other annual indices can be generated from the catch and effort data used for the linear modelling described above. The simplest estimate of mean annual CPUE is given by:

$$R_j = \frac{\sum_{k=1}^{M_j} C_{jk}}{\sum_{k=1}^{M_j} E_{jk}} \tag{18}$$

where C_{jk} denotes that catch and E_{jk} denotes the effort for each record k in year j. The series of annual estimates is termed the "Arithmetic" CPUE index in this report.

Another annual index is specified by

$$U_j = \exp\left[\frac{1}{M_j}\sum_{k=1}^{M_j} \ln\frac{C_{jk}}{E_{jk}}\right] \tag{19}$$

where U_j is the annual geometric mean of the CPUE observations. The resulting annual index is termed the "Unstandardised" CPUE index in this report. Annual estimates obtained using (19) are equivalent to the results obtained from a linear model where year is the only predictive factor.

Like the scaling described for the standardised index, the series specified by (18) and (19) can be scaled relative to their geometric means. This is done to provide comparability with the standardised indices. Given n years in each series, the geometric means of the arithmetic and unstandardised series are given by $\bar{R} = \sqrt[n]{\prod_{j=1}^{n} R_j}$ and $\bar{U} = \sqrt[n]{\prod_{j=1}^{n} U_j}$, respectively. Thus, each series can be scaled to the corresponding geometric mean as:

$$R'_j = \frac{R_j}{\bar{R}} \tag{20}$$

and

$$U'_j = \frac{U_j}{\bar{U}}. \tag{21}$$

The procedures described by (14), ((15), and (19) are necessarily confined to the positive catch observations in the data set as ln(0) is undefined. Observations with zero catch can be handled in a number of ways:

- Zero-catch records are frequently dropped from further consideration, usually because they are not accurately recorded. This is particularly true for catch records which are maintained by fishermen who frequently discount small amounts of catch as being inconsequential.
- A small increment can be added to the zero catch records so that ln(0) can be calculated. This is not a satisfactory solution because model parameter estimates are sensitive to the value selected for the increment.
- A linear regression model based on a binomial distribution and using the presence/ absence of the fish species as the dependent variable can be estimated using the same

data set. Explanatory factors are estimated in the model in the manner described in (14) and ((15). Such a model will provide another series of standardised coefficients of relative annual changes that is analogous to the series estimated from the lognormal regression. This approach has been followed for the data set based on observer records (PacHarvTrawl after 1996) where it is felt that zero catch records are likely to have greater reliability (see below).

- A combined model which integrates the two series of relative annual changes estimated by the lognormal and binomial models can be estimated using the Δ-distribution which allows zero and positive observations (Vignaux 1994). This approach was not followed in this analysis.

3. Biology

3.1. Mean weight

The mean weight of longspine thornyhead is expressed as the mean of PMFC-area specimen weights that have been normalized using the square root transformation:

$$\overline{W}_A = \left(\frac{1}{n_A} \sum_{i=1}^{n_A} w_i^{0.5} \right)^2 , \qquad (22)$$

where n_A = the number of specimens in area A;
w_i = weights for specimens $i = 1, \ldots, n_A$.

The PMFC area weights $\overline{W}_A$, are then weighted by the proportion of specimens in each area $p_A = n_A \big/ \sum n_A$. Data come from GFBio. The weighted mean is

$$\overline{W}' = \sum p_A \overline{W}_A = 114 \text{ g/fish} . \qquad (23)$$

The WCVI specimens are notably smaller than those in Tidemarks (5AB) and Rennell (5E). This perhaps reflects the longer period of exploitation with a consequent reduction in mean weight.

Table 1. Calculation of mean longspine thornyhead weight (g) by PMFC area.

PMFC Area	A	3C	3D	5A	5B	5E	Total
GFBio area code		3	4	5	6	9	
Mean weight by area (g)	$\overline{W}_A$	116	108	160	178	146	
Number of specimens	n_A	2,582	2,519	142	63	40	5,346
Proportion of all specimens	p_A	0.483	0.471	0.027	0.012	0.007	1
Mean contribution (g)	$p_A\overline{W}_A$	55.9	50.8	4.2	2.1	1.1	114

3.2. Length-weight relationship

3.2.1. Data selection

Data were selected from the DFO GFBio database using minimal qualifications:

- species identified as longspine thornyhead (code = 453);
- specimen identified as either male or female (codes = 1 and 2, respectively);
- lengths ≤ 350 mm (to remove *Sebastolobus alascanus* specimens probably misidentified as *S. altivelis*).

The above qualification yielded 4,181 longspine thornyhead specimens with the following distributions:

- by sex – males (1886), females (2295);
- by area – 3C (1966), 3D (1980), 5A (136), 5B(60), 5E(39);
- by gear – bottom trawl (4181);
- by year – 2000 (235), 2001 (1875), 2002 (987), 2003 (1084);
- by trip type – research (1014), charter (3117), observed commercial (50).

3.2.2. Results

Data for all available lengths and weights in GFBio were used to derive an empirical length-weight relationship. This assumes that all measurements are independent of collection method, area, and fishery. After fitting the data with a lognormal linear model (3) using standard minimization tools in S-Plus, the relationships for males and females are virtually identical. In other words, there appears to be no sex-specific difference in allometric growth.

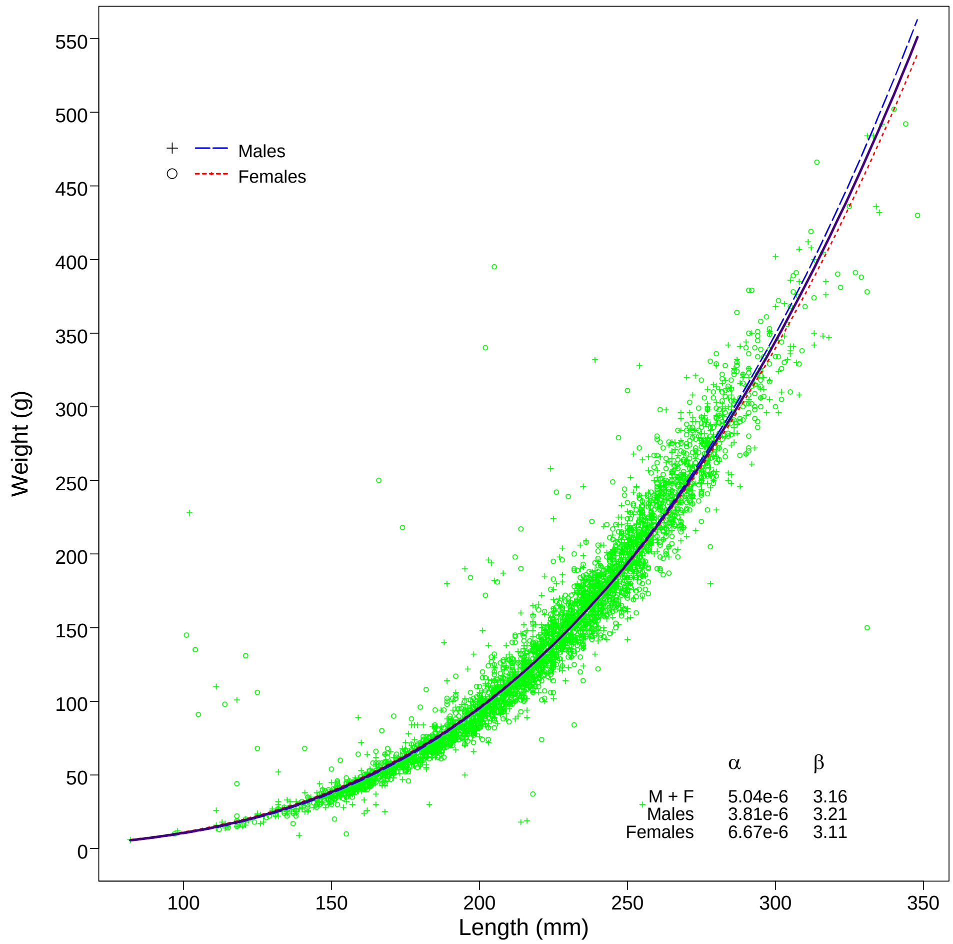

Figure 1. Longspine thornyhead weight vs. length fitted using a lognormal linear model: $\log W = \log\alpha + \beta \log L$ ..

3.3. Length-age relationship

3.3.1. Data selection

The data for age-length relationships comes from a special ageing project initiated by Dr. R. Beamish (Pacific Biological Station, Nanaimo BC, V9T 6N7). The specimens for this project all came from the 2001 thornyhead survey (Starr et al. 2002) and were deliberately chosen to cover a variety of sizes (i.e., non-random). The qualifications used here are minimal:

- species identified as longspine thornyhead (code = 453);
- specimen identified as either male or female (codes = 1 and 2, respectively);

The above qualification yielded 198 longspine thornyhead specimens with the following distributions:

- by sex – males (95), females (103);
- by area – 3C (66), 3D (132);
- by gear – bottom trawl (198);
- by year – 2001 (198);

- by trip type – charter (198).

3.3.2. Results

The length-age data for longspine thornyhead are variable and sparse. The von Bertalanffy fits through the data using (5) are not terribly convincing(Figure 2). For instance, the fit for females estimates t_0 at -45 years and L_∞ at 437 mm (which is much larger than the known size limit of 350 mm).

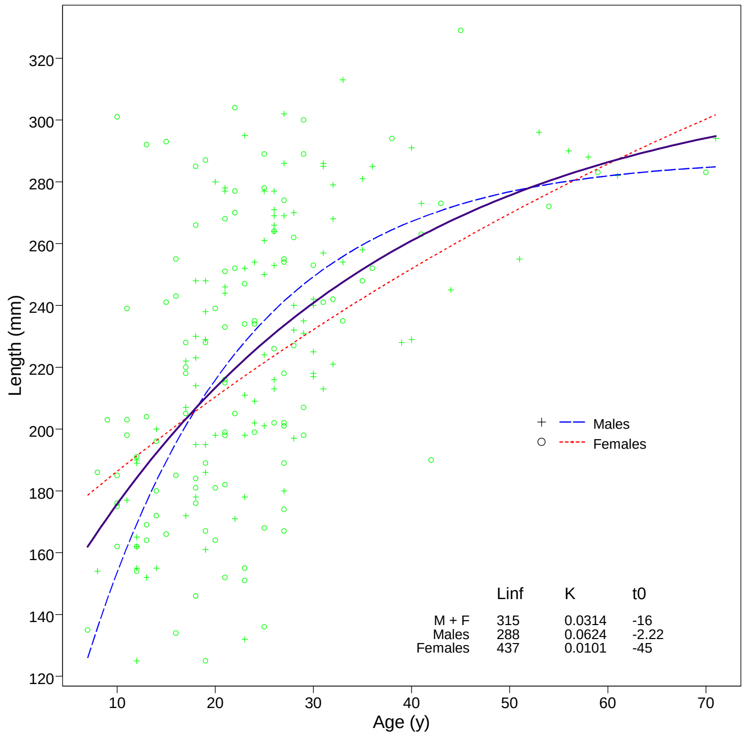

Figure 2. Length-at-age relationship fitted using von Bertalanffy growth equation (4).

3.4. Maturity, mortality, and generation time

Using the age data cited in Section (3.3.1), a maturity ogive is constructed (Figure 3). Due to the sparse information, the maturity data are binned in 4-year age groups. For each group, the proportion of mature individuals is calculated (Table 2) and the age of 50% maturity k is interpolated from the curves. Generally, k = 20 y (females 18 y, males 20 y). Assuming a natural mortality rate M = 0.10 (Ianelli et al. 1994), the generation time (6) is roughly 30 y.

Table 2. Proportions of mature longspine thornyhead by age group. Maturity is defined by codes 2-7. *p* = proportion mature fish, *n* = number of fish specimens, *A* = mean age of specimens in group, *σ* = standard deviation of the mean age.

Age	All				Males				Females			
Group	*p*	*n*	*A*	*σ*	*p*	*n*	*A*	*σ*	*p*	*n*	*A*	*σ*
5-8	0	5	7.8	0.45	0	1	8.0		0	2	7.5	0.71
9-12	0.12	25	10.9	1.13	0	8	11.9	0.35	0.25	12	10.7	0.98
13-16	0.23	22	14.5	1.22	0.33	3	13.7	0.58	0.29	14	14.5	1.22
17-20	0.41	37	18.4	0.99	0.35	17	18.4	0.94	0.50	18	18.4	1.04
21-24	0.53	38	22.3	1.19	0.60	15	22.5	1.19	0.52	21	22.0	1.12
25-28	0.63	40	26.4	1.03	0.57	21	26.3	1.06	0.72	18	26.5	0.99
29-32	0.86	21	30.3	1.11	0.79	14	30.6	1.02	1	7	29.9	1.21
33-36	0.78	9	34.3	1.32	0.80	5	34.4	1.34	1	3	34.7	1.53
37-40	0.75	4	39.3	0.96	0.67	3	39.7	0.58	1	1	38.0	
41-44	0.80	5	42.2	1.30	1	2	42.5	2.12	0.67	3	42.0	1
45-48	1	1	45.0						1	1	45.0	
49-52	1	1	51.0		1	1	51.0					
53-56	1	3	54.3	1.53	1	2	54.5	2.12	1	1	54.0	
57-60	0.50	2	58.5	0.71	1	1	58.0		0	1	59.0	
61-64	1	1	61.0		1	1	61.0					
69-72	1	2	70.5	0.71	1	1	71.0		1	1	70.0	

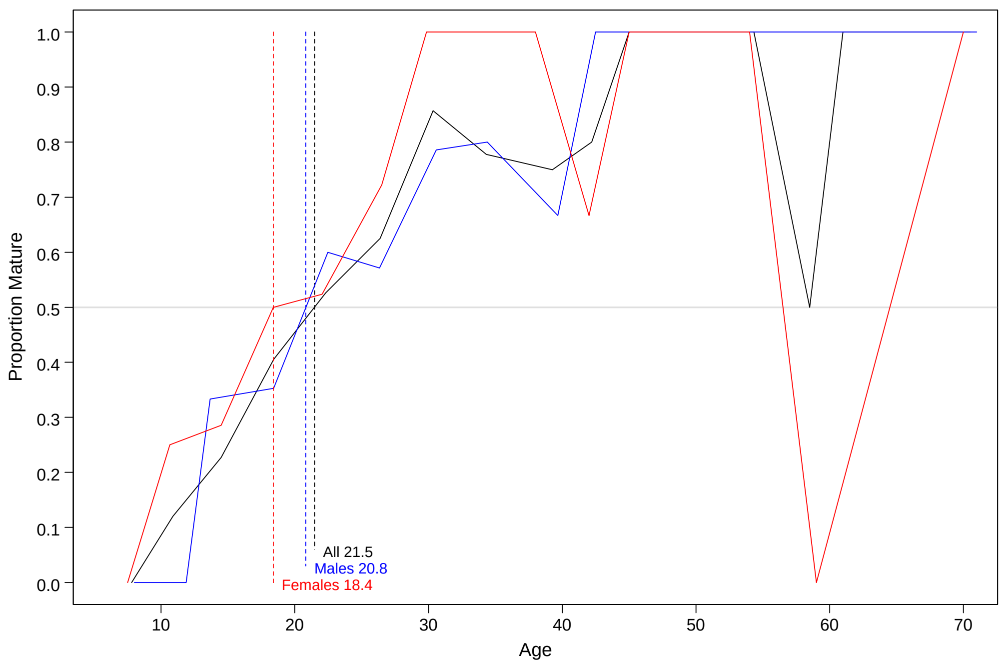

Figure 3. Maturity ogives for longspine thornyhead using grouped ages from 5 to 72 at 4-year age intervals. The age of each group is expressed as the mean of the observed ages in each group. Vertical dashed lines indicate ages at 50% maturity for males, females, and all available specimens, including those without a sex determination.

4. Distribution

4.1. Depth preference

There is a very strong relationship between depth and density as measured by CPUE (Haigh and Schnute 2003). Starr (2001, p.47) effectively showed that longspine thornyheads do not appear in tows shallower than 500 m. Records of *Sebastolobus altivelis* that appear in the PacHarvTrawl database (Figure 4) are probably the shallower congener *S. alascanus*.

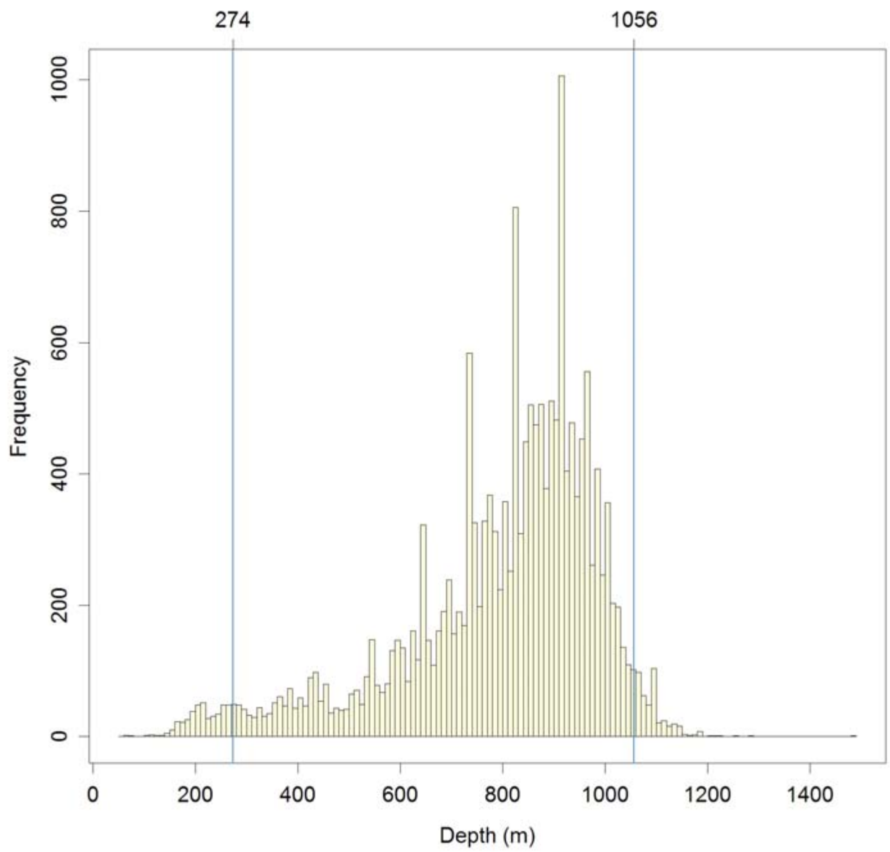

Figure 4. Histogram of depth-of-capture for longspine thornyhead from commercial trawl logs (1996-2004). The vertical lines denote the 2.5% and 97.5% quantiles.

4.2. Bathymetric coverage

Fishing events that captured longspine thornyhead were extracted from the observer trawl database PacHarvTrawl, from the hook and line database PacHarvHL, and from research surveys. Start locations of tows were plotted in ArcView and then converted to a 5 km × 5 km raster grid. Grid cells containing one or more events were deemed to be “occupied” by longspine thornyhead. The resulting raster layer comprised cells of binary values – either “true” (occupied) or “false” (not occupied). This raster layer was added to a second raster layer consisting of ocean depth at a resolution of 1 km^2. From the combined raster layer, the area of potential and occupied habitat was obtained over depth intervals of 100 m (Table 3).

Table 3. Bathymetric determination of total available and observed occupied areas by 100-m depth interval for longspine thornyhead. Based on events from commercial fishing and surveys located in 25 km^2 grid cells overlaid on a 1 km^2 ocean depth grid.

Depth Interval (m)	Total Area (km^2)	Occupied Area (km^2)	Percent Occupied
501-600	1,782	1,080	60.6
601-700	1,561	1,187	76.0
701-800	1,413	1,125	79.6
801-900	1,247	955	76.6
901-1000	1,470	1,084	73.7
1001-1100	1,623	1,024	63.1
1101-1200	1,804	948	52.5
1201-1300	1,731	817	47.2
1301-1400	1,692	838	49.5
1401-1500	1,630	552	33.9
1501-1600	1,478	304	20.6
Total:	17,431	9,914	56.9

4.3. Density proportional to CPUE

4.3.1. Data selection

Data were selected from the DFO PacHarvTrawl database using the following qualifications:

- species identified as longspine thornyhead (code = 453);
- observer logs (code=1);
- calendar years = 1996 to 2004;
- depth range = 500 to 1400 m;
- gear type = bottom trawl (code=1);
- effort >0 hours and ≤ 24 hours;
- successful hauls (code=0:1);
- valid spatial coordinates.

4.3.2. Methods

After qualification, CPUE was calculated as the simple ratio $U_i = C_i / E_i$ (kg/h) for each tow/set i. The U_i were located within a grid comprising 5 km × 5 km cells. In each grid cell, the mean CPUE was calculated:

$$\bar{U}_c = \frac{1}{n_c} \sum_{j=1}^{n_c} U_j \qquad (24)$$

where c = cell index;
n_c = number of tows in cell c.

4.3.3. Results

The dataset of bottom trawl tows gives a comprehensive extent of the BC fishery on longspine thornyhead. Other sectors (e.g., hook and line) do not catch this species in substantial numbers to warrant inclusion in the population density profile (Figure 5).

The highest densities of longspine thornyhead occur along the west coat of Vancouver Island (PMFC areas 3C & 3D). With the encouragement of fisheries management, other population concentrations were discovered in the Tidemarks region of the central Queen Charlotte Sound (QCS) and the northwest side of the Queen Charlotte Islands (WQCI) in 2000. The density map suggests that a minimum estimate of spatial occurrence is 11,700 km^2, although the bathymetry between 500 m and 1600 m comprising 17,775 km^2 is potentially suitable habitat. Deepwater biomass surveys off WCVI show that longspine thornyhead can live deeper than 1200 m (Starr et al. 2002, Starr et al. 2004, Krishka et al. 2005), at least down to 1600 m. The trawl fishery rarely sets tows deeper than 1200 m.

The area known as Flamingo (Figure 5) has been protected from directed longspine thornyhead fishing by the trawl fleet since 2002. Despite rough bottom topography in this region, trawl tows indicate that longspine thornyheads occur in Flamingo. In that sense, this region can perhaps be properly referred to as a refugium; however, it is not known whether these protected populations contribute significantly to the recruitment in other areas. Given the long planktonic phase of the larvae and juveniles, populations in Flamingo might “rescue” surrounding areas.

The bottom topography in the area known as Triangle is even rougher than that in Flamingo. Although Triangle has no official protection, trawl tows do not occur here. We currently do not know whether longspine thornyhead populations exist in this region.

For information purposes, the flat-surface areas between the 500 and 1600 m isobaths by management region are:

- WCVI .... 8,506 km^2
- Triangle .... 745 km^2
- Tidemarks .... 2,908 km^2
- Flamingo .... 2,455 km^2
- Rennell .... 3,162 km^2

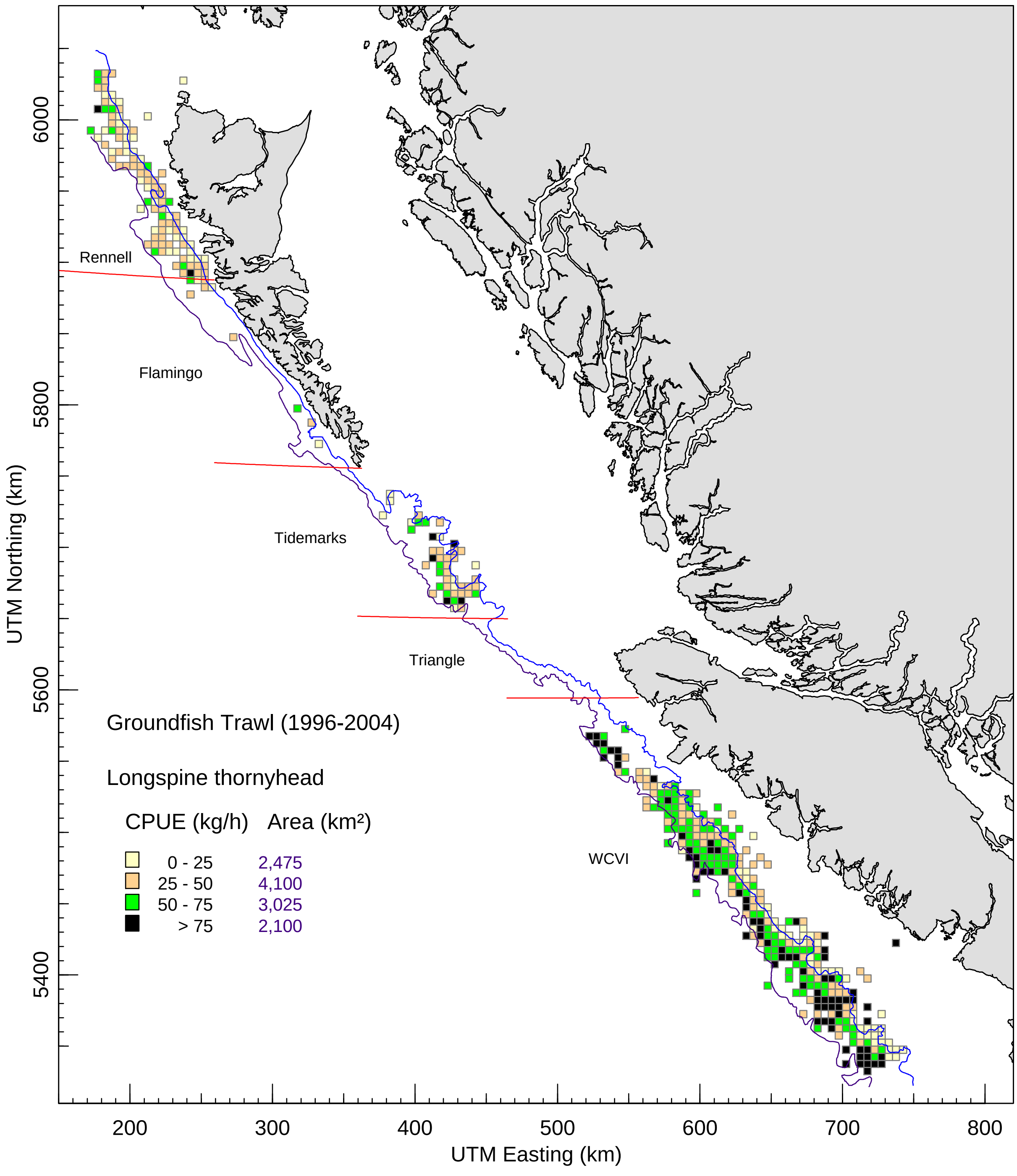

Figure 5. Mean CPUE (kg/h) of longspine thornyhead in 25 km^2 grid cells along the BC coast. The shaded cells give an approximation of the area of occupancy (11,700 km^2) as seen by groundfish trawl tows between 500 and 1400 m from 1996 to 2004. Isobaths displayed are 500 m and 1,600 m; the area between these isobaths approximates the extent of occurrence (17,775 km^2). The five DFO management regions for longspine thornyhead are delimited by horizontal red lines.

4.4. Concurrence of species in trawl tows

Within the depth range 274-1056 m (Section 4.1) and only for tows capturing longspine thornyhead, the total catch weight (landings + discards from the PacHarvTrawl database) for each species caught by the trawl fleet are converted to proportions of the total catch weight of all species caught, and ranked in descending order. The top 20 species are displayed as a horizontal bar chart (Figure 6).

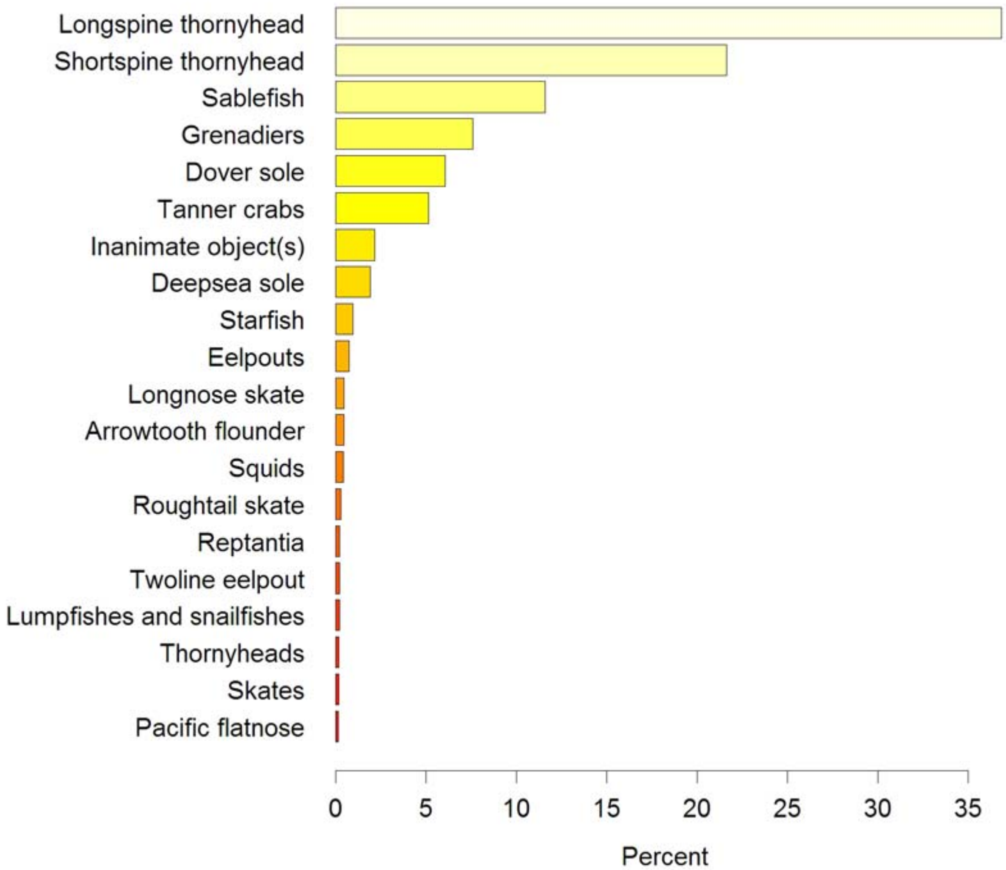

Figure 6. Concurrence of species in trawl tows (1996-2004) that captured longspine thornyhead in the preferred depth range (274-1056 m). Abundance expressed as a percent of total catch weight.

5. Population Trends

5.1. Biomass removals

The fishery for longspine thornyhead essentially started in 1996. Removals since then (Table 4) give an indication of the biomass that was present in the deepwater communities along the coast. A detailed account of the history of this fishery can be found in Schnute et al. (2004) and Haigh and Schnute (2003). The majority of the removals come from WCVI (86%), which is not too surprising given the population density map above (Figure 5). Coastwide, from 1996 to 2005, 6,524 t of longspine thornyhead were removed, which is equivalent to $6.5\times10^6\,\text{kg} \big/ 0.114\ \text{kg/fish} = 57\times10^6\ \text{fish}$.

Table 4. Annual (fishing year) total catch (kept + discarded) by the trawl fishery of longspine thornyhead (tonnes) in PMFC areas along the BC coast (3CD ≈ west coast of Vancouver Island, 4B ≈ Strait of Georgia, 5AB ≈ Queen Charlotte Sound, 5CD ≈ Hecate Strait, 5E ≈ west coast of the Queen Charlotte Islands, UNK =Unknown, CST = coastwide). Catches are rounded to the nearest tonne; entries marked '---' indicate no recorded catch. Data reside in PacHarvTrawl. Fishing years run from April to March, unless otherwise noted.

Year	3C	3D	4B	5A	5B	5C	5D	5E	UNK	CST
UNK	---	---	---	---	---	---	---	---	98	98
1996[1]	466	396	---	0	2	0	0	1	---	867
97[2]	185	107	---	0	0	---	---	1	---	293
1997	361	203	---	7	2	0	0	1	---	575
1998	431	392	---	6	1	0	1	8	---	839
1999	141	751	---	0	1	---	0	19	---	912
2000	163	513	---	54	31	0	0	144	---	905
2001	185	271	---	28	22	0	0	144	---	650
2002	216	249	---	48	27	0	---	116	---	657
2003	111	164	---	53	22	0	2	73	---	426
2004	110	93	---	6	5	0	1	45	---	259
2005[3]	7	24	---	0	0	0	---	12	---	44
Total	2,376	3,163	0	203	113	1	5	566	98	6,524

[1]Feb-Dec; [2]Jan-Mar; [3]Apr-Dec

Table 5. Annual (fishing year) total catch (kept + discarded) by the trawl and hook and line (HL) fisheries of longspine thornyhead (tonnes) along the BC coast. Historical quotas are reported from various management plans. Values are rounded to the nearest tonne; entries marked '---' indicate no recorded catch or quota. Data reside in the PacHarvTrawl and PacHarvHL databases. Fishing years run from April to March, unless otherwise noted.

Fishing	Catch (t)				Quota (t)			
Year	Trawl	HL	Halibut	Total	Trawl	HL	Halibut	Total
1996[1]	867	---	0	867	---	654[∇]	---	654
97[2]	293	---	---	293	225	---	---	225
1997[3]	575	---	---	575	860	900	---	1,760
1998	839	---	---	839	861	39	---	900
1999	912	---	---	912	855	45	---	900
2000	905	0	---	905	404 + 425[*]	29[∇]	30[∇]	889
2001	650	2	---	652	405 + 425[*]	27[∇]	28[∇]	885
2002	657	0	0	657	405 + 230[≈]	27[∇]	28[∇]	690
2003	426	---	---	426	405 + 230[≈]	26[∇]	28[∇]	690
2004	259	---	---	259	405 + 230[≈]	26[∇]	28[∇]	690
2005[4]	44	NA	NA	44	405 + 230[≈]	27[∇]	28[∇]	690
Total	6,426	2	0	6,429	7,000	1,800	170	8,973

[1]Feb-Dec; [2]Jan-Mar for Trawl; [3]Jan 97 – Mar 98 for HL; [4]Apr-Dec (incomplete catch records)
[*]exploratory quota for fishing north of line 230° True from Lookout Island
[≈]experimental quota for fishing north of 50°30'N
[∇]quota for longspine and shortspine thornyheads combined

5.2. GLM analysis of commercial CPUE

5.2.1. Methods

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, as outlined in Section 2.5. This approach, which is commonly used to analyse fisheries catch and effort data, is described by Hilborn and Walters (1992) and Quinn and Deriso (1999).

5.2.2. Data Selection

Data were selected from the DFO PacHarvTrawl database using the following criteria:

- Tow start date between 1 April 1996 and 31 March 2005 (3C/3D analysis)
- Tow start date between 1 April 2000 and 31 March 2005 (5A/5B & 5E analyses)
- Bottom trawl type
- Fished in a valid outside PMFC major region (3C, 3D, 5A, 5B, 5C, 5D, or 5E)
- Fishing success code ≤1 (code 0= unknown; code 1= useable)
- Catch of at least one fish or invertebrate species (no water hauls)
- Valid depth field with a depth greater than 500 m.
- Vessel had been in the fishery for at least three years with a minimum of five trips in each of those years (3C/3D analysis only)
- Valid latitude and longitude co-ordinates
- Valid estimate of time towed that was greater than 0 hours and less than 24 hours

The following explanatory variables were offered to the model, based on the tow-by-tow information in each record for the data remaining after the selection procedure:

- Fishing year (1 April–31 March)
- Month
- DFO locality (Rutherford 1999)
- Latitude separated in 0.1° bands beginning with 48°N
- Vessel
- Depth aggregated into 50 m depth bands beginning with 500 m
- PMFC major region (3C, 3D, 5A, 5B, 5C, 5D, or 5E)

Categories with relatively few observations were pooled into a single (“Plus”) category to reduce the number of parameters estimated.

5.2.3. Catches

Total annual landings and discards for longspine thornyheads are presented by PMFC major regions from 1994–95 to 2004–05 (Table 6). Virtually no landings were recorded for this species prior to the beginning of the controlled fisheries in early 1996, which are verified by the presence of an observer. Catches in 3C and 3D form the bulk of the landings, with the later development of smaller fisheries in 5A/5B (Tidemarks) and 5E (Rennell Sound: WQCI). Catches of this species have dropped considerably in the last two fishing years (Table 6) because of changes in the market for this species combined with high fuel costs.

Table 6. Total landed and discarded catches for longspine thornyheads in the combined GFCatch/PacHarvTrawl databases, summarised by standard 1 April–31 March fishing years for each of the PMFC major areas. Data from 1 April 1994 to 27 December 1995 are from the GFCatch database (Rutherford 1999). Data from 16 February 1996 to 31 March 2005 are from the PacHarvTrawl database. The groundfish fishery was closed from 28 December 1995 to 15 February 1996. These catches have been processed without data selection criteria except to restrict the depth to 500 m or deeper to avoid species misidentification with shortspine thornyheads.

Fishing			**PMFC Major Area**					
year	**3C**	**3D**	**5A**	**5B**	**5C**	**5D**	**5E**	**Total**
Landed catch								
94/95	0.0	0.0	0.0	0.0			0.0	0.0
95/96	0.0	5.0	0.0	0.0			0.0	5.0
96/97	578.8	450.4	0.1	0.0	0.0		0.3	1,029.5
97/98	314.9	175.2	5.4	0.3		0.0	0.3	496.1
98/99	362.7	342.8	3.9	0.3			4.5	714.3
99/00	120.8	670.1	0.0	0.0			13.8	804.8
00/01	138.7	439.9	49.5	25.9			115.4	769.4
01/02	167.1	246.8	24.5	18.2			130.9	587.6
02/03	190.9	226.9	45.0	25.4			104.4	592.6
03/04	98.1	145.5	46.9	20.5			65.8	376.8
04/05	84.4	74.9	4.4	1.8			31.0	196.4
Total	2,056.4	2,777.5	179.7	92.4	0.0	0.0	466.5	5,572.5
Discarded catch								
94/95	0.0	0.0	0.0	0.0			0.0	0.0
95/96	0.0	1.6	0.0	0.0			0.0	1.6
96/97	62.3	43.6	0.1	0.3	0.0		0.0	106.3
97/98	43.9	27.2	1.2	0.0		0.0	0.0	72.3
98/99	67.3	48.6	1.7	0.1			0.1	117.8
99/00	19.1	80.8	0.0	0.0			3.4	103.3
00/01	23.6	71.8	4.7	2.5			28.5	131.0
01/02	17.8	23.9	3.0	3.4			12.7	60.7
02/03	24.5	21.4	3.4	1.1			10.7	61.1
03/04	12.9	18.9	6.4	1.7			6.5	46.4
04/05	10.2	11.9	1.1	0.5			10.3	34.1
Total	281.5	349.6	21.8	9.6	0.0	0.0	72.1	734.6

5.2.4. Results – PMFC areas 3C & 3D (WCVI)

The 1% and 99% quantiles of depth from the selected data are 534 m and 1097 m, with sporadic observations at deeper depths (Figure 7). Consequently, the GLM model used all valid tows occurring between 500 and 1100 m.

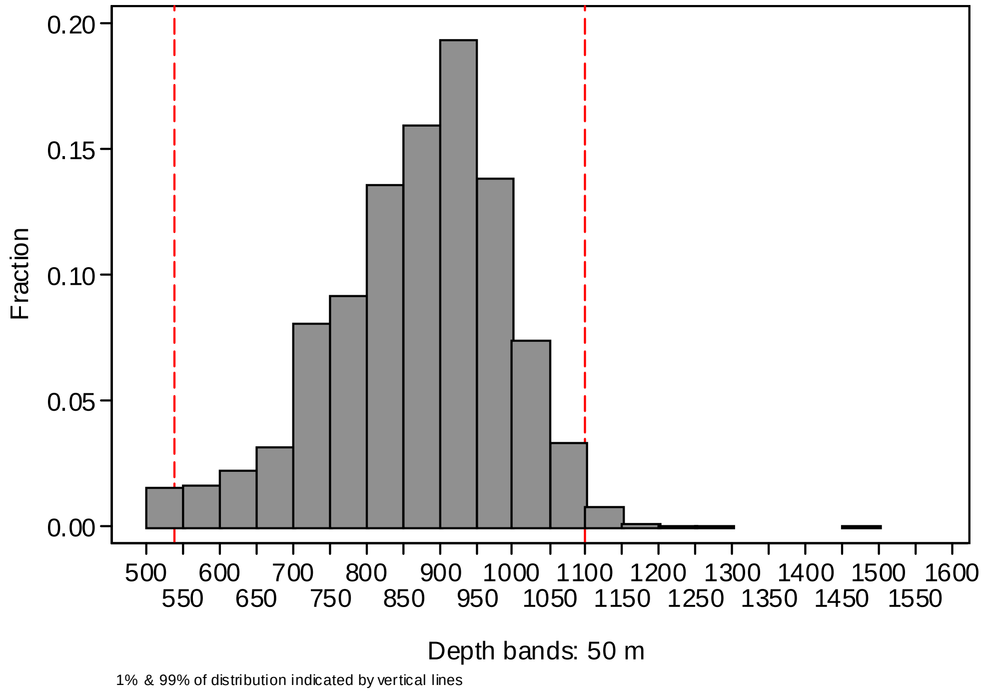

Figure 7. Depth distribution of longspine thornyheads for tows >500 m with landed longspine thornyhead catch in the combined areas 3C and 3D from 1996/97 to 2004/05 in 50-m intervals. Each bin interval is labelled with the upper bound of the interval. Vertical lines: 1% = 534 m, 99% = 1097 m.

The GLM analysis for PMFC areas 3C and 3D selected depth band category, vessel, 0.1° degree of latitude, and month as explanators in addition to fishing year in the final model and accounted for 42% of the variation (Table 7).

Table 7: Order of acceptance of variables into the 3C/3D model of successful catches of longspine thornyheads by core vessels (based on the vessel selection criteria of at least 5 trips in three or more fishing years) with the amount of explained deviance (R^2) for each variable. Variables accepted into the model are marked with an *. Fishing year was forced as the first variable.

Variable	**1**	**2**	**3**	**4**	**5**	**6**
Fishing year*	**0.0572**					
Depth bands*	0.2542	**0.2857**				
Vessel*	0.0912	0.1490	**0.3503**			
0.1° Latitude bands*	0.0858	0.1492	0.3329	**0.3901**		
Month*	0.0524	0.1138	0.3030	0.3796	**0.4168**	
DFO locality	0.0739	0.1205	0.3183	0.3795	0.3981	0.4235
PMFC major region	0.0000	0.0574	0.2860	0.3503	0.3908	0.4177
Improvement in deviance		**0.2285**	**0.0646**	**0.0398**	**0.0267**	**0.0066**

The final model did not vary much from the simple arithmetic mean CPUE or the geometric mean of the non-zero catches (Figure 8 and Figure 9; Table 8). Model residuals appear to fit the model assumption of lognormal error poorly at the tails of the distribution, although the majority of the data within the centre of the distribution match the distributional assumption (Figure 10).

Table 8. Arithmetic and standardised CPUE indices with upper and lower bounds of the standardised indices and the associated standard error for the 3C/3D model of non-zero catches of longspine thornyheads. The standardised series has been scaled to the geometric mean of the arithmetic series.

Fishing year	Arithmetic	Standardised	Lower bound	Upper bound	Standard error
96/97	76.6	77.1	74.6	79.7	0.0168
97/98	59.2	63.3	61.1	65.6	0.0178
98/99	62.5	58.4	56.7	60.2	0.0153
99/00	55.8	53.2	51.6	54.8	0.0154
00/01	55.6	53.0	51.2	54.8	0.0173
01/02	45.6	44.2	42.6	45.9	0.0186
02/03	43.5	45.3	43.7	46.9	0.0182
03/04	36.6	42.5	40.7	44.4	0.0222
04/05	40.2	37.7	35.6	39.9	0.0286

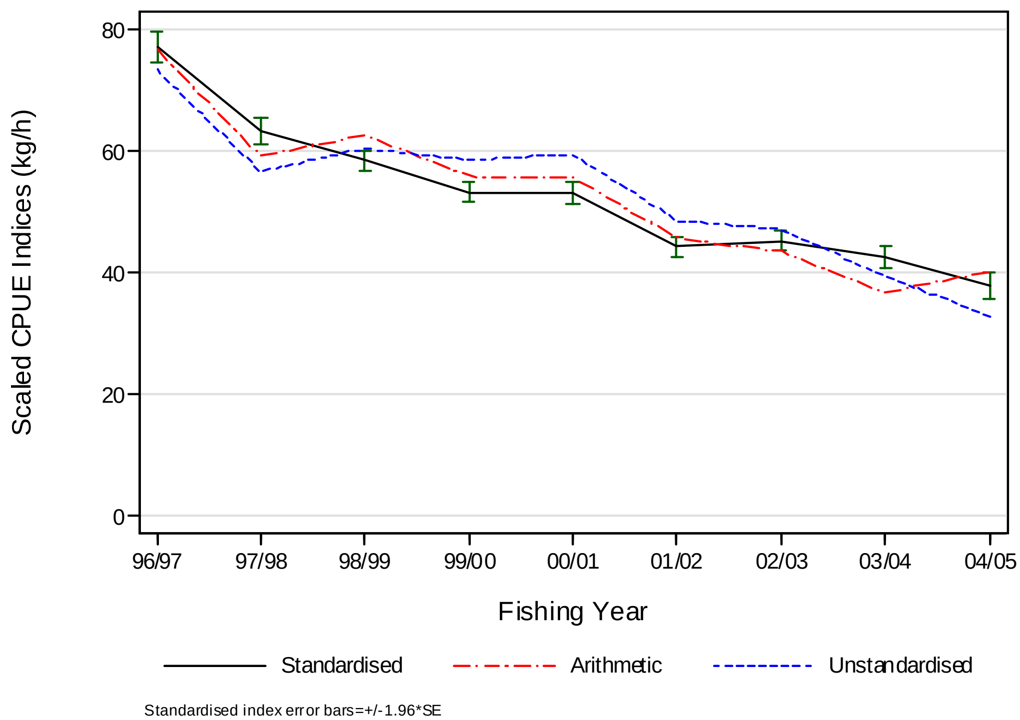

Figure 8. Three CPUE series for 3C/3D landed longspine thornyheads catches for the 1996/97 to 2004/05 fishing years. The solid line is a standardised analysis correcting for 50-m depth band, vessel, 0.1° latitude band, and month effects. The arithmetic series is the sum of the non-zero catch divided by the sum of the associated effort and the unstandardised series is the geometric mean of all positive CPUE observations.

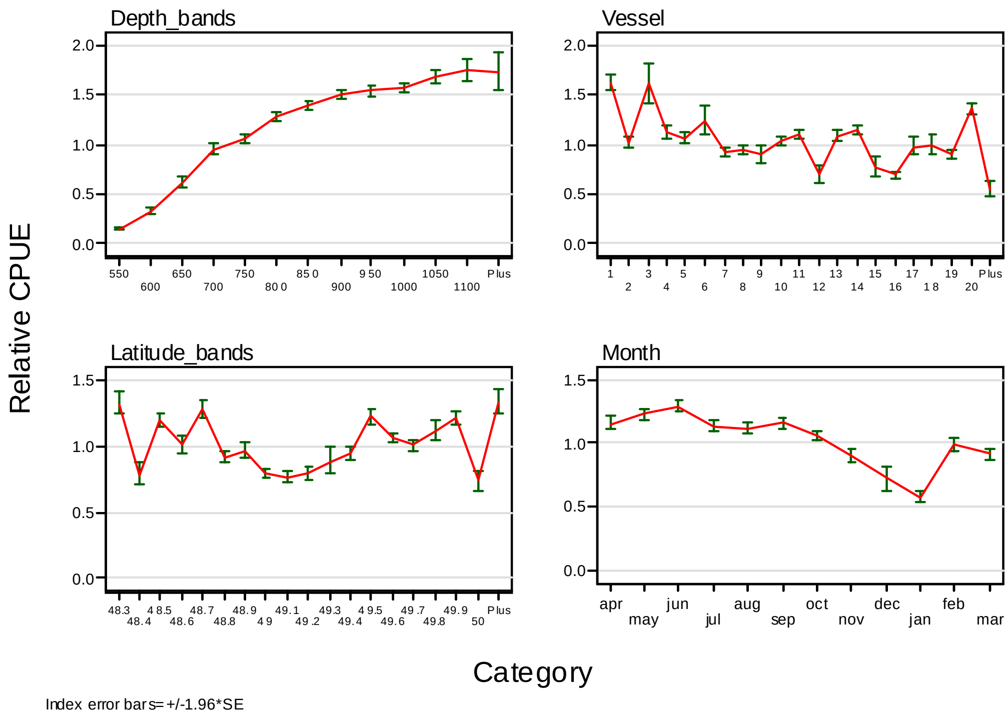

Figure 9. Plots of the coefficients for the categorical explanatory variables included in the standardised GLM analysis presented in Figure 8.

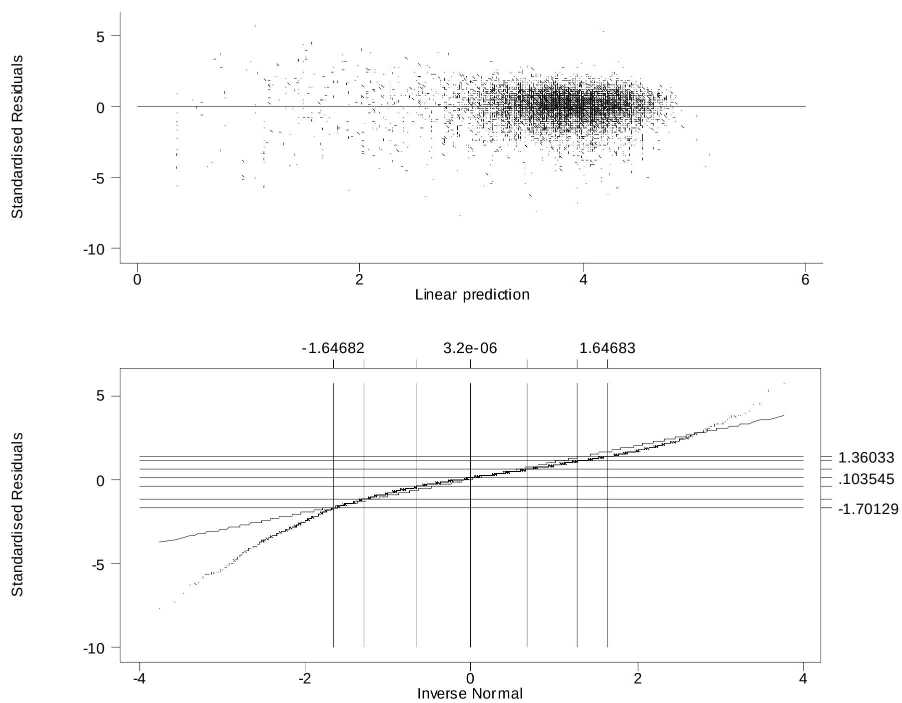

Figure 10. Standardised (Pearson) residuals for the 3C/3D GLM analysis presented in Figure 8. The outside horizontal and vertical lines represent the 5th and 95th percentiles of the theoretical and observed distributions.

5.2.5. Results – PMFC areas 5A & 5B (Tidemarks)

The 1% and 99% quantiles of depth from the selected data are 528 m and 967 m, with sporadic observations at deeper depths (Figure 11). Consequently, the GLM model used all valid tows occurring between 500 and 1000 m.

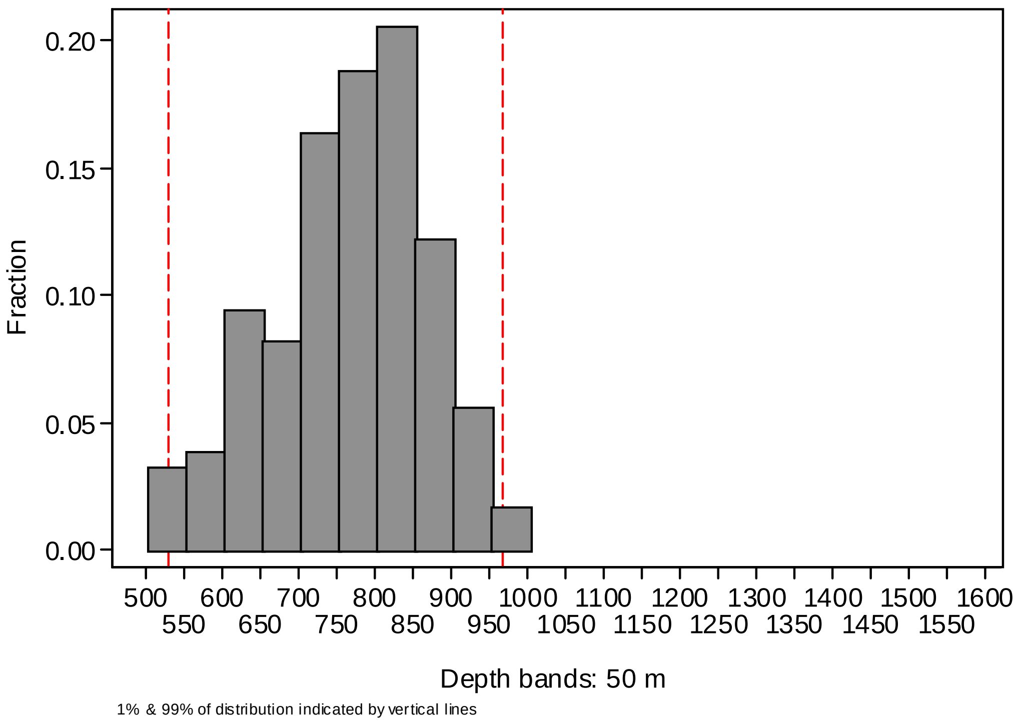

Figure 11. Depth distribution of longspine thornyheads for tows >500 m with landed longspine thornyhead catch in the combined areas 5A and 5B from 2000/01 to 2004/05 in 50-m intervals. Each bin interval is labelled with the upper bound of the interval. Vertical lines: 1% = 528 m, 99% = 967 m.

The GLM analysis for PMFC areas 5A and 5B selected month, vessel and depth band category in addition to fishing year as explanators in the final model and accounted for 31% of the variation (Table 9).

Table 9: Order of acceptance of variables into the 5A/5B model of successful catches of longspine thornyheads with the amount of explained deviance (R^2) for each variable. Variables accepted into the model are marked with an *. Fishing year was forced as the first variable.

Variable	**1**	**2**	**3**	**4**	**5**
Fishing year*	**0.1018**				
Month*	0.1411	**0.1874**			
Vessel*	0.0501	0.1487	**0.2485**		
Depth bands*	0.0710	0.1542	0.2467	**0.3136**	
PMFC major region	0.0134	0.1125	0.1917	0.2530	0.3194
DFO locality	0.0140	0.1132	0.1920	0.2549	0.3212
0.1° Latitude bands	0.0324	0.1211	0.1963	0.2545	0.3215
Improvement in deviance		**0.0856**	**0.0610**	**0.0651**	**0.0058**

As for the 3C/3D model, the final model did not vary much from the simple arithmetic mean CPUE or the geometric mean of the non-zero catches (Figure 12 and Figure 13; Table 10). The model is probably not well determined given the small number of observations in any single year. Model residuals fit the model assumption of lognormal error poorly in the lower tail of the distribution, although the remainder of the data match the distributional assumption (Figure 14).

Table 10. Arithmetic and standardised CPUE indices with standard errors and upper and lower bounds of the standardised indices for the 5A/5B model of non-zero catches of longspine thornyheads. The standardised series has been scaled to the geometric mean of the arithmetic series.

Fishing year	Arithmetic	Standardised	Lower bound	Upper bound	Standard error
00/01	50.7	52.0	47.6	56.7	0.0448
01/02	38.6	44.6	40.4	49.3	0.0507
02/03	41.0	40.2	36.7	44.1	0.0467
03/04	54.0	43.4	39.5	47.8	0.0490
04/05	30.7	32.9	27.6	39.3	0.0907

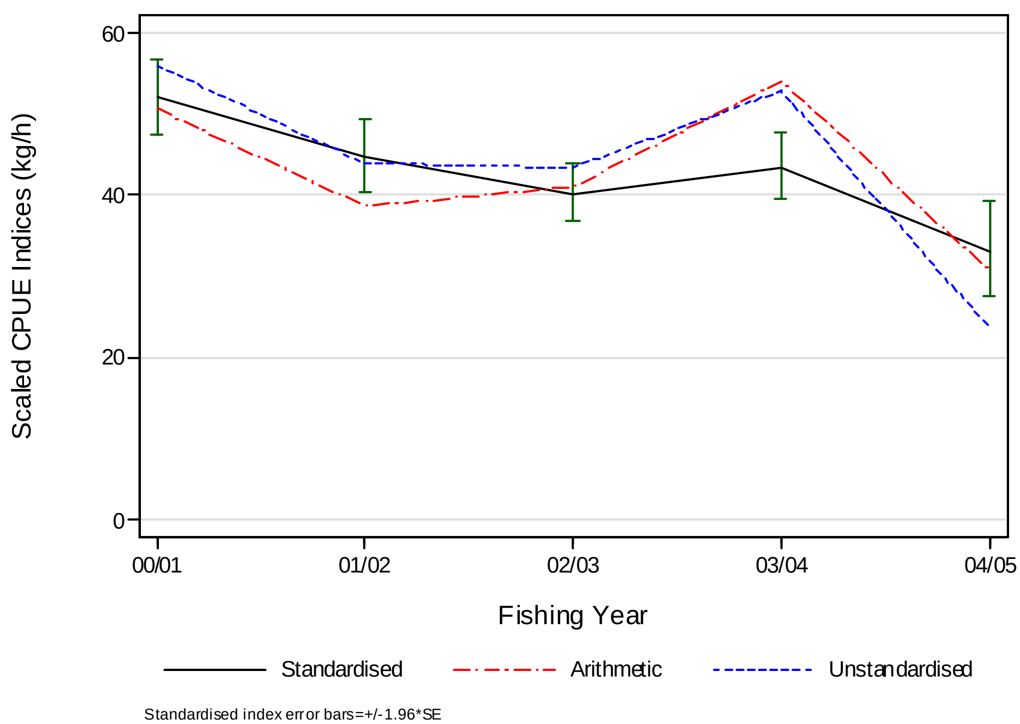

Figure 12. Three CPUE series for 5A/5B landed longspine thornyheads catches for the 2000/01 to 2004/05 fishing years. The solid line is a standardised analysis correcting for 50-m depth band, month and vessel effects. The arithmetic series is the sum of the non-zero catch divided by the sum of the associated effort and the unstandardised series is the geometric mean of all positive CPUE observations.

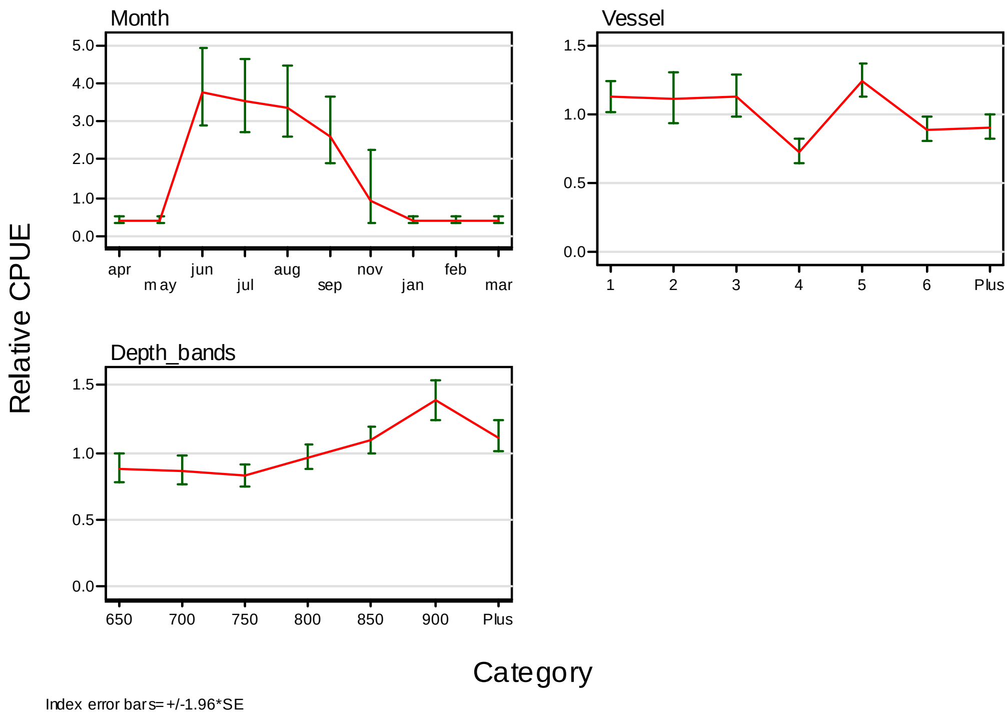

Figure 13. Plots of the coefficients for the categorical explanatory variables included in the standardised GLM analysis presented in Figure 12.

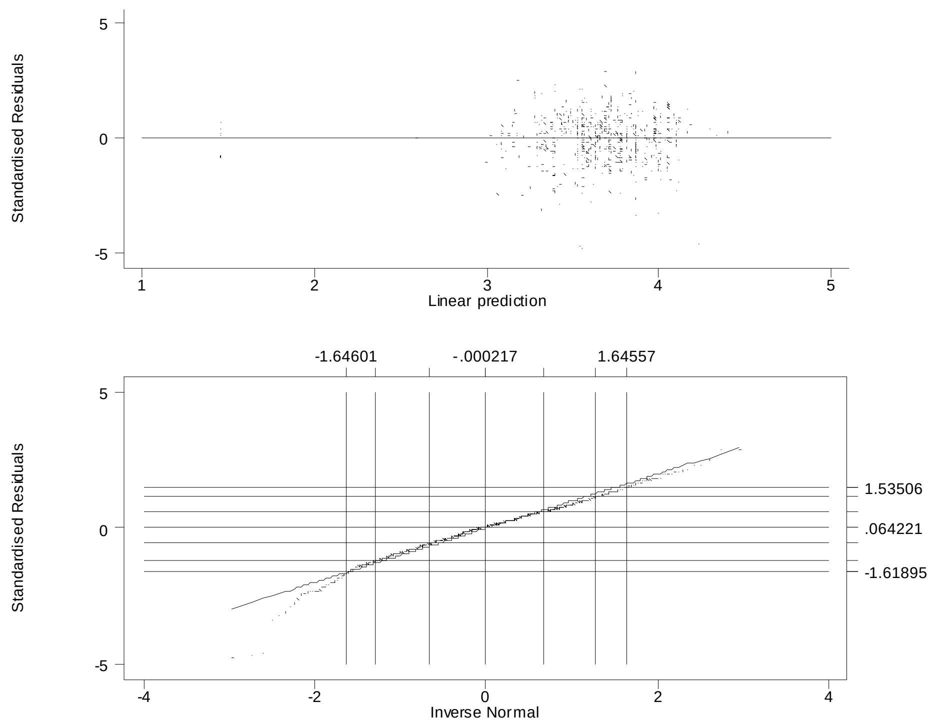

Figure 14. Standardised (Pearson) residuals for the 5A/5B GLM analysis presented in Figure 12. The outside horizontal and vertical lines represent the 5th and 95th percentiles of the theoretical and observed distributions.

5.2.6. Results – PMFC area 5E (Rennell Sound)

The 1% and 99% quantiles of depth from the selected data are 519 m and 1000 m, with sporadic observations at deeper depths (Figure 15). Consequently, the GLM model used all valid tows occurring between 500 and 1000 m.

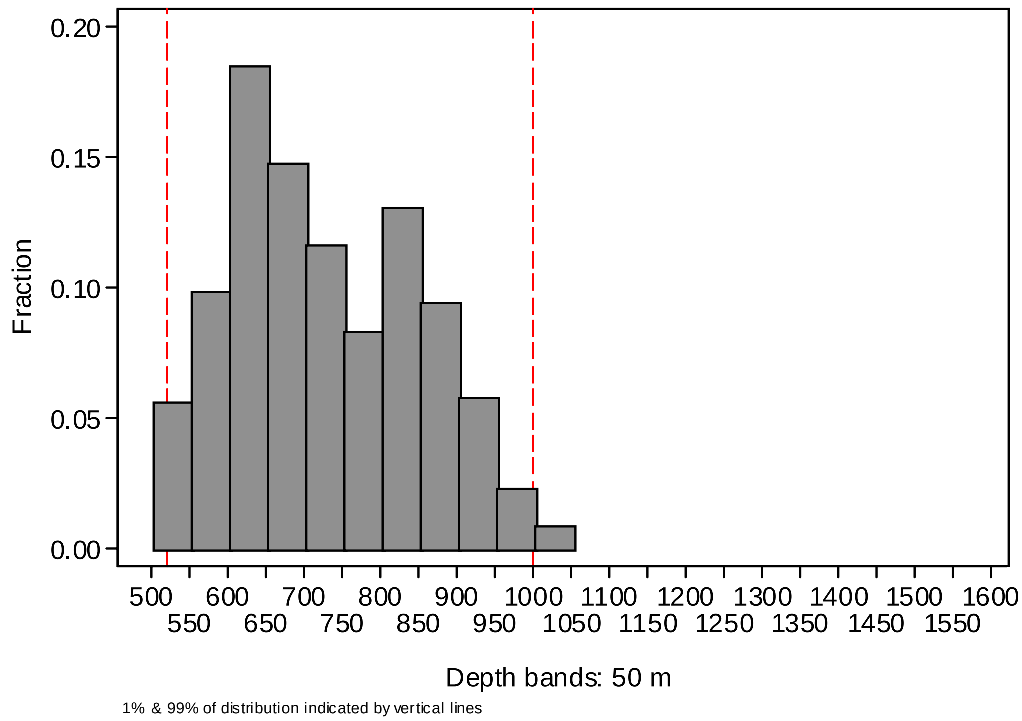

Figure 15. Depth distribution of longspine thornyheads for tows >500 m with landed longspine thornyhead catch in the Area 5E from 2000/01 to 2004/05 in 50-m intervals. Each bin interval is labelled with the upper bound of the interval. Vertical lines: 1% = 519 m, 99% = 1000 m.

The GLM analysis for PMFC area 5E selected month, vessel, depth bin category, and latitude bands in addition to fishing year as explanators in the final model and accounted for 37% of the variation (Table 11).

Table 11: Order of acceptance of variables into the 5A/5B model of successful catches of longspine thornyheads with the amount of explained deviance (R^2) for each variable. Variables accepted into the model are marked with an *. Fishing year was forced as the first variable.

Variable	**1**	**2**	**3**	**4**	**5**	**6**
Fishing year*	**0.1796**					
Month*	0.1440	**0.3002**				
Vessel*	0.0812	0.2225	**0.3348**			
Depth bands*	0.0468	0.2113	0.3195	**0.3571**		
0.1° Latitude bands*	0.0107	0.1916	0.3188	0.3518	**0.3699**	
DFO locality	0.0043	0.1900	0.3134	0.3499	0.3670	0.3762
Improvement in deviance		**0.1206**	**0.0346**	**0.0223**	**0.0128**	0.0063

As for the 3C/3D and 5A/5B models, the final model did not vary much from the simple arithmetic mean CPUE or the geometric mean of the non-zero catches (Figure 16 and Figure 17; Table 12). The model is better determined than the 5A/5B model but still has a small number of observations in any single year. Model residuals fit the model assumption of lognormal error poorly in the lower tail of the distribution, although the remainder of the data match the distributional assumption (Figure 18).

Table 12. Arithmetic and standardised CPUE indices with standard errors and upper and lower bounds of the standardised indices for the 5E model of non-zero catches of longspine thornyheads. The standardised series has been scaled to the geometric mean of the arithmetic series.

Fishing year	Arithmetic	Standardised	Lower bound	Upper bound	Standard error
00/01	43.5	41.8	39.2	44.6	0.0330
01/02	39.7	39.9	37.5	42.4	0.0317
02/03	27.7	31.0	29.2	33.0	0.0309
03/04	24.5	24.3	22.7	25.9	0.0333
04/05	18.6	17.4	16.0	18.8	0.0416

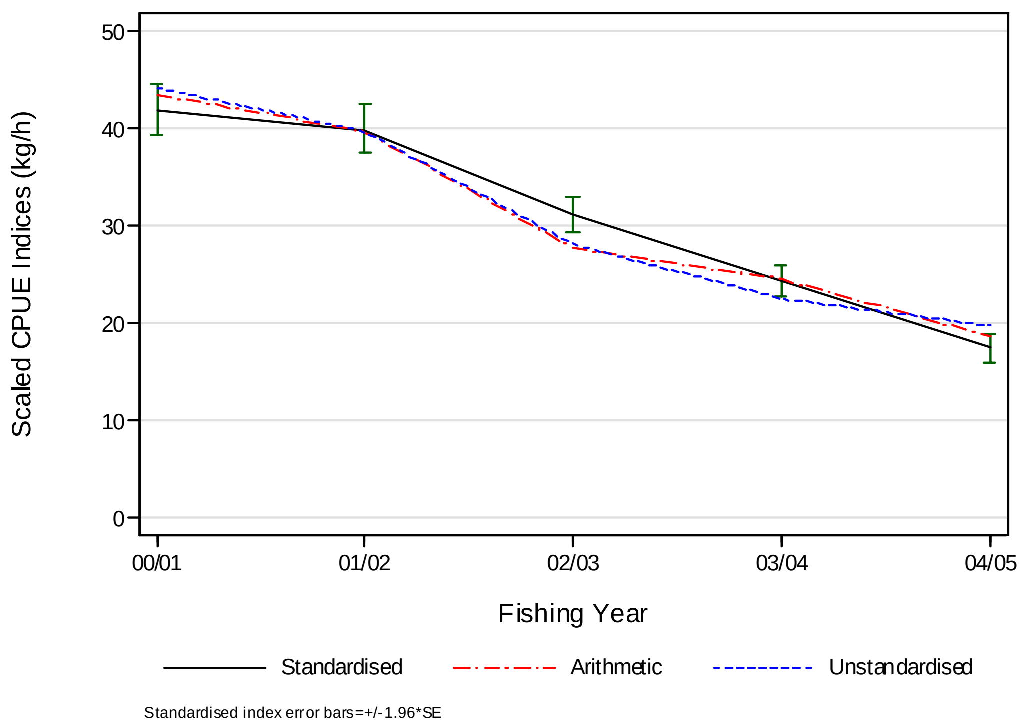

Figure 16. Three CPUE series for 5E landed longspine thornyhead catches for the 2000/01 to 2004/05 fishing years. The solid line is a standardised analysis correcting for 50-m depth band, month and vessel effects. The arithmetic series is the sum of the non-zero catch divided by the sum of the associated effort and the unstandardised series is the geometric mean of all positive CPUE observations.

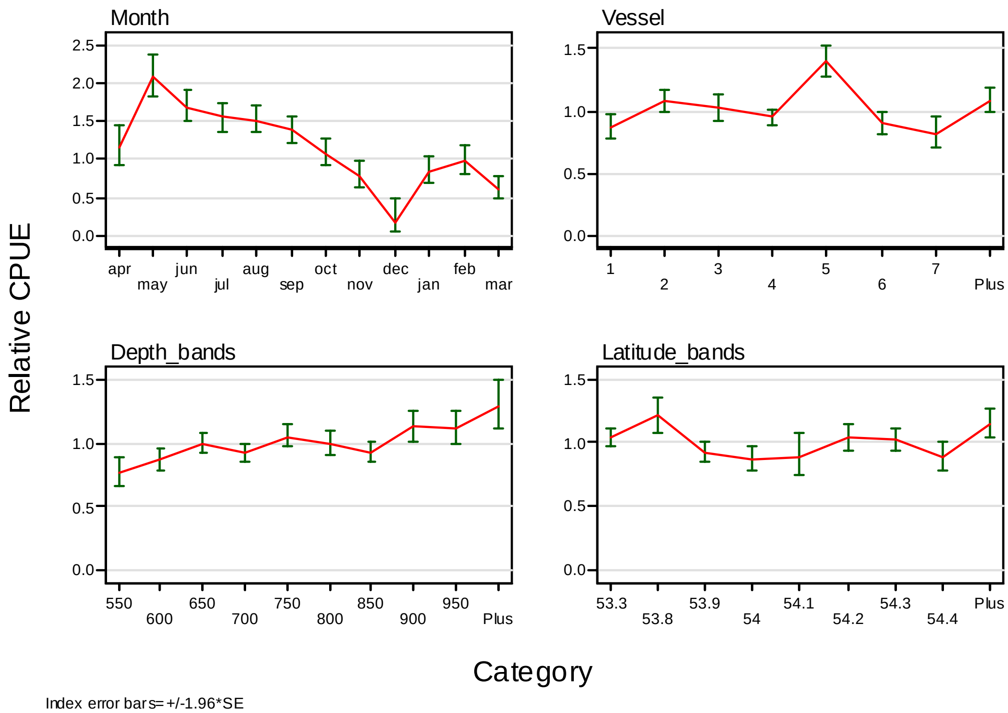

Figure 17. Plots of the coefficients for the categorical explanatory variables included in the standardised GLM analysis presented in Figure 16.

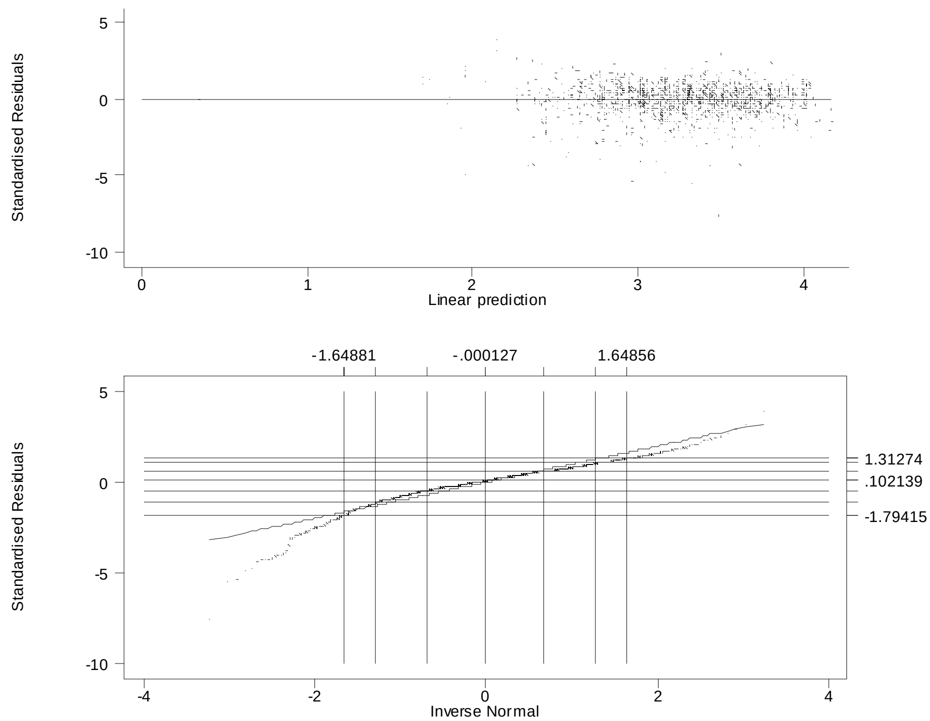

Figure 18. Standardised (Pearson) residuals for the 5E GLM analysis presented in Figure 16. The outside horizontal and vertical lines represent the 5th and 95th percentiles of the theoretical and observed distributions.

5.2.7. Comparison of CPUE trend lines

There is no evidence for any change in the proportion of tows which contain no longspine thornyheads in either the west coast of Vancouver Island data or the Rennell Sound data (Figure 19). There may be a possible increasing trend in the proportion of zero tows in the Tidemarks area, but this proportion is always less that the proportion of zero tows observed in the other two areas.

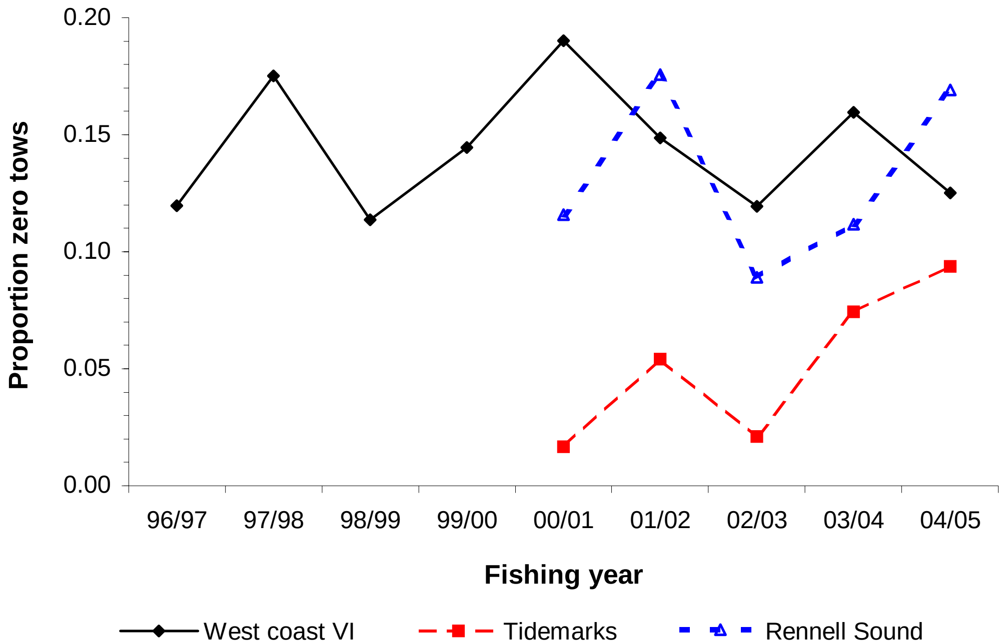

Figure 19. Proportion of zero-catch tows by analysis area and year. Proportions are based on the same data as those used for the GLM analyses.

The analysis for each fishery produced declining trends of relative CPUE beginning from the first year of each fishery (Figure 20): 8% y^{-1} for the WCVI data, 9% y^{-1} for the Tidemarks data, and 23% y^{-1} for the WQCI data. The total declines in the relative abundance indices have been 49% over 8 years for the for the WCVI data, 31% over 4 years for the Tidemarks data, and 65% over 4 years for the WQCI data. These levels of depletion should be interpreted with caution as they are derived from fishery dependent data and are subject to between year effects that originate from sources other than fish abundance. Some of the confounding factors cited by Schnute et al. (2004) are:

- Fishermen have experienced a recent increase in sablefish bycatch when fishing for longspines, especially in the north. Without adequate sablefish quota, skippers must seek out fishing opportunities where tows are less productive for sablefish.
- In the early years of the fishery, observers did not always sample to determine the species split between shortspine and longspine thornyheads, relying instead on information from the factory. More recent samples attempt to identify the complete species composition of each tow. This change in behaviour has possibly introduced a bias across years.
- Fuel costs have increased substantially. The fishery on longspines ranks high in fuel

consumption among all the groundfish fisheries, with tow durations in the range 4-12 h. Higher fuel costs and lower profit margins tend to discourage directed or exploratory fishing on the resource.

- The price of thornyheads has declined substantially in the last year, partly due to an increase in the Canadian dollar relative to the US dollar and Japanese yen. Again, a reduced profit margin tends to discourage directed fishing.

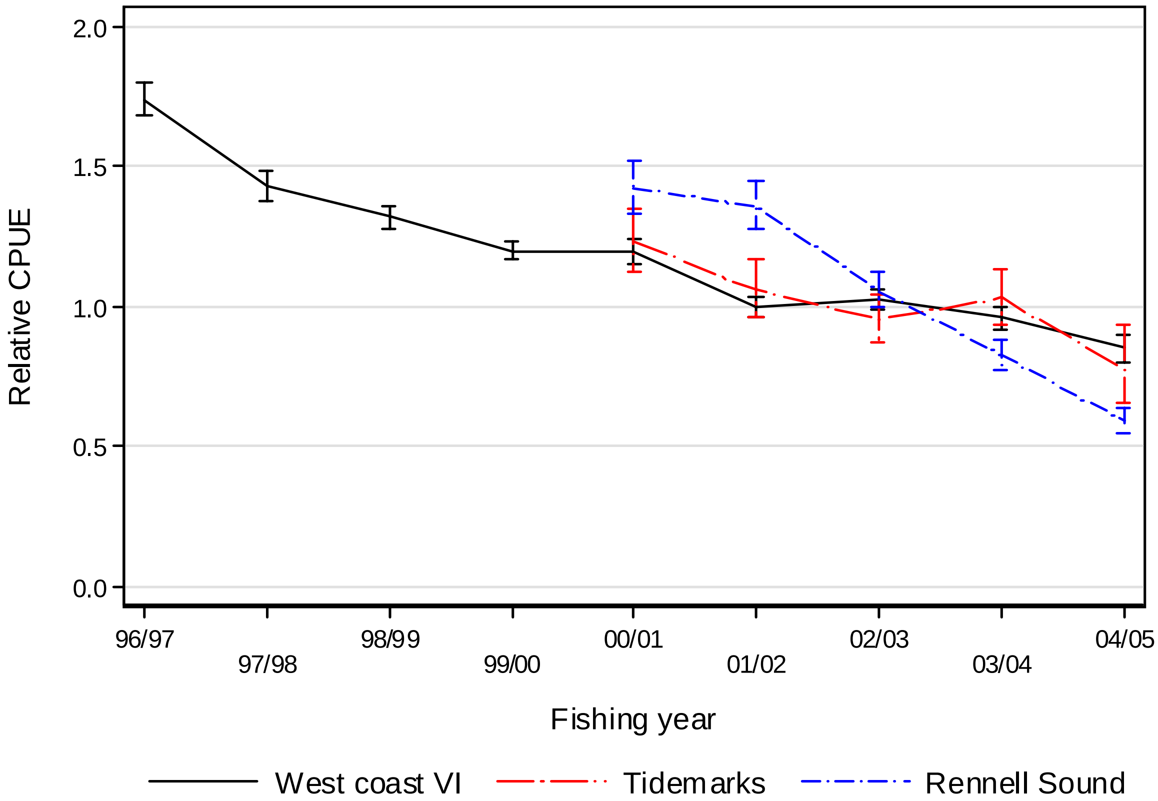

Figure 20. Comparison of CPUE indices for the three areas analysed. Each series has been standardised relative to the geometric mean over the period 2000/01 to 2004/05. The error bars show ± 95% confidence bounds.

5.3. WCVI longspine thornyhead survey

The WCVI longspine thornyhead survey conducted from 2001 to 2003 has been fully reviewed by Schnute et al. (2004) and survey details appear in various technical reports (Starr et al. 2002, Starr et al. 2004, Krishka et al. 2005). Abundance indices obtained from this survey show no trend over the three years of the survey and are consistent with CPUE trends (Figure 21). In future, a synoptic deepwater survey will hopefully continue this series.

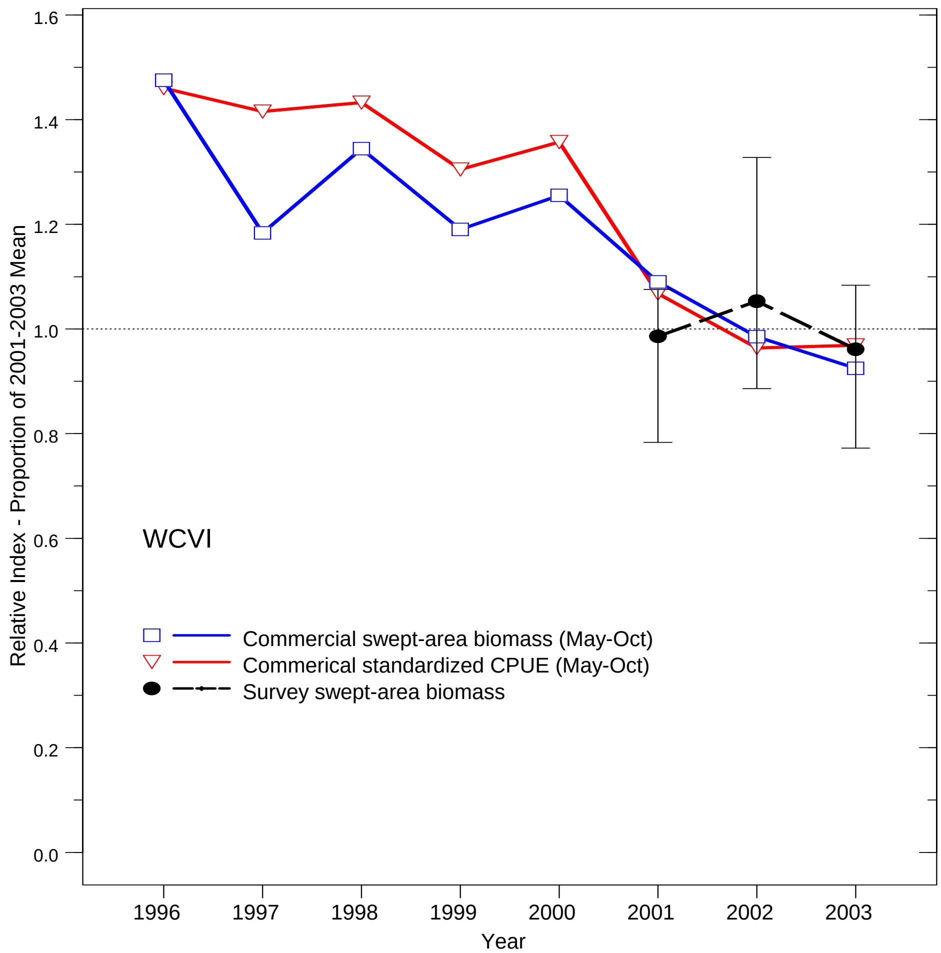

Figure 21. Comparison of annual abundance indices for the WCVI region – survey vs. commercial. Each trend is standardised to its 2001-2003 mean. Source: Schnute et al. (2004).

6. Technical Summary

Sebastolobus altivelis

Longspine thornyhead sébastolobe à longues épines

Range of Occurrence in Canada: BC continental slope between 500 and 1600 m

Extent and Area Information	
• *Extent of occurrence (EO)(km²)* Flat-surface area between isobaths 500 and 1600 m	17,775 km²
• *Specify trend in EO*	No change
• *Are there extreme fluctuations in EO?*	No
• *Area of occupancy (AO) (km²)* Grid of fish density (CPUE) using commercial trawl data	11,700 km²
• *Specify trend in AO*	No change
• *Are there extreme fluctuations in AO?*	No
• *Number of known or inferred current locations*	3
• *Specify trend in #*	No change
• *Are there extreme fluctuations in number of locations?*	No
• *Specify trend in area, extent or quality of habitat*	No change

Population Information	
• *Generation time (average age of parents in the population)*	30 years
• *Number of mature individuals*	Unknown
• *Total population trend:* WCVI (8y), Tidemarks (4y), Rennell (4y)	-8%/y, -9%/y, -23%/y
• *% decline over the last/next 10 years or 3 generations.*	Unknown
• *Are there extreme fluctuations in number of mature individuals?*	No
• *Is the total population severely fragmented?*	No
• *Specify trend in number of populations*	No change
• *Are there extreme fluctuations in number of populations?*	No
• List populations with number of mature individuals in each: Unknown	

Threats (actual or imminent threats to populations or habitats)
Overfishing in low-productivity environments. Roughly 49 million fish removed coastwide from 1996-2004.

Rescue Effect (immigration from an outside source)	
• *Status of outside population(s)?* USA: Unknown	
• *Is immigration known or possible?*	No
• *Would immigrants be adapted to survive in Canada?*	Yes
• *Is there sufficient habitat for immigrants in Canada?*	Unknown
• *Is rescue from outside populations likely?*	Possibly

Quantitative Analysis
This report designed specifically for citation by the COSEWIC Status Report

Current Status
COSEWIC: No designation

7. Acknowledgements

We are deeply indebted to all those people who worked on numerous biological surveys and observer groundfish trawl trips over the years. We thank the Canadian Groundfish Research and Conservation Society for its ongoing support. We are always grateful for Jon Schnute's guidance on mathematical notation and models. Finally, we appreciate the constructive comments from participants of the National Assessment Process (NAP) meeting, held November 2, 2005 at the Pacific Biological Station in Nanaimo BC.

Since 2003, DFO has worked with representatives from the groundfish industry as well as First Nations, recreational fishing, conservation and coastal community representatives through the Commercial Groundfish Integrated Advisory Committee (CGIAC). This advisory committee considers new developments and initiatives (specifically with regard to (i) Inshore Rockfish Conservation Strategy, (ii) Pacific Fishery Monitoring and Reporting Framework, (iii) Selective Fishing Policy, and (iv) Species at Risk Act) and their potential impact on commercial groundfish fisheries in the Pacific Region. A sub-committee of the CGIAC, the Commercial Industry Caucus (CIC), which includes fishing industry representatives directly involved in the commercial groundfish fisheries, has worked to develop recommendations in accordance with criteria set out by DFO.

8. References

Akaike, A. 1974. A new look at the statistical model identification. IEEE Transactions on Automatic Control AC-19: 716-723.

Effron, B. 1982. The jackknife, the bootstrap and other resampling plans. Philadelphia, Society for Industrial & Applied Mathematics 38: 92 p.

Francis, R.I.C.C. 1999. The impact of correlations on standardised CPUE indices. New Zealand Fishery Assessment Research Document 1999/42. 30 p. (Unpublished report held in NIWA library, Wellington, New Zealand)

Francis, R.I.C.C. 2001. Orange roughy CPUE on the South and East Chatham Rise. New Zealand Fishery Assessment Report 2001/26. 30 p.

Haigh, R. and Schnute, J.T. 2003. The longspine thornyhead fishery along the west coast of Vancouver Island, British Columbia, Canada: portrait of a developing fishery. North American Journal of Fisheries Management 23: 120-140.

Hilborn, R., and Walters, C.J. 1992. Quantitative fisheries stock assessment: choice, dynamics. Routledge, Chapman & Hall, Inc., New York. 570 p.

Krishka, B.A., Starr, P.J., and Choromanski, E.M. 2005. Longspine thornyhead random stratified trawl survey off the west coast of Vancouver Island, September 4-21, 2003. Canadian Technical Report of Fisheries and Aquatic Sciences 2577. 93 p.

Quinn, T.R. and Deriso, R.B. 1999. Quantitative Fish Dynamics. Oxford University Press. 542 p.

Rutherford, K.L. 1999. A brief history of GFCATCH (1954-1995), the groundfish catch and effort database at the Pacific Biological Station. Canadian Technical Report of Fisheries and Aquatic Sciences 2299: 66 p.

Schnute, J., Haigh, R., Krishka, B., Sinclair, A., and Starr, P. 2004. The British Columbia longspine thornyhead fishery: analysis of survey and commercial data (1996-2003). Canadian Science Advisory Secretariat, Research Document 2004/059. 75 pp.

Starr, P.J. 2001. Assessment of the Canadian longspine thornyhead (*Sebastolobus altivelis*) for 2001. Canadian Stock Assessment Secretariat, Research Document 2001/136, 57 p.

Starr, P.J., Krishka, B.A., and Choromanski, E.M. 2002. Trawl survey for thornyhead biomass off the west coast of Vancouver Island, September 15 – October 2, 2001. Canadian Technical Report of Fisheries and Aquatic Sciences 2421. 60 p.

Starr, P.J., Krishka, B.A., and Choromanski, E.M. 2004. Longspine thornyhead random stratified trawl survey off the west coast of Vancouver Island, September 6-23, 2002. Canadian Technical Report of Fisheries and Aquatic Sciences 2558. 81 p.

Vignaux, M. 1993. Catch per unit effort (CPUE) analysis of the hoki fishery, 1987–92. N.Z. Fisheries Assessment Research Document 93/14. 23 p. (Unpublished report held in NIWA library, Wellington, New Zealand)

Vignaux, M. 1994: Catch per unit effort (CPUE) analysis of west coast South Island and Cook Strait spawning hoki fisheries, 1987–93. N.Z. Fisheries Assessment Research Document 94/11. 29 p. (Unpublished report held in NIWA library, Wellington, New Zealand)

Appendix 1. Terms of Reference

National Advisory Process meeting to review marine species subject to upcoming assessment by COSEWIC

November 1 - 2, 2005
Pacific Biological Station
Nanaimo, British Columbia

Chairperson: Alan Sinclair

A. Background

The implementation of the federal Species at Risk Act (SARA), proclaimed in June 2003, begins with the assessment of a species' risk of extinction by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), an arm's-length scientific advisory body. This assessment initiates the regulatory process whereby the competent Minister must decide whether to accept COSEWIC's designation and add a species to Schedule 1 of SARA, which will result in legal protection for the species under the Act.

DFO, as the primary generator and archivist of information on aquatic species, will be expected to support the work of COSEWIC by providing the best information available on the status of a species to be assessed. DFO also benefits from this activity as COSEWIC can assess the status of species most accurately when all relevant information is made available to those assessing status.

A National Advisory Process (NAP) meeting to review Pacific marine species recently listed on COSEWIC's Call for Bids (January 2005) is scheduled for November 1st and 2nd, 2005 in Nanaimo, British Columbia. Contracts to prepare status reports were issued for the following Pacific species from this Call for Bids:

- Yelloweye rockfish *Sebastes ruberrimus*
- Longspine thornyhead *Sebastolobus altivelis*
- Canary rockfish *Sebastes pinniger*
- Quillback rockfish *Sebastes maliger*
- Rougheye rockfish *Sebastes aleutianus*
- Sea otter *Enhydra lutris*

B. General objectives

This advisory meeting is being held to peer-review DFO's information that would be relevant to determining a COSEWIC status designation for the five Pacific marine fish in the table above. Information relevant to determining the status of the sea otter will be peer-reviewed at a later date.

The intent of this meeting is to have on the science record:

a) What information is available related to the status and trends of, and threats to, these five species of Pacific rockfish in Canadian waters;

b) The strengths and limitations of the information; and,

c) What the meeting participants think are legitimate uses of the information, and why.

For the information that is reviewed for use by COSEWIC, non-DFO information will not be considered. The intent of this part of the meeting is simply to review and provide information from DFO to COSEWIC.

C. Specific objectives

The purpose of the meeting is to ensure that species information held by DFO is made available to COSEWIC, including the authors of the respective status reports, and the Chairs of the appropriate COSEWIC Species Specialist Subcommittee.

For each species, the meeting will review information on life history characteristics, distribution, and abundance in Canadian waters, along with threats, which could be used by COSEWIC to determine, following its assessment guidelines and criteria, the appropriate risk category. Discussion on each species will also consider the available information on population differentiation, which could support a COSEWIC decision of which populations below the species' level would be suitable for assessment and designation.

Documentation produced by this part of the meeting will include Research Documents summarising the available information on these species and Proceedings documenting discussions at the meeting.

A detailed description of the information to be produced for each species follows. In addition, information that can be made available on life history and ecological characteristics will be reviewed for each species to allow a general assessment of the resilience or general vulnerability of the species. Therefore, the following information will be reviewed to the extent that it is available:

1. Review life history characteristics

- Growth parameters: age and/or length at maturity, maximum age and/or length
- Fecundity
- Early life history pattern (e.g. duration of planktonic larval life, and major egg, larval, and juvenile transport mechanisms)
- Specialised niche or habitat requirements

2. Review designatable units

See COSEWIC 2005 "Guidelines for Recognizing Designatable Units below the Species Level".

COSEWIC Criterion— Declining Total Population

a) Summarize overall trends in population size (both number of mature individuals and total numbers in the population) over as long a period as possible and in particular for the past three generations (taken as mean age of spawners). Additionally, present data on a scale appropriate to the data to clarify the rate of decline.

b) **Identify threats to abundance**— where declines have occurred over the past three generations, summarize the degree to which the causes of the declines are understood, and the evidence that the declines are a result of natural variability, habitat loss, fishing, or other human activity

c) Where declines have occurred over the past three generations, summarize the evidence that the declines have ceased, are reversible, and the likely time scales for reversibility.

COSEWIC Criterion— Small Distribution and Decline or Fluctuation: by stock, for species in Canada as a whole, and for designatable units identified in 1 (if on a scale finer than stocks) and using information in the most recent assessments:

a) Summarise the current extent of occurrence (in km^2) in Canadian waters

b) Summarise the current area of occupancy (in km^2) in Canadian waters

c) Summarise changes in extent of occurrence and area of occupancy over as long a time as possible, and in particular, over the past three generations.

d) Summarise any evidence that there have been changes in the degree of fragmentation of the overall population, or a reduction in the number of meta-population units.

e) Summarise the proportion of the population that resides in Canadian waters, migration patterns (if any), and known breeding areas.

COSEWIC Criterion— Small Total Population Size and Decline and Very Small and Restricted: by stock, for species in Canada as a whole, and for designatable units identified in 1 (if on a scale finer than stocks), and using information in the most recent assessments:

a) Tabulate the best scientific estimates of the number of mature individuals;

b) If there are likely to be fewer than 10,000 mature individuals, summarize trends in numbers of mature individuals over the past 10 years or three generations, and, to the extent possible, causes for the trends.

2. Summarise the options for combining surveys to provide an assessment of status, and the caveats and uncertainties associated with each option.

3. For transboundary stocks, summarise the status of the population(s) outside of Canadian waters. State whether rescue from outside populations is likely.

As time allows, review status and trends in other indicators of the status of each of the species that would be relevant to evaluating the risk of extinction of the species. This includes the likelihood of imminent or continuing decline in the abundance or distribution of the species, or that would otherwise be of value in preparation of COSEWIC Status Reports.

D. Documentation

The meeting will produce the following documentation:

1. At least one Research Document for each of the species to be considered, summarising the overall status of the species and the data and information held by DFO which could be used by COSEWIC in making status designations. These Research Documents will cover the information called for in the Terms of Reference above.
2. Proceedings summarising the decisions, recommendations, and major points of discussion at the meeting, including a reflection of the diversity of opinion present in the discussions.