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Stock Assessment and Status of Longspine Thornyhead (*Sebastolobus altivelis*) off California, Oregon and Washington in 2005

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"The findings and conclusions in this report are those of the author and do not necessarily represent the funding agency".

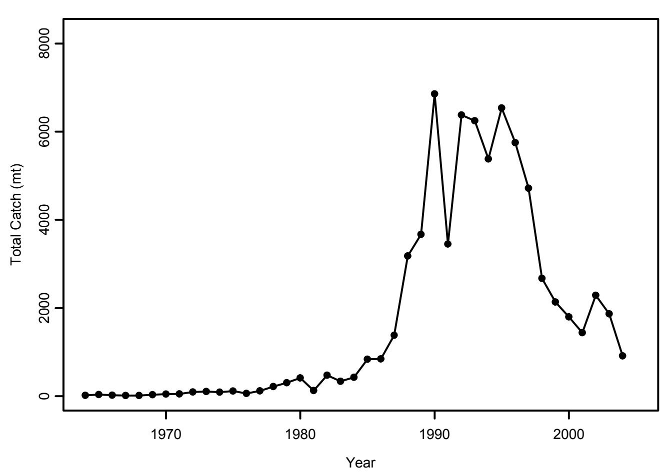
1. EXECUTIVE SUMMARY

Stock: This assessment pertains to the longspine thornyhead (*Sebastolobus altivelis*) population located off the west coast of the continental USA, from the US/Canadian border in the north to the southern end of the Conception INPFC area (32.5° latitude). The population of longspine thornyhead in this area is considered to be a single unit stock.

Catches: A single coast-wide commercial trawl fishery was modelled. Only very small amounts of longspine thornyhead are caught using other gears. Catches increased gradually during the 1960s and 1970s, but the fishery did not expand significantly until the late 1980s with the development of a market for smaller thornyheads. At their peak in the early 1990s, annual catches were around 6,000 mt. The catches have declined in recent years in response to increased management restrictions. Catches in this assessment were estimated for the period 1964-2004. Allowing for additional discarding in early years, inclusion of estimated foreign catches for 1965-1976, and estimation of additional historical catches for 1900-1963 had little impact on model results as these catches were small relative to those during the early 1990s.

recent longspine catches

Year	total catch (mt)
1995	6541
1996	5752
1997	4720
1998	2671
1999	2136
2000	1797
2001	1438
2002	2287
2003	1869
2004	912



Data and Assessment: This is the fourth stock assessment of west coast longspine thornyhead. The previous stock assessment was conducted by Rogers *et al.* in 1997. Data sources included in the current assessment are:

1. commercial landings and length composition information from California, Oregon and Washington obtained from the PACFIN database;
2. commercial landings and mean body weights from the California Department of Fish and Game (CDFG);
3. discard rates from 2 observer studies (1985-87, 1989-1991);
4. discard rates from the Enhanced Data Collection Project (EDCP);
5. discard rates and mean body weights from the West Coast Groundfish Observer Program (WGCOP);
6. biomass indices and length composition information from the Alaska Fisheries Science Center (AFSC) and Northwest Fisheries Science Center (NWFSC) FRAM slope surveys.

These data were used to fit an age-structured population dynamics model using version 1.19 of the length-age-structured model Stock Synthesis 2 (Methot 2005).

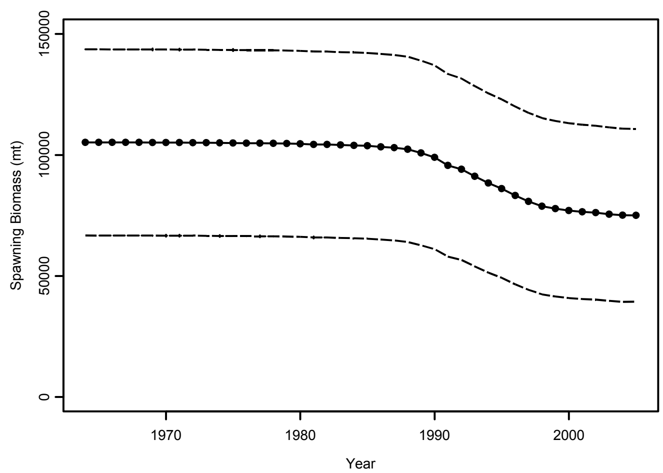
Unresolved problems and major uncertainties: The major sources of uncertainty in this stock assessment include: (1) the catchability coefficient (q) for the slope survey(s), and (2) the value(s) assumed for the rate of natural mortality (M). The assessment is data-limited and driven by the slope survey biomass estimates and the values for q and M. A likelihood profile for the slope survey catchability (q) revealed that although this parameter is highly uncertain, only extremely high values (>15, which are very unlikely) result in estimates of 2005 population status that are close to or below the minimum stock size threshold. Uncertainty in the parameter values for both q and M was accounted for in the variance estimates of derived model predictions through constrained estimation of q and unconstrained estimation of M.

Reference Points: The Pacific Fishery Management Council's current target harvest rate for longspine thornyhead is $F_{50\%}$, which was estimated to be 0.055 for the base-case model. The Council's current target biomass level for exploited groundfish stocks is $SB_{40\%}$, i.e., a spawning biomass that is 40% of that expected in the absence of fishing. The reference point at which groundfish stocks are defined to be overfished is currently $SB_{25\%}$, i.e., a spawning biomass that is 25% of that expected in the absence of fishing. Estimated values for $SB_{40\%}$ and $SB_{25\%}$ for longspine thornyhead are 42,063 mt and 26,289 mt respectively.

Stock Biomass: Total and spawning biomass of longspine thornyhead has shown a decline since the late 1980s, with the rate of this decline slowing since the mid 1990s due to reduced catches. The stock, however, is only lightly exploited, and the current spawning biomass is estimated to be over 75,000 mt, i.e. 71% of the unfished equilibrium level.

recent biomass estimates

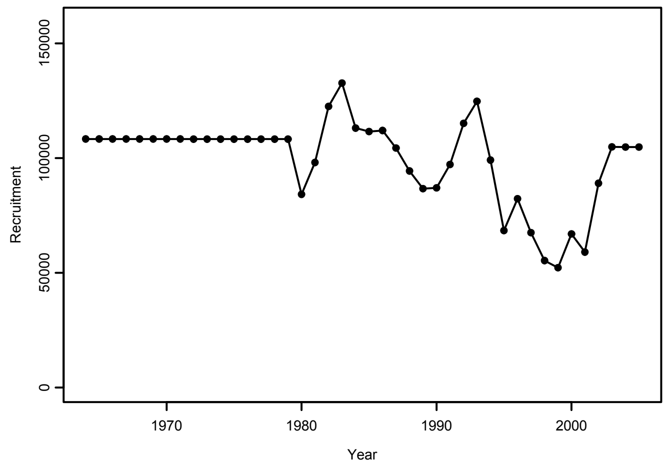
Year	Spawning Biomass (mt)
1996	83,222
1997	80,768
1998	78,789
1999	77,767
2000	77,012
2001	76,466
2002	76,164
2003	75,518
2004	75,079
2005	75,049



Recruitment: Expected annual recruitment was described by a Beverton-Holt function of spawning biomass. Annual deviations about this stock-recruitment curve were estimated for the years 1980 through 2002. The steepness parameter (*h*) was fixed at 0.75, and a likelihood profile over this parameter showed little sensitivity in the results to the value assumed for this parameter. The impact of recruitment variability on the biomass for longspine thornyhead is low due to the long-lived nature of the species. The bulk of the biomass for this stock is contained in a large number of old age-classes. Estimation of recruitment events is therefore difficult, and information is only really available to estimate recruitment for recent years when size-composition data from the slope surveys are available.

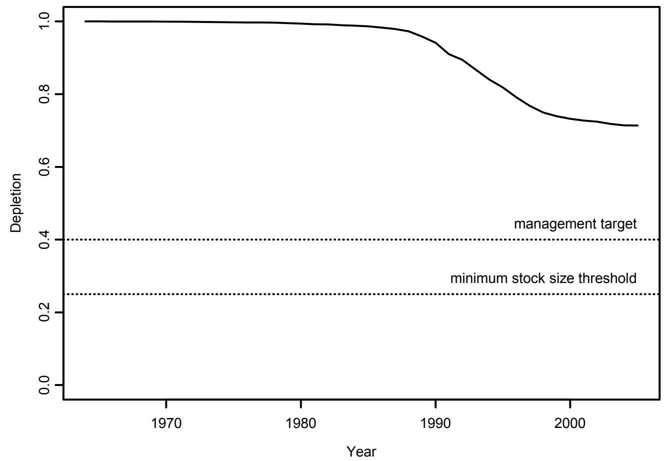
recent estimates of recruitment

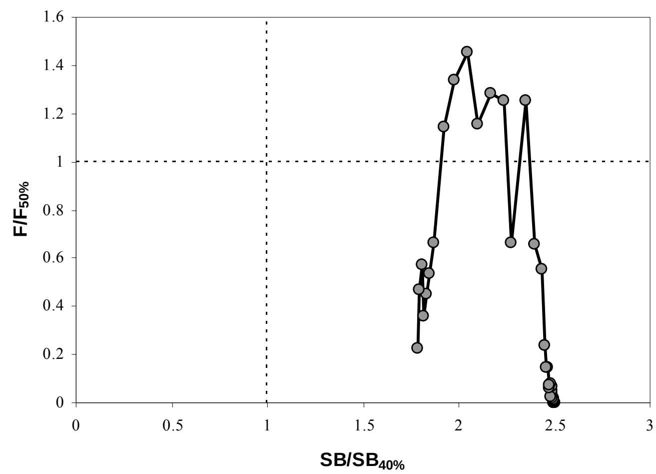
Year	# Recruits
1996	82,276
1997	67,444
1998	55,319
1999	52,265
2000	66,946
2001	59,009
2002	88,962
2003	87,572
2004	87,515
2005	87,511



Exploitation Status: 2005 spawning biomass of longspine thornyhead is estimated to be 71% of the unexploited equilibrium level. The stock is therefore well above the management target of $SB_{40\%}$. The current fishing mortality rate is also well below the F_{msy} proxy ($F_{50\%}$).

Year	Fishing mortality
1994	0.06
1995	0.08
1996	0.07
1997	0.06
1998	0.04
1999	0.03
2000	0.02
2001	0.02
2002	0.03
2003	0.03
2004	0.01





	Estimates (plus 95% C.I.)
Unfished Spawning Stock Biomass (SB_0)	105,157 mt (133,408 - 343,728)
Unfished Total Biomass (B_0)	228,275 mt
Unfished 2+ Biomass	227,972 mt
Unfished Recruitment (R_0)	108272 (51,422 - 159,692)
Spawning Stock Biomass at MSY (SB_{MSY})	28,305 mt
Basis for SB_{MSY}	$SB_{40\%}$ proxy
SPR_{MSY}	0.5
Basis for SPR_{MSY}	$F_{50\%}$ proxy
F corresponding to SPR_{MSY}	5.5%
MSY	3,687 mt

Management performance: Longspine thornyhead have been managed separately from shortspine thornyhead since 1992. Catches have tended to be below the Allowable Biological Catches (ABCs). ABCs for the years 1992-1994 were based on the Columbia, Moneterey, and Eureka INPFC areas. The ABCs for 1995-1997 were specified coast-wide north of Point Conception (34˚27'). ABCs since have excluded the Conception INPFC area. A separate ABC for the northern area of Conception (34˚27'–36˚00') was implemented for 2005.

Year	ABC (mt)	OY (mt)	catch (mt)	discard (mt)
1995	7,000	6,000	5,593	948
1996	7,000	6,000	4,904	848
1997	7,000	6,000	4,013	707
1998	4,531	4,531	2,266	405
1999	4,531	4,531	1,811	325
2000	4,531	4,531	1,523	274
2001	2,851	2,656	1,219	219
2002	2,851	2,656	1,941	346
2003	2,851	2,656	1,588	281
2004	2,851	2,656	776	136
2005	2,851	2,656	-	-

Forecasts: The base-case model was projected to 2016 under the F_{MSY} proxy of $F_{50\%}$. Estimated catches were above the current (2004) OY, and twice the current estimated catches. Forecast results are given in the following table:

Year	Total Biomass (mt)	Age 2+ Biomass (mt)	Spawning Biomass (mt)	Spawning Depletion	Recruitment	Exploitation rate	ABC	=	OY
2005	162,642	162,395	75,049	0.71	87,511	1.7%	2,838		2,838
2006	160,037	159,768	74,012	0.70	104,604	1.8%	2,831		2,831
2007	157,441	157,147	72,853	0.69	104,414	2.5%	3,953		3,953
2008	153,786	153,492	71,031	0.68	104,104	2.5%	3,860		3,860
2009	150,302	150,009	69,149	0.66	103,769	2.5%	3,766		3,766
2010	147,020	146,728	67,259	0.64	103,416	2.5%	3,671		3,671
2011	143,964	143,673	65,419	0.62	103,055	2.5%	3,577		3,577
2012	141,150	140,860	63,684	0.61	102,698	2.5%	3,483		3,483
2013	138,589	138,300	62,089	0.59	102,355	2.5%	3,391		3,391
2014	136,287	135,999	60,657	0.58	102,034	2.4%	3,304		3,304
2015	134,240	133,952	59,398	0.56	101,740	2.4%	3,225		3,225
2016	132,439	132,153	58,319	0.55	101,480	2.4%	3,155		3,155

Decision Table: Models with different combinations of values for *M* and *q* were chosen to represent a 'best case' and a 'worst case' scenario to bracket the base-case analysis to develop the decision table because *M* and *q* were determined to be key sources of uncertainty in the assessment. The three analyses were projected forward under two harvest regimes: 1) annual catches equal to the current removals – the average estimated catch during 2000-2004, and 2) annual catches equal to those resulting from an $F_{50\%}$ control rule for the base-case model. All projections predicted that the stock would continue to decline, although, in all cases, the 2016 spawning biomass was estimated to still be above the proxy for B_{MSY}.

				"Worst" q=1.34 M=0.07		Base q = 1.03 (based on prior) est. M = 0.06		"Best" q=0.79 M=0.05	
Management action	Year	Catch (mt)	Landings (mt)	Spawning Biomass	Depletion	Spawning Biomass	Depletion	Spawning Biomass	Depletion
	2005	1,640	1,410	50,274	0.64	75,049	0.71	122,513	0.78
Average of last 5 years	2006	1,640	1,410	49,942	0.64	74,578	0.71	121,828	0.78
	2007	1,640	1,410	49,519	0.63	73,987	0.70	120,997	0.77
	2008	1,640	1,410	49,004	0.63	73,271	0.70	120,009	0.77
	2009	1,640	1,410	48,419	0.62	72,452	0.69	118,886	0.76
	2010	1,640	1,410	47,807	0.61	71,572	0.68	117,677	0.75
	2011	1,640	1,410	47,217	0.60	70,687	0.67	116,443	0.74
	2012	1,640	1,410	46,686	0.60	69,845	0.66	115,244	0.74
	2013	1,640	1,410	46,233	0.59	69,082	0.66	114,125	0.73
	2014	1,640	1,410	45,865	0.59	68,419	0.65	113,115	0.72
	2015	1,640	1,410	45,589	0.58	67,868	0.65	112,233	0.72
	2016	1,640	1,410	45,408	**0.58**	67,437	**0.64**	111,492	**0.71**
	2005	2,838	2,423	50,274	0.64	75,049	0.71	122,982	0.78
OY - F50% for base model	2006	2,831	2,423	49,386	0.63	74,012	0.70	121,722	0.77
	2007	3,953	3,390	48,410	0.62	72,853	0.69	120,308	0.76
	2008	3,859	3,316	46,816	0.60	70,989	0.68	118,185	0.75
	2009	3,765	3,239	45,205	0.58	69,067	0.66	115,965	0.74
	2010	3,671	3,159	43,624	0.56	67,137	0.64	113,700	0.72
	2011	3,576	3,075	42,127	0.54	65,259	0.62	111,460	0.71
	2012	3,482	2,990	40,754	0.52	63,487	0.60	109,309	0.69
	2013	3,391	2,903	39,523	0.51	61,858	0.59	107,292	0.68
	2014	3,304	2,818	38,443	0.49	60,391	0.57	105,440	0.67
	2015	3,224	2,737	37,517	0.48	59,101	0.56	103,773	0.66
	2016	3,154	2,664	36,746	**0.47**	57,990	**0.55**	102,301	**0.65**

Regional Management: Evidence from genetic work does not indicate any biological structuring of the longspine population along the west coast. The slope survey biomass indices do not indicate clear differences in population trend by INPFC area, although apparent increasing trends in northern areas are not as distinct in the Conception INPFC area. Slope survey biomass estimates do suggest that there are differences in longspine thornyhead density north and south of Point Conception within the Conception INPFC area. The large Conception INPFC area potentially contains a large proportion of the stock biomass, and has only been lightly exploited by the fishery. Uncertainty regarding the size of the population in the Conception INPFC area has resulted in a separate OY for this area. The spawning biomass of longspine north of the Conception area will likely be more depleted relative to that indicated by the base-case model, simply due to differing exploitation rates.

Research and Data Needs: A more thorough investigation/examination of the slope surveys is required to better determine the catchability coefficient (*q*) and selectivity. More extensive estimates of thornyhead density and habitat associations, perhaps from remote camera observations would improve knowledge regarding slope survey parameters and help to resolve uncertainty for these parameters. The density of longspine thornyhead in the region south of Point Conception also needs verifying, as does the extent of stock biomass beyond the deepest extent of the current slope surveys. Length compositions of discards would provide more information on recent year class strength, improving the model estimates of recruitment and variation in retention.

Uncertainty associated with the value(s) for the rate of natural mortality could be reduced by improved estimates of longevity and growth, along with improved confidence in ageing data. Implications of age- or size-specific natural mortality rates, due to predation by sablefish and shortspine thornyheads should be explored further, perhaps by adopting a multipsecies modelling approach. A more spatially-explicit modelling framework would enable the inclusion of survey data currently not used in the assessment, and enable testing of the implications for spatial structuring in the stock, such as geographic differences in density.

2. INTRODUCTION

This is an assessment of the longspine thornyhead (*Sebastolobus altivelis*) stock along the west coast of the continental USA. The analyses presented here follow the previous assessment (Rogers *et al.* 1997) by considering longspine thornyheads separate from shortspine thornyhead (*S.alascanus*), although the two species made up a single market category in the historical fishery, are often difficult to separate in early landings data, and are similar in many respects (Jacobson and Vetter 1996).

2.1 Distribution

Longspine thornyhead occur from the southern tip of Baja, California, to the Aleutian Islands (Jacobson and Vetter 1996, Orr et al. 1998). There appear to be no distinct geographic breaks in stock abundance along the west coast (Rogers *et al.* 1997). Adult longspine thornyhead are bottom dwellers, and inhabit the deep waters of the continental slope throughout their range.

This assessment pertains to the longspine thornyhead population along the west coast of the continental United States. Bottom trawl surveys and camera sled observations show that longspine occur at depths greater than 600 m, with a distribution to about 1400 m depth (Jacobson and Vetter 1996), and a peak in abundance and spawning biomass in the "oxygen minimum zone" (OMZ) at about 1000 m depth (Wakefield 1990; Jacobson and Vetter 1996). Longspine are better adapted to deep water than shortspine (Siebenaller 1978; Siebenaller and Somero 1982). Wakefield (1990) estimated that 83% of the longspine population resides within an area of the continental slope bounded by 600 and 1,000 m depth.

Unlike shortspine thornyhead, the mean size of longspines is similar throughout the depth range of the species (Jacobson and Vetter 1996). Camera sled observations indicate that longspines do not school or aggregate, and are distributed relatively evenly over soft sediments (Wakefield 1990). Differences in density of individuals at depth do occur with latitude however, with higher densities of longspine in deep water (1000-1400 m) off Oregon than off central California (Jacobson and Vetter 1996).

2.2 Stock structure

Longspine thornyheads are sedentary bottom dwellers that, based on camera sled observations, are unlikely to move great distances up and down the coast after they settle as juveniles (Wakefield 1990; Jacobson and Vetter 1996). It is unlikely that separate, local stocks exist, and it has been suggested that longspines exist as a continuous population along the west coast (Rogers *et al.* 1997). Both species of thornyhead have extended egg, larval and pelagic juvenile stages (18-20 months for longspine) (Moser 1974) during which mixing is likely to occur, decreasing the likelihood of reproductive isolation.

Population genetic studies based on mitochondrial DNA sequences (mtDNA) support the prediction of wide ranging dispersal with little to no geographic population diversity off the US west coast (Stepien *et al.* 2000). For modelling purposes, one stock of longspine thornyhead was assumed to exist in the assessed area.

2.3 Bathymetric demography

The strong relationship between depth and size found in shortspine thornyhead (Jacobson and Vetter 1996) is not observed for longspines, with the distribution of longspines being relatively uniform with depth (Rogers et al. 1997). Figure 1 shows this insensitivity in the length composition of longspines with depth. Unlike shortspines, longspine do not undergo an ontogenetic migration to deeper waters (Wakefield 1990).

2.4 Species associations

Longspine and shortspine thornyheads have different but overlapping depth ranges (Jacobson and Vetter 1996), and, due to the bathymetric demography of shortspines, it is frequently larger specimens of this species that are found with longspines. As such, the two species do not tend to be the same size at the same depth. However, there is some overlap in size at the shallower end of the longspine bathymetric distribution. Settled longspine thornyheads are prey for both sablefish (*Anoplopoma fimbria*), and large shortspine, and longspine are common in stomach samples of both species (Laidig et al. 1997; Buckley et al. 1999). Size distribution data for longspines found in sablefish and shortspine stomachs indicate a high incidence of predation by these species on settled juvenile longspine, with longspine above 20cm rare in stomach data (Laidig et al. 1997, Buckley et al. 1999). These two species are the major predators of longspine thornyheads on the continental slope, suggesting that the rate of predation mortality could be lower for adult longspine than for juveniles.

Thornyheads are captured with Dover sole (*Microstomus pacificus*) and sablefish, the peak spawning biomass for these two species also occurring in the OMZ.

2.5 Spawning and early life history

The spawning season for longspine thornyheads appears to be extended, and occurs over several months during February, March and April (Pearcy 1962; Best 1964; Moser 1974; Best 1964; Wakefield and Smith 1990). Both thornyhead species produce a bi-lobed jellied egg mass that is fertilized at depth and which then floats to the surface where final development and hatching occur (Pearcy 1962). An extended larval and pelagic juvenile phase follows, which is thought to be 18-20 months long (Moser 1974; Wakefield 1990). Juvenile longspine settle on the continental slope at depths between 600 and 1200 m (Wakefield 1990). Moser (1974) reports a mean length at settlement of 4.2-6.0 cm, although pelagic juveniles up to 69 mm in length have been collected in midwater trawls off Oregon (J. Siebenaller unpubl. data, as cited in Wakefield and Smith 1990).

Following settlement, longspine thornyhead are strictly benthic (Jacobson and Vetter 1996). No apparent pulse in recruitment during the year was observed by Wakefield and Smith (1990), perhaps due to long (4-5 months) spawning season, variation in growth rates, and variation in the duration of the pelagic period (Wakefield and Smith 1990).
There is potential for cannibalism because juveniles settle directly on to the adult habitat (Jacobson and Vetter 1996). Video observations from submersibles and ROVs indicate that thornyhead are sit-and-wait predators that rest on the bottom and remain motionless for extended periods (John Butler, NOAA Fisheries, Southwest Fisheries Science Center, CA, as cited in Jacobson and Vetter 1996).

2.6 Fecundity and maturity

Estimates for reproductive parameters of longspine thornyheads are difficult to obtain, due to difficulties in assessing maturity stage without histological examination (Pearson and Gunderson 2003). Estimates of the length at 50% maturity based on histological examinations are provided by Jacobson (1991, N=120) and Pearson and Gunderson (2003, N=239). Ianelli *et al.* (1994) used visual estimates of maturity stage to model maturity at length (N=3,738). Table 1 lists the parameter values provided by these studies. The length at which 50% of females are mature ranges from 18-20 cm, which corresponds to ages of approximately 12-15 years.

Adult females release between 20,000 to 450,000 eggs over a 4-5 month period (Best 1964; Moser 1974). Wakefield (1990) and Cooper *et al.* (2005) both found linear relationships between fecundity and somatic weight. The data analysed by Cooper *et al.* (2005) indicated that fecundity of longspine between 20 and 30 cm in length ranged from 20,000 to 50,000 eggs.

This assessment used the parameter values obtained by Pearson and Gunderson (2003) to determine the maturity at length, as these values were determined from histological samples, used individuals collected from locations throughout the west coast, and were based on a larger sample size than the histology estimates provided by Jacobson (1991).

2.7 Age and growth

There is considerable uncertainty regarding age and growth of thornyheads (Jacobson and Vetter 1996), although data indicate that longspine thornyhead are long lived. Age estimates of over 40 years have been obtained from otoliths using thin-section and break-and-burn techniques (Ianelli et al. 1994). High frequencies of large longspine thornyheads may be due to a strongly asymptotic growth pattern, with accumulation of many age groups in the largerst size-classes (Jacobson and Vetter 1996). Size at age data (Ianelli et al. 1994) indicate that longspine grow to a maximum size of about 30cm TL at ages of about 25-45 years, with little or no sexual dimorphism in length at age (longspines in British Columbia, Canada also display no sexual dimorphism, Starr and Haigh 2000). Orr et al. (1998) report a maximum length for longspines of 38 cm, although individuals of this size are rare in both trawl surveys and commercial landings. Growth increments on otoliths suggest that juveniles reach 80 mm after 1 year of life as demersal juveniles (Wakefield unpubl. data, as cited in Wakefield and Smith 1990), which corresponds to an age of 2.5 - 3 years old.

Estimates of mean length at age for longspine, based on the Von Bertalanffy growth curve, have been published by Jacobson (1991, N=192) and Kline (1996, N=478). The data used by Jacobson (1991) originated from fish in port samples from commercial landings in Oregon, and ages were obtained from sectioned otoliths (Jacobson 1991). Length and age data used by Kline came from California during 1990-1991. Values for the parameters of these two growth curves are given in Table 1, and the differences in predicted mean lengths at age from the two curves are shown in Figure 3. The length and age observation pairs for these two curves were analysed together with additional data (Donna Kline, Moss Landing Marine Laboratory, pers. comm.) for this assessment to obtain a third growth curve based on a larger sample size (N=815). Details of this analysis can be found in Appendix A, and the resulting curve is shown in Figure 3, with corresponding parameter values given in Table 1. Estimates of the variability in length at age for the new growth curve are listed in Table A.1. The parameter values, and the associated estimates of variability of length at age used for this assessment were those obtained from the analysis of the larger dataset, conducted for this assessment.

2.8 Natural mortality

The longevity of longspine thornyheads is uncertain. The species appears to be long-lived, although not as much as shortspine. The maximum age observed by Jacobson et al. (1990) was 45 years, which, according to the authors, corresponds to a rate of natural mortality, *M* of 0.1 yr^{-1}. In their 1994 assessment, Ianelli et al. used a range for *M* of 0.08 – 0.12 yr^{-1}. Recently, Pearson and Gunderson (2003) obtained a much lower estimate of 0.015 yr^{-1} for *M* from a prediction model based on a gonadal somatic index (GSI). This value for *M* would suggest that longevity of longspines is much greater than the maximum age observed, and, given the growth information presented above, that a large proportion of the population would be of a size around the asymptotic length. Food habits data indicate that predation mortality on adult longspine thornyheads is lower than that on juveniles, and the low mortality rate calculated by Pearson and Gunderson (2003) for adults could reflect an age-dependent mortality schedule determined by predation risk.

The base-case analyses in this assessment estimated the value of *M* within the model, with sensitivity of the results to the fixed values used in previous assessments examined. The possibility of a reduced mortality rate for adult longspine due to a low predation risk was also investigated by allowing for a different value for *M* for adults.

2.9 History of the fishery

Longspine thornyhead are exploited in the limited entry deep-water trawl fishery operating on the continental slope that also targets shortspine thornyhead, Dover sole and sablefish. A very small proportion of longspine landings are due to non-trawl gears (gillnet, hook and line). Longspine and shortspine thornyhead make up a single market category. The thornyhead fishery developed in Northern California during the 1960s, with early landings being primarily from the Eureka INPFC area. The fishery then expanded north and south, and the majority of the landings of longspine thornyhead have since been in the Monterey, Eureka, and Columbia INPFC areas (Figure 4), with some increase in landings from the Conception and Vancouver INPFC areas in recent years (Figure 4).

Total landings of both thornyhead species increased to about 2,000 mt by 1981, although longspines accounted for less than 10% of this. Coast-wide landings of thornyheads increased to 10,000 mt by 1990, but have decreased since, to annual landings of around 2,000-2,500 mt (Figure 4). Annual landings of longspine increased to about 5,000 mt in the early 1990's, and have since decreased to around 1,500 mt (Figure 4). The proportion of the total thornyhead landings that is longspine increased to over 70% during the mid-1990's, but the relative percent contribution by longspines to coastwide landings has since decreased.

The markets for longspine thornyheads along the west coast developed at different rates than for shortspine (Rogers *et al.* 1997). A primarily domestic market for thornyheads developed in the Eureka INPFC area in California during the early 1960s. Initially, thornyheads were sold with other rockfish under a variety of names. Large thornyheads (minimum size 12-14 inches) were trimmed and sold as ocean catfish, and also later sold filleted as "Skin-on Perch". Due to size restrictions, there was little market for the smaller longspines, and these early fish were primarily shortspine. Smaller fish began to be taken by processors in Eureka during the late 1970's, and by the early 1980's, the minimum marketable size was 10 inches. This decrease in the minimum marketable size for thornyheads probably facilitated the development of the fishery for longspines.

An export market for thornyheads developed during the late 1980's because a similar species, *S. macrochir*, was depleted off Japan. As the Japanese market developed, processors began accepting fish as small as 7-8 inches, and landings of the smaller longspine thornyhead increased. As the market for smaller longspine developed, the trawl fishery moved into deeper water where longspine thornyheads are more common.

Trends toward deep-water fishing, higher prices, and increased landings for thornyheads occurred later in Oregon and Washington than in California (Rogers *et al.* 1997). A coastwide minimum marketable size of 10 inches was apparently in effect during 1990. However, this was replaced by a two-tiered price structure in 1991 (Pete Leipzig, Fishermen's Marketing Association, as cited by Jacobson, 1991). Marketing of thornyheads in Oregon as "Skin-on Perch" with a 10 inch minimum limit continued until about 1992 (Whitey Forsman, Pacific Coast, Warrenton OR, as cited by Rogers *et al*. 1997).

Exvessel prices for thornyheads increased substantially in 1994 and in 1995, although these have decreased since. The 1994 increase was likely a result of increased management restrictions on catches, and changes in the relative value of the Japanese yen and US dollar (Whitey Forsman, Pacific Coast, Warrenton OR, as cited by Rogers *et al.* 1997).

At the time of the previous assessment (1997), processors coastwide imposed an 8 inch minimum size limit for thornyheads (Jay Bornstein, Bornstein Seafoods, Bellingham, WA; Whitey Forsman, Pacific Coast, Warrenton OR; Jerry Thomas, Eureka Fisheries, CA, all as cited by Rogers *et al.* 1997). Up to seven size categories had different prices, and longspines had lower prices than shortspines of the same size, due to both a lower condition factor (lower weight at length) and coloration differences in skin and flesh.

Catches of longspine thornyhead have declined in recent years along with increased management restrictions for both thornyhead species.

2.10 Management history

Management of thornyheads has become more restrictive and complex in recent years (Table 2). Thornyheads were added to the deepwater complex managed by the Pacific Fishery Management Council (PFMC) in 1989. Catch limits for the thornyhead species group were first implemented in 1991, although it was not until 1995 that catch limits were separated by species with the implementation of more restrictive trip limits. Bi-monthly cumulative limits for longspine in recent years have generally been offset so as to maintain informal ratios of longspine to shortspine limits, in order to prevent the total catch of shortspine from exceeding its OY. Although the depth range for longspine extends well beyond the depths at which shortspine are most abundant, no management options have been available for specifying higher longspine limits only in the zone where they could be caught with minimal coincident catch of shortspines.

2.11 Management performance

The Allowable Biological Catch (ABC) and Optimum Yield (OY) for longspine thornyhead has declined since the adoption of separate ABCs for the two thornyhead species by the PFMC in 1992 (Table 3). Estimated catches (landings plus discard) of longspines have been below the harvest guidelines, due to the challenge involved in fully exploiting this resource without exceeding the OYs for shortspine.

3. ASSESSMENT

3.1 Data

The only source of fishery-independent data available for longspine thornyheads is the slope survey conducted by the NMFS. The depths surveyed by the NMFS triennial shelf surveys do not adequately cover the distribution of longspines, and so were not used to provide estimates of abundance or population length composition.

3.1.1 Landings

Landings information for longspine thornyhead was compiled from the PACFIN database for the period 1981-2004 (data extracted 04/27/05). Landings of longspine during the period 1964-1980 were obtained from the last assessment by Rogers et al. (1997). Figure 4 shows the time series of landings of longspine for the period 1964-2004 broken down by the five INPFC areas. Annual landings by INPFC area are also given in Table 4. The trawl fishery was either considered as a coast-wide fleet, or as separate northern (Vancouver and Columbia INPFC areas) and southern fleets (Eureka, Monterey,and Conception INPFC areas, Table 4).

The majority of longspine thornyhead are captured using bottom-trawl gear types. These are all considered as the same fishery. A very small proportion of the catch is landed by non-trawl gear types. However, the maximum annual total of these landings is less than 1% of the total landings, and so the non-trawl landings are subsumed into the bottom trawl landings for the purposes of this assessment.

The PACFIN database covers the entire west coast, and contains entries from all three state agencies, California Department of Fish and Game (CDFG), Oregon Department of Fish and Wildlife (ODFW), and Washington Department of Fish and Wildlife (WDFW). Longspine appear in the database in three forms, LSPN (longspine) – which represent port-sample verified longspine thornyhead, LSP1 (nominal longspine) – fish recorded as longspine in logbooks, and THDS – the mixed thornyhead category. It is therefore necessary to allocate the mixed thornyheads to species by some method. Total annual landings of longspine thornyhead by INPFC area were estimated using the following equation:

$$\mathrm{LST}_{y,A} = \mathrm{LSPN}_{y,A} + \mathrm{LSP1}_{y,A} + \lambda_y \mathrm{THDS}_{y,a} \tag{1.1}$$

$$\lambda_y = \frac{\sum_{\mathrm{A}} \left(\mathrm{LSPN}_{y,A} + \mathrm{LSP1}_{y,A} \right)}{\sum_{\mathrm{A}} \left(\mathrm{LSPN}_{y,A} + \mathrm{LSP1}_{y,A} + \mathrm{SSPN}_{y,A} + \mathrm{SSP1}_{y,A} \right)}$$

where $\mathrm{LST}_{y,A}$ is the estimated landings of longspine in INPFC area *A* during year *y*,

$\mathrm{SSPN}_{y,A}$ is the port-sample verified landings of shortspine in INPFC area *A* during year *y*,

$\mathrm{SSP1}_{y,A}$ is the nominal shortspine landings for INPFC area *A* during year *y*.

The landings provided by Rogers *et al.* (1997) were based on landings of thornyheads recorded in CDFG bulletins and reports. These landings were allocated to species for the years 1978 and 1979 based on the average ratio of shortspine to longspine in landings of thornyheads during 1980 and 1981. Allocation of landings to species during 1964-1977 was based on reducing the estimated proportion of longspine to shortspine in landings to half that for 1978-1979, as the minimum size acceptable to the market at this time (12-14 inches) would have eliminated most longspines from the landings (Rogers *et al.* 1997).

In order to assess the sensitivity of the model to increased numbers of landings from the time-period prior to the PACFIN data, an alternative landings history was constructed to include possible longspine catch from foreign vessels during 1965-76, and bycatch of longspine in the sablefish trawl fishery during 1900-1963. Details of the methodology used in determining this additional time-series of landings are given below when describing the relevant sensitivity analyses.

3.1.2 Discards

Discard rates (defined as the weight discarded divided by the total caught weight (i.e. discarded plus retained weight)) for longspine thornyhead likely changed with changes in market price-at-size and acceptable minimum size over the course of the fishery. Management restrictions in place from the mid-late 1990s may have also affected the discarding of longspine.

Discard data for longspine thornyhead were available from a number of sources. Overall estimates of discard rate from observers on commercial vessels for the northern (Oregon and Washington) fishery in 1985-1987 were 28% for both shortspines and longspines (Rogers 1994; Rogers *et al.* 1997). An estimate of discards for longspines from a second observer study in the Eureka INPFC area deepwater fishery from 1989-1991 of 13% is provided by Hankin (1991). Helser *et al.* (2002) analysed data from the Enhanced Data Collection Project (EDCP) to produce discard estimates for longspine by INPFC area for the years 1995-1999. Discard rates were also available by INPFC area from the west coast groundfish observer program (WCGOP) for the years 2000-2003 (Hastie pers. comm.). These data are summarized in Table 5. The recent data would suggest that current discard rates are higher in the North than in the South (Table 5). A coefficient of variation (CV) of 0.2 (20%) was assumed for these data.

Including this information in a stock assessment modelling framework is challenging, because reliable estimates of discards are not available over the full time-period. Additionally, these data are unavailable for years when the discarding rates likely changed the most during the expansion of the fishery. Four different discard scenarios were considered, which contrasted the assumptions made regarding how discarding in the fishery changed over time, and how to make use of the available data.

1. The population dynamics model was fitted to the data in Table 5 using a single retention function for the entire time-period of the commercial fishery (1964-2004). This scenario therefore assumed no time-dependence in the size retention of the fishery, although discarding could differ annually due to annual differences in the length composition of the population.
2. The model was only fitted to the available data as above, but the retention function for the fishery was given a time-varying component, split into four sections (blocks) corresponding to different periods of the fishery (1964-1977, 1978-1987, 1988-1994, 1995-2004). These time periods are based on differences in the minimum acceptable market size (Table 6), and with regulatory changes in entire-net mesh size (Table 2). As a lack of data precludes estimation of the relevant parameters, the lengths at 50% retention for the time blocks 1964-1977 and 1978-1987 were set to the minimum size accepted by processors for these periods (30 and 25 cm respectively). The width of

the retention function was set to be the same value for both of these earlier time blocks.

3. The model was fitted to a time-series of discard rates modified from one developed for the previous assessment by Rogers *et al.* (1997). Information related to the minimum acceptable market size was used to develop estimated discard rates for the whole time series of the fishery (Table 6). The last two assessments for shortspine thornyhead have used this approach in their determination of the discard rate (Rogers *et al.* 1998; Piner and Methot 2001). The retention function for the fishery was varied over time in the same four year blocks as for scenario 2. However, in this case the discard data were used to inform the model about the parameter values for these curves. Data from the EDCP and WCGOP were used as estimates in recent years. The additional estimated discard rate time series data was given a CV of 0.3.
4. Same as scenario 3, except that the time-series of discards followed assumptions by Ianelli *et al.* (1994) in relation to the time-varying component of the retention function, with a single fixed time-block for the years 1964-1987.

3.1.3 Mean body weights

Information from the WCGOP was compiled by Hastie (pers. comm.) to obtain estimates of mean body weight by INPFC area of both the discarded and retained portions of the catch for 2002 and 2003. Observer data from Oregon and Washington in 1985-87 and 1988-90 give an average size of discarded longspine thornyhead of 8 inches. These lengths were converted to weight using the length-weight relationship (Table 1) for inclusion in the model fitting process. Table 7 shows these data. No estimates of variance were associated with these data. A CV of 0.2 was assumed for the WCGOP data, and a CV of 0.3 was assumed for the extrapolated data.

3.1.4 Commercial length compositions

Length composition data from port samples of the commercial landings were obtained from the PACFIN database (BDS data extracted 04/27/05), and were separated by agency. Years for which data were available were: 1981-2004 (CDFG); 1986, 1990-1994, 1996-2004 (ODFW); and 2001-2004 (WDFW). Only entries of type LSPN were used in creating the annual length compositions. Expanded annual length compositions for the coastwide fleet and separate northern and southern fleets for each agency were obtained by weighting the length frequency information in the port samples by the ratio of the trip weight to the weight sampled for length frequency information. Sample sizes for the commercial length data were assumed to be equivalent to the number of trips sampled for longspine lengths. Longspine and shortspine thornyhead are similar in appearance, and it is possible that some species mis-identification may occur when length measurements are taken. 'Longspines' in the PACFIN database of length greater than 40 cm were not included when expanding the length data as these were most probably shortspines. This approach was consistent with the previous assessment. The coastwide length compositions are given in Table 8, while Table 9 shows the length data separated into northern (Vancouver and Columbia INPFC areas) and southern (Eureka, Monterey, and Conception INPFC areas) fleets. Figure 5 shows that there is some evidence from the length data that the mean length of the landings has declined since the early 1980s.

The coastwide length compositions were recalculated for he sensitivity tests that removed the Conception INPFC area from the model, in order not to include length data from this area.

3.1.5 Logbook CPUE index

The use of logbook information to obtain indices of relative abundance for longspine thornyheads is challenging, due to the large number of (primarily) sequential management restrictions during the 1990s for both thornyhead species, and the likely associated changes in discarding and fishing practices over the course of the fishery. Brodziak (unpublished manuscript) estimated a standardized index of relative abundance for longspine thornyheads based on logbook information for 1978-1987. The market for thornyheads was stable during this time, and so it was assumed that the level of discarding likely did not change appreciably over these years. To avoid species mis-identification problems, it was assumed that all thornyheads caught in tows at depths greater than 500 fm were longspine. Two indices were developed, one based on all tows which caught longspine, and one based on tows that caught any of the four DTS species. The annual estimates of relative abundance from both logbook indices (Table 10) were given a CV of 0.25. Although the base-case model described below did not include either of these indices, sensitivity of the assessment results to their inclusion was evaluated.

3.1.6 Slope survey biomass indices

Data from two slope surveys were used in the assessment: the slope survey conducted by the AFSC with survey years spanning the range 1988-2001, and the annual FRAM slope survey conducted by the NWFSC from 1998-2004. Helser et al. (2004, 2005) used generalized linear mixed effects models (GLMMs) to obtain standardized biomass indices for both these surveys, and also used this modelling framework to obtain a combined biomass index based on data from both surveys. The methodology used to obtain the biomass indices by strata is documented in Helser et al. (2004, 2005). This standardization procedure followed previous analyses of the AFSC slope surveys by using the information for 1988-1996, when survey coverage was not equivalent to recent years, to develop two “super-years”, 1992 (data from years 1988-1993) and 1996 (data from years 1995-1996). Unlike the survey estimates from 1997-2004, latitudinal coverage for these two super years was not coastwide. The 1992 estimate excluded biomass in the Conception INPFC area, and the 1996 estimate excluded biomass in both the Conception and Monterey INPFC areas. Only the slope survey biomass estimates for 1997-2004 were used in this assessment, owing to the non-synoptic nature of the 1992 and 1996 estimates. The CVs of the biomass estimates were set at the values obtained by Helser et al. (2005) from the GLMM, and are given in Table 11.

The biomass estimates (Figure 6) were based on an area expansion north of Point Conception. The modelled catch rates for the Conception INPFC area were therefore not expanded to the entire area. The area south of Point Conception was only surveyed during the 2002-2004 NWFSC FRAM surveys, and catch rates for longspine in this area were much lower than those north of Point Conception (Owen Hamel, NOAA Fisheries, pers. commn.). An expansion of biomass estimates to the area south of Point Conception for the remaining years would assume that the density of longspine is similar in both sections of the INPFC area, and would result in an inflated and biased estimate of stock biomass, particularly as more than 70% of the Conception INPFC area is south of Point Conception, and this INPFC area is large compared to the other INPFC areas. Figure 7 shows the biomass estimates by INPFC area for the combined slope survey analysis.

As the landings included data from the entire Conception INPFC area, the base case analyses allowed for the possibility for the slope survey biomass estimates to be a relative index of abundance. The catchability (q) of the survey(s) were assumed to have an expected value of 0.7, based on the known ratio of slope survey biomass in areas north of Point Conception (U.S./Canada border to Point Conception) to that coastwide (U.S./Canada border to Mexico border) during 2002 to 2004. In order to account for uncertainty in the value for this parameter, the objective function was penalised during estimation with respect to the value estimated for q. Previous assessments, and those for shortspine, have been found to be sensitive to the value(s) assumed for this parameter. Sensitivity analyses therefore investigated the implications of using different penalties on q, and to fixing q at various values. Sensitivity tests also examined a coastwide expansion for determining the slope survey biomass estimates, and which removed the Conception area from the analysis completely, were also conducted.

3.1.7 Slope survey length compositions

Length composition information from the slope surveys is available for both the AFSC and NWFSC FRAM surveys, for all years in which the surveys were conducted. However, only the length information from those years in which survey coverage was synoptic were used. Slope survey length compositions were therefore available for the years 1997, 1999-2001 for the AFSC survey, and for years 1998-2004. for the NWFSC FRAM survey. Separate length compositions for the two surveys were developed, even when both surveys were conducted in the same year.

Coastwide length frequencies for the NWFSC FRAM survey were developed as follows:

The length compositions were formed for each stratum/year combination by scaling up the lengthed individuals to the total CPUE (in numbers) for each tow and then dividing by the summed CPUE in that stratum/year. To create final length compositions for this survey, each stratum composition was weighted by a total number index for that stratum. The number index for each stratum was calculated by calculating the average weight from the length composition for that stratum (based on the length-weight relationship for longspine, Table 1), and then dividing the biomass estimate for the stratum by that average weight.

Length compositions for the AFSC slope survey were expanded in a similar way.

Table 12 gives the expanded length compositions for both surveys, along with the total number of fish measured and the number of tows in surveys that caught longspine. The input sample sizes for the slope survey length data were assumed to be equivalent to the number of tows.

As the weightings for the slope survey length compositons by area are determined by the biomass estimates, the slope survey length compositions were recalculated for sensitivity analyses that used different biomass estimates than the base-case model.

3.2 History of modelling approaches

This is the 4th stock assessment of west coast longspine thornyhead. Previous assessments were conducted by Jacobson (1990, 1991), Ianelli *et al.* (1994), and Rogers *et al.* (1997). The 1990 and 1991 assessments were very similar. Important features included reviews of available biological data, and analyses of trends in mean lengths from port samples and catch rates calculated from logbook data. Swept-area and video biomass estimates were used to estimate 'average' biomass levels and exploitation rates in the Monterey to US-Vancouver management areas. The available data were used to conduct analyses of yield-, revenue-, and spawning biomass-per-recruit, and develop estimates of the then target level of $F_{35\%}$.

The 1994 assessment utilized coast-wide abundance estimates based on slope survey data, an updated analysis of the logbook data, and fishery length composition data to estimate the parameters of length-based Stock Synthesis models, under different assumptions regarding discarding practices.

The most recent assessment by Rogers *et al.* (1997) used a length-based version of Stock Synthesis 1 to fit an age-sturctured model to data for the Monterey, Eureka, Columbia and Vancouer INPFC areas. Models were fitted to biomass estimates and length data from the AFSC slope surveys (1988-1996), a logbook CPUE index, discarded proportions by year, and length composition data from California and Oregon. Sensitivity to discard rates based on changes in prices and minimum size were explored.

3.3 Model description

The data described above were used to fit an age-structured population dynamics model using the length-age-structured modeling software Stock Synthesis 2. (version 1.19, compiled 04/27/2005, Methot 2005). This software is the standard for the 2005 west coast groundfish assessments. Full documentation of the software, the population dynamics model, and the observation model used to fit the available data are found in Methot (2005). The parameters of the model are listed in Table 13, along with details as to which parameters were pre-specified and which were estimated during the model fitting process.

3.3.1 Stock, area, and fleet definition

A single coastwide stock of longspine thornyhead was assumed to inhabit the area covered by the assessment, which included the Conception, Monterey, Eureka, Columbia, and Vancouver INPFC areas. The commercial trawl fishery was treated as a single fleet. Sensitivity analyses separated the fishery into two fleets, the North (Vancouver and Columbia INPFC areas) and the South (Eureka, Monterey and Conception INPFC areas). This division was based on several factors – a) it follows the approach in the previous assessment (Rogers *et al.* 1997), b) the market and price for longspine developed differently in the north than in the south (Rogers *et al.* 1997), which would affect historical discarding rates, c) recent data suggest differences in discarding behaviour, and d) there is some evidence that longspine exhibit bathymetric demography in their distribution in the northern areas. This separation into two fleets was not assumed to represent the base-case scenario due to significant uncertainty in historical discard estimates, and a lack of information to sufficiently parameterize differences in discard behaviour on a regional basis over the entire time series of the fishery.

3.3.2 Likelihood components

The population dynamics model was fitted to the available data using an observation model which contained the following likelihood components:

1. Commercial length compositions, 1981-2004 (Tables 8 and 9),
2. Commercial discard rates:
    a. observer data: 1986, 1990, 1995-2003 (Table 5), or,
    b. size-based time-series of discard rates: 1964-2003 (Table 6),
3. Average body weights of discarded/retained fish: 1979-1980, 1990, 2002-2003 (Table 7),

4. Coastwide slope survey biomass estimates (Table 11), 2 scenarios:
   a. Combined survey GLMM estimates, 1997-2004.
   b. Separate survey GLMM estimates,
      i. AFSC slope survey: 1997, 1999-2001,
      ii. NWFSC slope survey: 1998-2004.
5. Log-normal penalty on *q*, the catchability of the slope survey(s),
6. AFSC slope survey length compositions: 1997, 1999-2001 (Table 12),
7. NWFSC FRAM slope survey length compositions: 1998-2004 (Table 12),
8. Log-normal penalty on recruitment residuals for 1980-2002 with variance of deviations equal to σ_R^2,
9. Logbook CPUE index: 1978-1987 (Table 10, sensitivity test only).

Length data were organized into 31 length bins of width 1cm (first length bin with low bound 5cm includes all fish <5 cm, final length bin 35 cm includes all fish 35-40 cm).

3.3.3 Maturity

Maturity at length was assumed to be time-invariant and described by the logistic function for maturity obtained by Pearson and Gunderson (2003). The curve described by Ianelli *et al*. (1994) was also used as a sensitivity test.

3.3.4 Age and growth

Growth was assumed to follow the Von Bertalanffy function with parameter values equal to those obtained in the analysis conducted for this assessment (Table 1, Appendix A). The CV of mean length at age was assumed to be a linear function of age, with the CV at age 3 and that at age 40 equal to 0.13 and 0.05 respectively (Table 13). Growth curve parameter values were fixed at these values for all years, and not estimated within the model. The maximum age assumed for the accumulator age (plus group) was 80. This is much higher than the maximum observed age. However, software performance is enhanced when the mean length at the maximum age is approximately the asymptotic length of the population (L_∞) (Methot 2005). Mean length at age 80 is 31 cm.

3.3.5 Natural Mortality

The rate of natural mortality, *M*, was estimated within the model, and was assumed to be invariant with time and age. Sensitivity of the base-case model results to fixed values of *M* of 0.015 yr^{-1}, 0.1 yr^{-1}, and 0.15 yr^{-1} was evaluated. A possible reduction in mortality rate for adults was also investigated in sensitivity tests by allow *M* for age 12+ fish to differ from that for younger animals. This age corresponds approximately to a mean length of 18 cm and hence the age of 50% maturity. Food habits data for sablefish show a reduction to zero incidence of longspine thornyhead over the length range 15-20 cm. Sensitivity tests which both used fixed values for the two mortality rates and which allowed these parameters to be estimated within the model were conducted.

3.3.6 Selectivity and retention

The selectivity patterns for both the commercial fleet and the slope survey(s) were modeled as functions of length, assumed to be time-invariant, and allowed to be dome-shaped. Estimation of bottom trawl selectivity by Lauth *et al*. (2004a) using camera sled observations suggests that survey selectivity is not asymptotic. Models which assumed that commercial fleets and/or slope surveys had logistic selectivity (with both inflection and slope parameters estimated) were also considered. The dome-shaped selectivity ogives for both the fishery and survey(s) were modeled as double-logistic functions.

Table 13 details the parameters of these functions and summarizes the details of their estimation.

The slope survey(s) and fishery(s) were also given an additional age-based selectivity function, which set knife-edge selectivity between 0 and 1 at age 18 months (Table 13). Individuals younger than this are pelagic and thus not available to the survey or the fishery.

Retention functions enable size-specific modeling of the discarded portion of the catch. Estimation of retention functions varied depending on the discard scenario. Retention functions were defined as logistic curves, with restrictions as given in Section 3.1.2 and Table 13.

Lauth *et al.* (2004a) show that the relative vulnerability at length for thornyheads may not be described completely by the parametric distributions described above. Currently however, Stock Synthesis 2 does not include the facility to model penalized process errors in the selectivity function, which would be required to mimic the functions used by Lauth *et al.* (2004a) adequately. It is not likely, however, that the data are sufficient to enable estimation of the large number of parameters that such an approach would entail.

The assumption that selectivity does not vary over time further introduces error because the depth distribution of the fishery has changed over time. However, the relative length frequency of longspine does not change appreciably with depth (Figure 1), so failure to account for time-varying selectivity due to depth-specific factors may not be critical.

3.3.7 Catchability

Estimation of population abundance is highly dependent on the catchability coefficient (q) assumed for the slope surveys, as these are the only indices of population abundance. Previous assessments have considered the slope survey biomass estimates as absolute estimates of abundance because the surveys cover the entire range of the stock modeled, and as such fixed q at 1. However, the expansion of the Conception area to just that area north of Point Conception, coupled with the landings data coming from the entire Conception area, results in an expectation that the survey biomass estimates would constitute a relative index of abundance.

Rather than fixing the value of q, the uncertainty associated with this parameter was accounted for in the base-case model by estimating q but including a penalty on q in the objective function. The penalty (“prior”) on q in the base-case model was log-normal with a CV of 20% and an expected value of 0.7. The expectation that q would be 0.7 was based on the known ratio of slope survey biomass in areas north of Point Conception (U.S./Canada border to Point Conception) to that coastwide (U.S./Canada border to Mexico border) during 2002 to 2004 (when data south of Point Conception was available).

Slope survey biomass indices are assumed to be lognormally distributed around the true available survey biomass. The implications for the assessment results of assuming different fixed values for q were explored in the sensitivity analyses.

Sensitivity analyses that included the logbook CPUE relative index of abundance also estimated an additional q parameter. This index was assumed to be directly proportional to the vulnerable biomass (observations are lognormally distributed around the product of the vulnerable biomass and the catchability coefficient).

3.3.8 Stock-recruitment relationship

Expected annual recruitment followed a Beverton-Holt function of spawning biomass. Annual deviations about this stock-recruitment function were estimated for 1980 through 2002. Recruitment residuals were not estimated for 2003 and 2004 as the corresponding year-classes will not be available to the slope survey until 2005 and 2006 due to the extended pelagic phase. The annual recruitment deviations were distributed normally in natural log-space, with a standard deviation of the residuals of σ_R. It is not possible to estimate the variance of these process errors in the penalized likelihood framework employed by the assessment software, so σ_R was fixed at specific values (base-case 0.6). In the absence of auxiliary information, the steepness parameter (h) was also fixed (base-case 0.75). Implications of changing the values for the fixed stock-recruitment parameters (σ_R and h) and the time-period for which recruitment residuals are estimated were explored in sensitivity analyses.

3.3.9 Initial conditions

The population was assumed to be in unfished equilibrium at virgin biomass (B_0) with the associated stable age structure at the beginning of the time-series of landings in 1964. No initial equilibrium fishing mortality rate was therefore estimated. Expected recruitment in 1964 was also assumed to be equivalent to that at B_0 (i.e. R_0). Landings of longspine thornyhead at the beginning of the time series in the mid-1960s are low (Table 4), and the assumption of unfished equilibrium prior to this is probably not unreasonable if landings represent catch. However, total catches at this time could have been much greater than landed biomass if discarding was high during the early period. The sensitivity of model results to additional landings prior to 1964 was explored by extending the catch history back in time to 1900.

3.4 Model selection and evaluation

The base-case scenarios reflect the 'most likely' set of assumptions described above. Sensitivity tests then examine the sensitivity of the model outputs to changes to these assumptions.

3.4.1 Parameter estimation

Parameter estimation within Stock Synthesis 2 is conducted using the AD Model Builder (ADMB) Package (Otter Research, Ltd.) to obtain the maximum posterior density (MPD) estimates of the model parameters for given estimation scenarios. When no prior distributions are assumed for the model parameters, these MPDs are equivalent to the maximum likelihood estimates. The use of the ADMB package for stock assessment purposes is desirable because the derivatives of the objective function with respect to the model parameters are calculated analytically (as opposed to numerically), and because the package provides a means of obtaining Bayesian posterior distributions using the Markov Chain Monte Carlo (MCMC) technique, facilitating quantification of uncertainty regarding model parameters and stock status.

The parameters of the population dynamics model estimated during the model-fitting process for the base-case model are listed in Table 13 and include: average recruitment at virgin spawning biomass (R_0), the rate of natural mortality (M), annual recruitment residuals for the period 1980-2002, the catchability of the slope survey (q), selectivity parameters for the bottom trawl fishery and slope surveys, and retention parameters for the bottom trawl fishery. Additional parameters estimated during sensitivity tests are the catchability coefficient (q) of the logbook CPUE index, the catchability coefficient (q) for the combined slope survey (no penalty), the steepness parameter (*h)*, and a separate rate of natural mortality (*M*) for fish aged 12+.

Asymptotic standard errors for the estimates of the model parameters and derived variables of interest were determined for the base-case model using the delta method.

3.4.2 Evaluation of model structure

Table 14 provides details of the contributions of the various data types to the likelihood function, the number of estimated parameters, and summarized results for several versions of the set of model assumptions described above. These models used different combinations of fleets, surveys, and selectivity patterns. Akaike's Information Criteria (AIC) is also given in Table 14 for those models which have identical likelihood functions. It is not possible to compare all the models in Table 14 using AIC because the contribution of the commercial length composition data to the likelihood function changes with assumptions about fleet designation due to changes in the sample sizes, as does that for the slope surveys depending on whether separate or combined biomass indices are considered.

Models which assumed asymptotic (logistic) selectivity provided a poorer fit to the data (higher total negative log-likelihood) than those which assumed selectivity was dome-shaped. Comparison of models using AIC also suggests that models that allowed for dome-shaped selectivity are the more parsimonious representations of the data (Table 14). The results were relatively insensitive to both the separation of the catch history into a northern and southern fleet, and treatment of the NWFSC and AFSC slope surveys as two separate indices of abundance. An analysis of the single fleet scenario which used the same fishery length composition data as the "two fleet" scenarios (model 6 in Table 14) shows that the fits to these data are not markedly improved even when separate selectivity patterns are estimated for the northern and southern fleets. The benefits of considering separate northern / southern fleets are improved fits to the WCGOP discard data, and also to the mean body weight data, although the latter are not comparable with those of the "single fleet" models as the data are different (Table 8).

MPD estimates of derived model quantities such as 2005 depletion and SB_0 were relatively insensitive to changes to the assumptions regarding model structure (Table 14). Estimates of unfished virgin biomass (B_0) were unsurprisingly lower for those models which assumed asymptotic selectivity for the slope survey, and these analyses also tended to be more optimistic about 2005 stock status than scenarios where survey selectivity was allowed to be dome-shaped. Scenarios which considered an asymptotic selectivity pattern for the commercial fleet(s) were also more optimistic about 2005 stock status than the base-case.

The results in Table 14 show that there does not appear to be great benefit in assuming the additional model complexity that results from consideration of two fleets or separate slope surveys. The latter is not surprising because the length composition data do not differ greatly between the AFSC and NWFSC time series. The insensitivity of the results to these model structure assumptions also suggests that the amount of uncertainty not accounted for by extending these scenarios further may be minimal. The sensitivity analyses presented below are therefore all based on a single coast-wide fleet, and a combined slope survey as the base-case model.

3.4.3 Recruitment

The models presented in Table 14 estimated annual recruitments for 1980-2002, with a σ_R of 0.6. Recruitment residuals were not estimated for 2003 and 2004 because the corresponding year-classes will not be available to the slope survey until 2005 and 2006 due to the extended pelagic phase. The fishery length composition data do not provide much information about recruitment because the majority of the landings are fish around 25 cm in length, which corresponds to a large number of older (20+ years) age classes. The slope survey length compositions include smaller fish (the length compositions of longspine discarded in the trawl fishery were not available) and should inform the model about recruitment. However, these data are only available towards the end of the time series. Figure 8 shows the asymptotic standard errors of the recruitment residuals (estimated for 1964-2002) for four values for σ_R. These estimated standard errors only drop from approximately σ_R to lower values during the early-mid 1990s, suggesting that recruitment should not be estimated prior to this point. Figure 9 also shows that there is little gain in fit to the length composition data for both the fishery and the slope survey with increased numbers of estimated recruitments.

3.4.4 Model fits and residual analysis

The base-case fits to the combined slope survey biomass estimates are shown in Figure 10. The increasing trend in the medians of these data is not mimicked very well by the model (Figure 10), with the model fit indicating a fairly static trend in recent years. However, the model predictions are not inconsistent with the data given the CVs of the data (Figure 10). The lack of fit to the increasing trend in the slope survey data is also clearly observed on inspection of the standardized residuals (Figure 10).

The fits to the discard rate data are shown in Figure 11. The 1986 estimate was poorly predicted, due to inflexibility in the model to adjust retention over time, with an estimated discard rate of about 0.14 for the entire time-period. The EDCP and WCGOP data were mimicked rather well, although the standardized residual plot over time (Figure 11, lower right panel) shows that the recent WCGOP data were under-estimated and there was an over-estimation of the mid-1990s discard data from the EDCP analysis. However, again, the model fits are not inconsistent with the data.

Similarly, there were under-estimates of the mean body weight data in the 1970s-80s, and over-estimates of the recent WCGOP data (Figure 12). These fits are consistent with the understanding that discarding was higher earlier in the fishery due to a lack of a market for smaller thornyheads, and that the size of the discards has likely decreased over time as a result of more smaller fish being retained in the landings in recent years.

The effective sample sizes of the length composition data obtained from the base-case fits are compared to the input number of trips and tows in Figure 13. The effective sample sizes were consistently an order of magnitude or more higher than the assumed sample sizes for the survey length data. This suggests that there is more information in the length composition data than would be expected given the assumption of a multinomial error distribution and the input sample sizes. The Pearson residuals for the trawl fishery length data (Figure 14) do not show any distinct trends, although there are some larger residuals at the beginning of the time series, when the sample sizes for the length compositions are small. There also appear to be consistent under-estimations (positive residuals) for the largest length bin observations, particularly at the start of the time series. These positive residuals are also found for the base-case fits to the slope survey length data (Figure 15), although again there are no distinct cohort effects visible in the residuals.

The base-case fits to the length-composition data for the trawl fishery are shown in Figure 16. These data are generally mimicked very well, although there are some over-estimates of the mean length for some combinations of agency/year (*e.g.* OR 1994, CA 1998, CA 2001). The recent length data from Washington (2001-2004) were not mimicked at all well by the model (Figure 16). An examination of the assumed sample sizes reveals that many of these poorly-fitted length compositions had a low number of trips associated with them (Table 11).

The length composition data for the slope surveys were mimcked extremely well by the base-case model (Figure 17). The model seemed unable to capture completely the relatively large number of 10-15 cm fish (approx. age 5 years) in the 1997 AFSC length composition (Figure 17), despite estimating a large recruitment in 1992 (Figure 18). There is some indication in the NWFSC length composition for 2004 of a large number of two year olds, mimicked by the model, and corresponding to an estimated larger than average recruitment event in 2002 (Figure 18).

Figure 18 shows the recruitment residuals for the base-case model (left panel). The results show clear trends with time in that largely positive residuals were estimated prior to 1994, with those since (with the exception of 2002) being estimated to be negative. It should be noted that the variability in the estimated recruitment residuals is much less than the input standard deviation of 0.6. Figure 19 shows the time series of the estimated recruitments for the base-case model.

3.5 Base-case results

The model-estimates for key derived quantities (B_0, SB_0, SB_{2005}, 2005 depletion) for the base-case are given in Table 14 (model #1). The results suggest that the population is only lightly exploited, with 2005 spawning biomass being 71% of that in the unfished equilibrium state. Current spawning biomass (SB_{2005}) is estimated to be 75,049 mt (Table 14), with total biomass in 2005 being 162,642 mt.

The time series of the MPD estimates of spawning biomass for the base-case model are listed in Table 15 and plotted in Figure 20, along with their estimated asymptotic 95% confidence intervals. The estimated 95% confidence intervals for spawning biomass are very large, reflecting the uncertainty accounted for by estimating M and q. Estimated numbers at age over time are listed in Table 16. Spawning biomass is estimated to have declined only slightly during the first 20 years of the fishery. A steeper decline accompanied the increase in catches over the period 1989-1997, and the decline in spawning biomass has since slowed with the reduction of catch in recent years. A approximately constant discard rate of 0.14 was estimated for the base-case model, resulting in total catches that peak at 6,857 mt in 1990 (Table 15).

The rate of natural mortality M, was estimated to be 0.06 yr^{-1}, which is much lower than that assumed in the previous assessment (0.1 yr^{-1}). It should be noted however, that the confounding effect of dome-shaped selectivity and the lack of age data in the assessment reduce the importance of the point estimate for this parameter. The value of estimating M within this model is that it allows the variance estimates for derived model quantities such as spawning biomass to reflect uncertainty about this parameter (Figure 20).

The MPD for the catchability coefficient of the combined slope survey, *q*, was estimated at 1.03 (Table 14), which essentially leads to the biomass indices being treated as estimates of absolute abundance. This value is high given that the penalty has a mean of 0.7 (CV=0.2), and would indicate that in the absence of the penalty, the data would force the model to a *q* larger than 1. This was explored in the sensitivity analyses presented in Section 3.6. Again, the value of estimating *q* in this manner lies in the ability to allow for its uncertainty.

Recruitment variability is estimated to have had a very small impact on population abundance. Such a result is unsurprising given the long-lived, asymptotic growth life history exhibited by the species. Figure 19 shows the time series of the estimated recruitments for the base-case model, which are also given in Table 15. Strong year classes were estimated for 1982-83 and 1992-93, although the absolute increase in numbers from the average recruitment in these years was small (Table 15, Figure 19 left panel). Figure 19 also shows the distribution of the estimated recruitments about the stock-recruitment relationship.

The MPD of the time-series of the depletion of the spawning biomass is shown in Figure 21, along with the management target and overfishing level. The base-case model estimates longspine thornyhead to be well above the management target of $SB_{40\%}$. Instantaneous fishing mortality rates are presented in Table 15, and plotted through time in Figure 22. These reached a peak in the early 1990s with the development of the fishery and increased catches. Current F's are estimated to be low, and have averaged around 0.02 in recent years (Table 15).

Figure 23 shows the MPD estimates of the selectivity and retention functions for the fishery, and the selectivity function for the combined slope survey. The estimated selectivity at length for the slope survey drops off very quickly following the peak at around 23cm (Figure 23).

3.6 Sensitivity analyses

Sensitivity analyses explore the implications of some of the base-case assumptions. The results and descriptions of these analyses are summarized in Table 17.

3.6.1 Model structure

Table 14 shows the results for a number of models which used different combinations of the numbers of fleets and surveys. Estimates of 2005 spawning stock status (2005 depletion) were insensitive to these changes to the model structure, with all models estimating a depletion in 2005 of either 71% or 72% (Table 14).

3.6.2 Selectivity

Analyses which assumed that the slope survey selectivity was asymptotic produced smaller estimates of population abundance (Table 14). This is unsurprising, because asymptotic selectivity implies that a larger proportion of the population is available to the survey than when selectivity is allowed to be dome-shaped. These analyses were also somewhat more optimistic about 2005 stock status (Table 14). Models assuming asymptotic selectivity in one or both of the fishery and the slope surveys provided markedly poorer fits to the length composition data (Table 14).

3.6.3 Discard scenarios

The results of analyses which considered discard scenarios 2, 3, and 4 are shown in Table 17. These analyses provided better fits to the commercial length composition data than did the base-case model, and the fits to the mean body weight data also improved. As discard scenario #2 used the same data as the base-case model, these two models are directly comparable. Discard scenario #2 actually provided a poorer fit to the discard data than the base-case, as the model substantially over-estimated the observed 1986 discard rate. However the contribution of the fit to these data must be weighed against the other sources of information, and the improvement in fit obtained to the length compositions prior to 1988 probably means that the importance of the single 1986 discard data point was reduced. The penalized estimates of q for the three alternative discard scenarios were less than that for the base-case model, resulting in slightly more optimistic estimates of 2005 stock status than the base-case model.

Table 18 lists the time-series of estimated total catch for the four discard scenarios. The landings which are inflated substantially under the discard scenarios are primarily those prior to 1988, when catches were small. As a result, predictions of total and spawning biomass differ only slightly from the base-case model. Interestingly, despite the increased catches, the model results when the value of q for the slope survey was fixed at 1 are very similar to those for the base-case scenario.

3.6.4 Recruitment

The analyses which increased the amount of recruitment variability (σ_R) resulted in more optimistic predictions of stock status and a larger estimated spawning biomass (Table 17). A plot of the recruitment residuals for the run in which σ_R = 1.0 (Figure 18, right panel) reveals some runs of negative residuals, which are occasionally offset by high spikes of recruitment. These high recruitments are, however, not evident in the length composition data. The model predictions do change with changes in the length of the estimated recruitment time series (Table 17). However the magnitude of this change is small. Models that only estimate a few recruitments (or none) are more optimistic about 2005 depletion. When recruitment is estimated from the start of the time series (model #11, Table 17), initial population size is increased relative to the base-case model, and the model predicts a 2005 depletion of 74%. These estimates presumably reduce the proportion of larger / older fish in the population towards the end of the time series, to match the proportions observed in the length data. However, Figure 9 shows that there is relatively little benefit to the fit to the length composition data when the number of recruitment residuals estimated is increased.

3.6.5 Slope survey catchability

Models that assumed different values for the slope survey catchability coefficient, q, led to markedly different results from those for the base-case model (Table 17). The MPD estimate for q (with no penalty) is 2.55, which is high, and not very likely given the survey coverage and camera sled observations that suggest, if anything, that the value for q is less than 1. This high estimate of q predicts a smaller abundance than the base-case model, and a 2005 depletion of 56%. The steep decline in abundance enables the model to mimic the decline in the mean length of the catch (Figure 5). The difficulty associated with obtaining a reasonable estimate for q is due to: a) the slope survey being the only index of abundance used, but (given the CVs) there being no apparent or contrasting trends in the biomass estimates, and b) the survey index occurring after the catches have declined from their maximum in the early 1990s.

A likelihood profile was constructed for q to represent its uncertainty and to determine an approximate 95% confidence for q (Figure 24). Figure 24 also shows the

2005 depletion predicted over the profile for *q*. The depletion is not below 0.4 over the range considered for *q*. The value for *q* would need to be extremely high (>15) for 2005 depletion to be less than 0.25. Such values for *q* are well outside the estimated 95% confidence interval. Given the belief that *q* is substantially less than this, and probably close to or less than 1, it is extremely unlikely that the longspine population is presently near or below the Minimum Stock Size Threshold.

Models 18-20 in Table 17 demonstrate the results of using different penalties to constrain the estimation of *q*. The model results are very sensitive to the choice of the penalty, although, even for models 18 and 19, where a more relaxed (CV=30%) penalty was used, model estimates of *q* are not so high as to produce a spawning depletion markedly different from that for the base-case model.

It should be noted that the meanings of catchabilities much greater than 1 are not straightforward, given that a large proportion of the stock biomass is of a size estimated to have a low selectivity. For these individuals, a high *q* would perhaps indicate an 'effective' availability (product of catchability and selectivity) close to 1.

3.6.6 Natural Mortality

The analyses which assumed different values for the rate of natural mortality unsurprisingly led to markedly different estimates of biomass and spawning biomass from the base-case model (Table 17). The estimates for these quantities for model # 22, which assumed $M = 0.015 yr^{-1}$, the value estimated by Pearson and Gunderson (2003), were very large (Table 17), and given the fixed value of $q = 1$, imply a perhaps implausible quantity of fish not available to the fishery and the survey. Models that allowed for a change in the value for *M* for age 12+ fish (model #'s 24-28, Table 17) all led to more optimistic appraisals of 2005 depletion than the base-case model, as the lower mortality rate for older fish meant a larger contribution to the spawning stock biomass. The model fit was improved when the mortality rate for younger fish was $> 0.2 yr^{-1}$.

Interpretation of the estimated values for *M* is challenging given dome-shaped selectivity and a lack of age data. Model estimates in this assessment were lower than that used in previous assessments. The incorporation of the impact of size-dependent predation mortality is an interesting approach and warrants further attention. However, any estimates of mortality (both for young or old fish) will be complicated by the selectivity patterns.

3.6.7 Steepness

The longspine thornyhead population is estimated in the base-case model to be only lightly exploited. It is intuitive that model predictions would only be sensitive to very low values for steepness. When the steepness parameter (*h)* was estimated within the model, the MPD was at the upper bound for this parameter (1, model #29, Table 17). A likelihood profile over steepness (Figure 25) shows very little change in model fit with different values for steepness, and that only the very low values for this parameter (0.2) are outside the estimated 95% confidence interval. Figure 25 also shows that the change in estimated 2005 depletion as steepness is varied from 0.2 to 1 is less than 1%.

3.6.8 logbook CPUE index

The results of analyses which included the logbook CPUE indices for 1978-1987 given in Table 10 (model #'s 30-31, Table 17) did not differ very much from the base-case model, although they were slightly more optimistic regarding 2005 stock status

(73% unfished spawning biomass). These data do not show a clear trend over time, and are for years when catches were low relative to those in the early 1990s.

3.6.9 Alternative landings

A time-series of alternative landings was constructed, which represented possible longspine thornyheads in foreign catches from 1965-1976 (Rogers 2003 only includes shortspine), and longspine thornyhead caught as bycatch in the sablefish trawl fishery from 1900-63. The 1965-76 landings (Table 19) are calculated as 7% (Rogers *et al.* 1997) of the shortspine landings time-series which includes the foreign catches (Owen Hamel, NWFSC, NOAA Fisheries, pers. comm.). The 1900-63 time series of landings (Table 20) was calculated by estimating longspine catch as being 12% (ratio of longspine catch to shortspine catch during 1964-77, Rogers *et al.* 1997) of the estimated shortspine catch during this period (50% of sablefish catch, Owen Hamel, NWFSC, NOAA Fisheries, pers. comm.). A discard rate of 0.7 (Table 6) was then assumed to calculate the landings.

Sensitivity tests which included these additional landings (model #'s 32-33, Table 17) gave results similar to the base-case model. As with the different discard scenarios, these landings occurred prior to the expansion of the fishery, and do not correspond to a large proportion of the total catch over the entire time period.

3.6.10 Slope survey biomass estimates

The results of sensitivity analyses which used different values for the slope survey biomass estimates reflect these different data. Expansion of the catch rates for the northern Conception areas to the area south of Point Conception to produce coastwide biomass estimates (model #'s 34 and 35, Table 17) resulted in biomass estimates markedly larger than those used in the base-case model (Table 21). As the same removals were applied, it is not unsurprising that these analyses estimated higher values for stock biomass, and also predicted 2005 stock status to be more optimistic than the base-case model.

When the Conception area was removed from the calculations of slope survey biomass estimates, length compositions, and landings completely, the 2005 stock status was only slightly more pessimistic than for the base-case model with the value for q fixed at 1 (model # 36, Table 17). When the value for q was reduced to 0.7, model predictions were similar to those for the coastwide expansion (model # 37, Table 17).

Estimates of population size and stock status were sensitive to the values calculated for the slope survey biomass estimates. This is unsurprising, as the slope survey is the only index of abundance used to fit the model.

3.6.11 Length composition weighting

Setting the input sample sizes of the slope survey length compositions to 200 (model # 38, Table 17) had little impact on the model predictions relative to the base-case model. Increasing the sample size for the fishery length composition data to 200 resulted in a less optimistic estimate of 2005 stock status (model # 39, Table 17). The model estimated value for q for this analysis was 2.84, as the increased weight assigned to the length data reduced the importance of the penalty on q. Highly variable recruitments (r.m.s.e. of residuals = 0.9) were also estimated in an attempt to mimic the changes in the length data.

3.6.12 Maturity at length

There was little change in the estimate of population status when the parameter values governing the maturity at length were fixed at the estimates used by Ianelli *et al.* (1994). However, estimates of spawning biomass declined slightly (model #40, Table 17). This is because the alternative maturity ogive has a higher length at 50% maturity than that used in the base-case model (Table 1, Figure 2), resulting in a smaller proportion of the total population being composed of mature fish.

3.6.13 Historical analysis

The base-case estimates are more optimistic in terms of stock status than the previous assessment. The two longspine models chosen for consideration in Rogers *et al.* (1997) estimated spawning biomass in 1996 to be 55% and 63% of that in 1964. Estimates of unfished biomass were also higher, with 1964 total biomass estimated at 88,161 and 104,500 mt. These estimates are substantially lower than the base-case estimate of B_0 (228,275 mt) presented here. Part of this can be attributed to the difference in the areas considered by the two assessments. The previous assessment did not include the Conception INPFC area. Also, the previous assessment assumed that the selectivity of the slope survey was asymptotic rather than dome-shaped. Sensitivity analyses that assumed asymptotic selectivity for the slope survey predicted unfished population estimates which were lower than in the base case, but still much higher than in the previous assessment (Table 14).

3.6.14 Uncertainty appraisal

The value assumed for catchability of the slope survey was by far the most important source of uncertainty in the analyses presented above. This is consistent with previous assessments for this stock and indeed other DTS species. Model results were also very sensitive to the value(s) assumed for *M*, the rate of natural mortality. The amount of recruitment variability assumed in the assessment model also affected the model results significantly. The sensitivity of the MPD estimates to the length of the estimated recruitment time series would be expected to be lessened when the unobserved process errors for which there are no information (early recruitments) are integrated over within, say, a Bayesian analysis.

Uncertainty regarding the values for *q* and *M* could be incorporated into a Bayesian framework. However, the assessment results and sensitivity tests (Tables 14 and 17) suggest that very informative priors would probably be required for the algorithm implemented in ADMB to converge in an adequate timeframe. Estimation of these parameters when calculating the MPD estimates, as in the base case model (with a penalized likelihood term for *q*) enabled uncertainty in the values for these parameters to be accommodated in the variance estimates produced for derived model quantities such as spawning biomass. The large central 95% envelope surrounding the point estimate for the time series of spawning biomass in Figure 20 reflects the implications of accounting for uncertainty in these two key parameters.

The uncertainty regarding the value for *q* reflects considerable uncertainty in the use of the slope survey biomass index data. The uncertainty in extrapolating estimated densities of longspine thornyhead north of Point Conception to the area south of this point is noted, and is reflected in the differences among biomass estimates for the Conception INPFC area depending on the area used for the expansion (Tables 11 and 21). The selectivity of both the survey and the fishery are also uncertain. Evidence would suggest that selectivity is probably dome-shaped (Lauth *et al.* 2004a). However the extent to which this is so depends on a number of factors, including the possible persistence of biomass at depths greater than that surveyed or fished. The meaning of estimated catchabilities greater than one for a trawl survey on the slope is also unclear, particularly with respect to dome-shaped selectivity.

4. REFERENCE POINTS

The Pacific Fishery Management Council's current target harvest rate for longspine thornyhead is $F_{50\%}$, which corresponded to an F of 5.5% for the base-case model. The Council's current target biomass level for exploited groundfish stocks is $SB_{40\%}$, i.e., a spawning biomass 40% of that expected in the absence of fishing. The reference point at which groundfish stocks are defined to be overfished is currently $SB_{25\%}$, i.e., a spawning biomass 25% of that expected in the absence of fishing. Estimated values for $SB_{40\%}$ and $SB_{25\%}$ for longspine thornyhead are 42,063 mt and 26,289 mt respectively. West coast longspine thornyhead are estimated to be well above the management target (Figure 21), and the current fishing mortality rate is substantially lower than the F_{MSY} proxy of $F_{50\%}$ (Table 15). Figure 26 shows the management performance relative to the target for the base case model. Fishing mortality rates were estimated to be higher than $F_{50\%}$ in the 1990s during the expansion of the fishery, but have since declined to well below this (Figure 26, Table 15).

5. HARVEST PROJECTIONS AND DECISION TABLE ANALYSIS

Projections and decision tables are used to assess the implications of alternative management control rules for a given set of possible states of nature. The forecast module of Synthesis 2 was used to conduct 12-year projections to 2016 under two separate harvest regimes for three alternative states of nature, the base-case model, and two alternative bracketing hypotheses representing the sensitivity to the key areas of uncertainty associated with the assessment, the values for *M* and *q*.

Alternative values for *M* and *q* were chosen from the 10^{th} and 90^{th} percentile masses based on the ASE variance estimates for these parameters. These values were 0.05 and 0.07, and 0.79 and 1.34, for *M* and *q* respectively. Model runs using different combinations of these values were then conducted, with the two combinations producing the most optimistic and pessimistic results in terms of 2005 depletion being chosen as the alternative states of nature for the decision table. Table 23 gives the results for these analyses, with the combination q=1.34 and M=0.07 being deemed the 'worst' case scenario, and q=0.79 and M=0.05 selected as the 'best' case.

The alternative values for *M* and *q* evaluated do not produce results greatly different from the base case model, with 2005 spawning depletion estimated as 64% and 74% for the worst and best case scenarios respectively (Table 23). Indeed, results of sensitivity tests might indicate that these values do not encompass the full range of uncertainty associated with these parameters. Asymptotic standard errors are only approximations to a possible posterior distribution, and should be treated with scepticism. However, basing the designation of alternative states of nature on an objective criterion such as that chosen does have merit over the selection of models based purely on a desire to see contrast in projection results.

The three states of nature were projected to 2016 under two harvest regimes: a) the average catches over recent years (2000-2004), and b) the catches expected from the base-case model when projected into the future using the F_{MSY} proxy of $F_{50\%}$. For the base-case $F_{50\%}$ regime, the catches for 2005 and 2006 were fixed to the current ABC for both the northern Conception and All but Conception areas (2,850 mt). As the base-case model estimates the stock to be well above the management target, no adjustment using the 40:10 rule was necessary. The high catches associated with a projection of the 'best' case scenario under a $F_{50\%}$ control rule were not chosen for the projections because the actual recent catches are much lower than those expected under the base-case model and a $F_{50\%}$ harvest rate, and even these catches would not likely be achieved due to current management constraints on other DTS species.

The results of the projections are given in Table 24. They show that the stock is estimated to continue to decline under both harvest regimes, with a 2016 depletion of 64% that of the unfished spawning biomass for the base-case model when catches remain at their current levels. However, despite the decline, the projections all estimate that the stock will be above the target level, with a 2016 depletion of 0.47 for the 'worst' case scenario under the catches expected from the base-case $F_{50\%}$ regime. It should be noted that projections under the base-case $F_{50\%}$ assume annual catches that are twice the size of the current estimated catch (Table 24, Table 15).

6. RESEARCH NEEDS

1. Abundance indices: A more thorough examination of the slope survey is required to better determine the catchability coefficient (*q*) and selectivity of the slope surveys, to help resolve uncertainty for these parameters. More extensive estimates of thornyhead density and habitat associations, perhaps from remote camera observations (*e.g.* Lauth *et al.* 2004b) would likely improve knowledge regarding slope survey parameters, and also enable more appropriate area expansions when developing biomass estimates for the species.
2. Geographic distribution: Additional surveys in the area south of Point Conception are required to verify apparent differences in longspine thornyhead densities within the Conception INPFC area.
3. Age data: Reducing the uncertainty associated with estimates of longevity, and improved confidence in ageing data would reduce the uncertainty associated with the value for the rate of natural mortality. An increased understanding regarding growth of longspine thornyheads would help determine to what extent temperature and/or food availability may complicate growth estimates from otolith annuli.
4. Expanded discard data: Length compositions of discards would provide more information on recent year-class strength, improving the model estimates of recruitment and variation in retention.
5. Age-specific mortality rate: The implications of age or size-specific natural mortality rates should be investigated further, as food habits data suggest that this occurs. Development of the relevant sensitivity tests presented here could also be complemented by inclusion of time series of predator abundance as environmental forcing factors, or perhaps by the adoption of a multi-species modelling approach for the relevant components of the deepwater complex.
6. Spatial modelling: A modelling approach which was more spatially-explicit would enable the inclusion of survey data from years when coverage was not coast-wide, and would also enable investigation into the implications of spatial structure within the longspine thornyhead population. Length composition data do indicate an increased number of smaller fish in northern areas.

7. Depth distribution: Longspine thornyhead are found in abundance at the deepest extent of the current slope survey. There is a need to understand the extent of the biomass currently unavailable to both the surveys and fishery due to depth (using trawls, towed cameras, or other means).

7. RESPONSES TO STAR PANEL REQUESTS

1. Investigate the implications of having two natural mortality rates, blocked in the region above and below 15 or 20 cm.

Rationale: The *M* estimated by Pearson and Gunderson (2003, 0.015 yr^{-1}), and the dome-shaped selectivity curve, could reflect lower mortality rates for mature adults relative to juveniles. Food habits data also seem to support this (Laidig *et al.* 1997, Buckley *et al.* 1999), with high predation on longspines up to 15-20 cm by both sablefish and shortspine thornyheads.

Fish aged 12 and older were assigned a separate value for *M*, as detailed in the sensitivity analyses. A number of model runs were conducted, using a range of fixed values for the two *M*'s, or by estimating one or both of the parameters. Table 17 summarises the more important of these analyses. Models with two mortality parameters resulted in slightly improved model fits to the length composition data (Table 17). While an interesting approach, and one that deserves additional consideration outside the assessment process, the lack of age data to support this approach, coupled with very large (unrealistic) biomass levels when estimating *q*, were arguments for not considering these analyses for the base-case model.

2. Evaluate the implications of differences in slope survey catch rates for the Conception area north and south of Point Conception.

Rationale: An evaluation of the NWFSC survey data (Owen Hamel, pers. commn.) suggested that catch rates are higher in the northern part of the Conception area.

The models in the initial assessment draft were fitted to the results of an analysis of the slope survey which expanded catch rate data for the Conception INPFC area to the entire area, including that south of Point Conception (biomass estimates shown in Table 21). As catch rates appear to be lower south of this feature, the GLMM analysis was repeated by Tom Helser (NWFSC, NOAA Fisheries) for both the combined and separate survey approaches for longspine thornyheads to only include the area north of Point Conception when calculating the biomass estimates (revised biomass estimates shown in Table 11). Slope survey length frequency composition data were also re-evaluated to be consistent with the new estimates.

The results of model runs which used the revised biomass estimates form part of the base-case model in this assessment report. Analyses using these data provided lower estimates of spawning stock biomass, and a slightly less optimistic prediction regarding stock status than those model runs that used the original estimates. The model also seemed unable to fit the increasing abundance trend suggested by the revised survey data. Table 17 details the results of sensitivity tests which were fitted to the coastwide biomass estimates.

3. Runs with a prior of 1 on q with a 30% CV. Try this with and without Conception. If feasible, profile across q both with and without the Conception data.

Rationale: With the original biomass estimates, the values estimated for *q* were close to 6, which is considered unrealistic for the species/gear combination. Model estimates for other slope species, and empirical estimates (camera-sled survey and trawl survey comparison, Lauth *et al.* 2004a) suggest that *q* is likely to be close to or less than 1. A penalty or 'prior' on *q* was deemed appropriate. The request to do this with and without the Conception area was made based on the slope survey biomass estimate shortcomings noted in request #2.

The results of these analyses showed that the penalty on *q* did indeed restrict the value of *q*. However estimates were still appreciably higher than 1. These analyses were superceded during the STAR Panel meeting by other model runs from request #5 (see below) using the revised biomass estimates, and are not presented in this assessment report.

4. Look at the early slope survey length composition data, to evaluate whether there is contrast between this and more recent slope survey data.

Rationale- the lack of contrast in the recent survey length frequency data could reflect the fact that these data were collected after the major period of fishing. As the complications of markets, gear and depth of fishing may mask any changes in length composition from fisheries data, evaluation of early slope survey data may be useful in determining whether there were changes in the size structure of the population.

Survey data from 1988-1996 (1992 and 1996 AFSC "super-years") are not directly comparable to the 1997-2004 data, due to differences in spatial coverage. This makes comparison of length composition information difficult as it is not possible to determine the proper weightings for the relevant areas. However, visual inspection of these earlier data did not indicate any differences in size distributions over time.

5. To evaluate a reasonable approach for estimating *q*, runs were requested using an informative prior on *q* for 0.5 and 0.7 (30% CV). Estimate *M* with no constraints, or fix *M* at 0.07 if a lack of convergence occurs.

Rationale: Constrained estimation of *q* using a penalty was deemed appropriate by the STAR Panel. The expectations of 0.5 and 0.7 reflect the fact that the revised slope survey biomass estimates are now known likely to be negatively biased.

Penalizing *q* with the revised biomass estimates and a reduced expectation (0.5 & 0.7 rather than 1) resulted in lower estimates for *q* than in previous analyses. A penalty with expected value 0.7 and a CV 20% resulted in an estimate of *q* of 1.03. The same expectation, but with a less restrictive penalty (CV of 30%) led to an estimate of *q* of 1.5. Tables 14 and 17 summarise the results of these and additional analyses, the former of which being chosen as the base-case. It was noted that the estimates of *M* were consistently lower than those used in previous assessments.

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Table 1 : Values available and sources of parameters governing weight at length, mean length at age, and maturity at length.

Biological parameter	Source Jacobson (1991)	Ianelli et al. (1994)	Kline (1996)	Pearson & Gunderson (2003)	This assessment
Length-weight relationship, $w=al^b$					
a	4.30E-06				
b	3.352				
Von Bertalanffy growth curve					
L_∞ (cm)	33.86		30.06		31.2
K	0.0585		0.072		0.064
t_0	-0.38		-1.9		-2.02
	(N=192)		(N=478)		(N=815)
Maturity at length					
L_{50} (cm)	18.8	22.1		17.8	
slope	-0.593	-0.766		-1.79	
	(N=120)	(N=3738)		(N=239)	

Table 2 : History of Pacific Fishery Management Council actions for longspine thornyheads.

Date	Management Action
01-Jan-89	Defined the Deep Water Complex (DWC) to include sablefish, dover sole, arrowtooth flounder (ATF), and thornyheads (TTH).
26-Apr-89	Weekly trip limit on DWC of only 1 landing above 4,000 lbs (1.8 mt), not to exceed 30,000 lbs (13.6 mt).
10-Oct-89	Removed overall trawl poundage and trip frequency limits for DWC.
03-Oct-90	15,000 lb (6.8 mt) trip limit on DWC, with only 1 landing per week above 1,000 lbs (0.55 mt). Biweekly and twice weekly landing options.
01-Jan-91	Coast wide weekly limit for TTH set at 7,500 lbs (3.4 mt). Only 1 landing of DWC per week above 4,000 lbs (1.8 mt). Biweekly and twice weekly options.
31-Jul-91	Increased weekly trip limit for TTH to 12,500 lbs (5.7 mt).
01-Jan-92	Established a cumulative landing limit per specified 2-week period of 25,000 lbs (11.4 mt) TTH.
09-May-92	Minimum codend mesh size for roller gear north of Point Arena, CA increased from 3" to 4.5". No double-walled codends.
29-Jul-92	Reduced the cumulative 2-week landing limit for TTH from 25,000 lbs to 20,000 lbs (9.1 mt).
07-Oct-92	Reduced the cumulative 2-week landing limit for TTH to 15,000 lbs (6.8 mt).
01-Jan-93	A 2-week cumulative limit for TTH set at 20,000 lbs (9.1 mt).
21-Apr-93	Reduced the TTH limit to 35,000 lbs (15.9 mt) per 4-week period.
01-Jan-94	Reduced the TTH limit to 30,000 lbs (13.6 mt) per month.
01-Jul-94	Reduced the TTH limit to 8,000 lbs (3.6 mt) per 4-weeks.
01-Dec-94	Reduced the TTH limit to 1,500 lbs (0.7 mt) per 4-weeks north of 36°N latitude.
01-Jan-95	Monthly cumulative limit for TTH set at 20,000 lbs (9.1 mt), of which no more than 4,000 lbs (1.8 mt) may be shortspine.
01-Apr-95	Reduced the TTH limit to 15,000 lbs (6.8 mt), with no more than 3,000 lbs (1.4 mt) shortspine.
01-Sep-95	Reduced the TTH limit to 8,000 lbs (3.6 mt), with no more than 1,500 lbs (0.7 mt) shortspine.
08-Sep-95	Minimum mesh now applies throughout the net, mod. chafing gear requirements.
30-Nov-95	Prohibited further landings of TTH.
01-Jan-96	Two-month cumulative limit for TTH set at 20,000 lbs (9.1 mt), of which no more than 4,000 lbs (1.8 mt) may be shortspine. Open access TTH daily limit set at 50 lbs (23 kg) Coast wide with one landing per vessel per day.
03-May-96	Prohibited open access TTH landings north of Point Conception.
01-May-97	Two-month cumulative limit for TTH set at 15,000 lbs (6.8 mt), of which no more than 3,000 lbs (1.4 mt) may be shortspine.
Sep-97	Monthly cumulative limit for TTH set at 7,500 lbs (3.4 mt), of which no more than 1,500 lbs (0.7 mt) may be shortspine.
Jan-98	Two-month cumulative limit for longspine set at 10,000 lbs (4.5 mt).
May-98	Two-month cumulative limit for longspine set at 12,000 lbs (5.5 mt).
Sep-98	Monthly cumulative limit for longspine set at 6,000 lbs (2.7 mt).
Oct-98	Monthly cumulative limit for longspine set at 7,500 lbs (3.4 mt).
Nov-98	Two-month cumulative limit for longspine for November and December set at 15,000 lbs (6.8 mt) in addition to monthly limit of 7,500 lbs (3.4 mt).
Jan-99	Three-month cumulative limit for longspine set at 12,000 lbs (5.5 mt).
Apr-99	Two-month cumulative limit for longspine set at 8,000 lbs (3.6 mt).
Oct-99	Monthly cumulative limit for longspine set at 4,000 lbs (1.8 mt).
Jan-00	Non-trawl open access fishery - closed North of Point Conception, 50 lb/day (23 kg), no more than 1,000 lbs (0.45 mt)/2 months both species South of Point Conception.
Jan-00	Two-month cumulative limit for longspine set at 12,000 lbs (5.5 mt).
May-00	Two-month cumulative limit for longspine set at 4,000 lbs (1.8 mt).
Nov-00	Two-month cumulative limit for longspine set at 6,000 lbs (2.7 mt).
Jan-03	Two-month cumulative limit for longspine North of 40°10' set at 14,000 lbs (6.4 mt) (large footrope)
Jan-03	Two-month cumulative limit for longspine North of 40°10' set at 5,000 lbs (0.9 mt) (small footrope)
Jan-03	Two-month cumulative limit for longspine South of 40°10' set at 16,000 lbs (7.3 mt)
Aug-03	Two-month cumulative limit for longspine North of 40°10' set at 11,500 lbs (5.2 mt)
Aug-03	Two-month cumulative limit for longspine North of 40°10' set at 11,500 lbs (5.2 mt)
Nov-03	Two-month cumulative limit for longspine North of 40°10' set at 2,000 lbs (0.9 mt) (small footrope)
Nov-03	Two-month cumulative limit for longspine North of 40°10' set at 4,500 lbs (2.05 mt)
Nov-03	Two-month cumulative limit for longspine North of 40°10' set at 4,500 lbs (2.05 mt) (large footrope)
Jan-04	Two-month cumulative limit for longspine North of 40°10' set at 10,000 lbs (4.5 mt)
Jan-04	Two-month cumulative limit for longspine South of 40°10' set at 10,000 lbs (4.5 mt)
May-04	Two-month cumulative limit for longspine North of 40°10' set at 18,000 lbs (8.2 mt) (large footrope) and 1,000 lbs (0.45 mt) (small footrope)
May-04	Two-month cumulative limit for longspine South of 40°10' set at 18,000 lbs (8.2 mt)
Nov-04	non-trawl open access fishery - closed North of Point Conception, 50 lb/day (23 kg), no more than 1,000 lbs/2 months South of Point Conception.
Jan-05	non-trawl open access fishery - closed North of Point Conception, 50 lb/day (23 kg), no more than 1,000 lbs/2 months South of Point Conception.
Jan-05	Two-month cumulative limit for longspine North of 40°10' set at 18,000 lbs (8.2 mt) (large footrope) and 1,000 lbs (0.45 mt) (small footrope)
Jan-05	Two-month cumulative limit for longspine South of 40°10' set at 10,000 lbs (4.5 mt)

Table 3 : Management performance history for west coast longspine thornyhead. * indicates Harvest Guideline (HG) rather than OY.

Species	Year	Area	ABC (mt)	OY (mt)
Both	1991	Columbia	3,200	
Both	1991	Eureka	1,300	
Both	1991	Monterey	1,400	
Longspine	1992-1994	Columbia, Eureka, Monterey	10,100	
Longspine	1995-1997	North of Pt. Conception	7,000	6000*
Longspine	1998-2000	All but Conception	4,102	4,102
Longspine	1998-2000	Conception north of 34.27'	429	429
Longspine	2001-2005	All but Conception	2,461	2,461
Longspine	2001-2005	Conception north of 34.27'	390	195

Table 4 : Total landings (mt) of longspine thornyheads by INPFC area (where available) for the period 1964-2004.

Year	Vancouver	Columbia	North	Eureka	Monterey	Conception	South	Total
1964	-	-	0	-	-	-	13	13
1965	-	-	0	-	-	-	30	30
1966	-	-	0	-	-	-	21	21
1967	-	-	0	-	-	-	10	10
1968	-	-	0	-	-	-	10	10
1969	-	-	0	-	-	-	29	29
1970	-	-	0	-	-	-	42	42
1971	-	-	0	-	-	-	44	44
1972	-	-	0	-	-	-	82	82
1973	-	-	0	-	-	-	93	93
1974	-	-	0	-	-	-	77	77
1975	-	-	0	-	-	-	99	99
1976	-	-	0	-	-	-	54	54
1977	-	-	0	-	-	-	102	102
1978	-	-	0	-	-	-	188	188
1979	-	-	0	-	-	-	263	263
1980	-	-	0	-	-	-	357	357
1981	0	0	1	105	5	0	110	111
1982	0	29	29	209	173	1	383	412
1983	4	75	79	155	60	2	217	296
1984	5	73	78	182	109	1	292	370
1985	11	151	163	393	172	1	566	729
1986	11	102	112	378	206	38	621	733
1987	2	81	83	666	242	207	1,116	1,199
1988	11	86	97	2,436	225	1	2,663	2,760
1989	25	620	644	2,076	25	438	2,538	3,182
1990	37	1,782	1,820	3,079	138	898	4,117	5,937
1991	37	954	991	1,403	244	341	1,988	2,979
1992	236	1,963	2,199	2,129	633	536	3,298	5,497
1993	344	2,183	2,527	1,713	610	523	2,847	5,374
1994	423	1,752	2,177	1,555	747	131	2,437	4,614
1995	732	1,590	2,323	1,765	1,068	437	3,271	5,594
1996	419	1,525	1,944	1,567	1,006	386	2,960	4,904
1997	406	1,114	1,520	1,319	887	286	2,493	4,013
1998	196	630	826	804	438	198	1,440	2,266
1999	106	500	606	627	448	131	1,206	1,812
2000	65	514	590	514	307	93	933	1,523
2001	82	396	479	409	258	70	739	1,218
2002	124	474	598	587	622	133	1,343	1,941
2003	104	401	505	589	354	141	1,083	1,588
2004	27	116	145	210	293	119	631	776

Table 5 : Discard rate data for longspine thornyheads. 1986 data are from a 1985-1987 observer program (Rogers 1994), 1990 data from an observer study during 1989-1991 (Hankin 1991), 1995-1999 data are from Helser et al. (2002)'s analysis of the EDCP data, and 2000-2003 data are from the WCGOP (Hastie pers. comm.).

Year	Vancouver	Columbia	North	Eureka	Monterey	Conception	South	Coastwide
1986			0.28					
1990				0.13			0.13	
1995								0.10
1996								0.12
1997								0.13
1998								0.17
1999								0.20
2000			0.20	0.17	0.13		0.15	0.17
2001			0.20	0.16	0.13		0.15	0.16
2002			0.16	0.17	0.15		0.16	0.16
2003			0.23	0.16	0.09		0.13	0.16

Table 6 : Discard time series for use in discard scenarios #3 (A), and #4 (B). Also shown are the minimum acceptable market sizes used in the model to restrict the retention curve parameters in discard scenario #2. (modified from Rogers *et al.* (1997), Ianelli *et al.* (1994), and Rogers *et al.* (1998).

Year	A	B	size (cm)
1964	0.7	0.7	30
1965	0.7	0.7	30
1966	0.7	0.7	30
1967	0.7	0.7	30
1968	0.7	0.7	30
1969	0.7	0.7	30
1970	0.7	0.7	30
1971	0.7	0.7	30
1972	0.7	0.7	30
1973	0.7	0.7	30
1974	0.7	0.7	30
1975	0.7	0.7	30
1976	0.7	0.7	30
1977	0.6	0.7	30
1978	0.5	0.7	25
1979	0.4	0.7	25
1980	0.3	0.7	25
1981	0.3	0.7	25
1982	0.3	0.7	25
1983	0.3	0.7	25
1984	0.3	0.7	25
1985	0.3	0.7	25
1986	0.28	0.7	25
1987	0.2	0.7	25
1988	0.1	0.08	
1989	0.1	0.08	
1990	0.13	0.08	
1991	0.1	0.08	
1992	0.1	0.08	
1993	0.1	0.08	
1994	0.05	0.08	

Table 7 : Average body weight data (kg). 2002-2003 data are from the West Coast Groundfish Observer Program (Hastie pers. comm.), 1986 and 1989 data are based on the mean lengths of discard reported by Rogers *et al.* (1997), and 1978-1980 data are based on fishery mean lengths (Jacobson 1991).

Year	Vancouver	Columbia	North	Eureka	Monterey	Conception	South	Coast
discarded								
1986			0.100					0.100
1989			0.100					0.100
2002			0.063	0.077	0.076		0.076	0.072
2003			0.066	0.074	0.068		0.071	0.069
retained								
1978				0.330			0.330	0.330
1979				0.320			0.320	0.320
1980				0.300			0.300	0.300
2002			0.172	0.181	0.210		0.205	0.194
2003			0.186	0.145	0.208		0.169	0.174

Table 8 : Coast-wide length compositions (cm length bins) of the commercial landings. The '#trips' column refers to the number of sampled trips for that year/fleet/agency combination, whereas the '#fish' column refers to the actual number of fish measured.

Year	Agency	# trips	# fish	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Coastwide																	
1981	CA	2	39	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1982	CA	13	2112	0.005682	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.012311	0.000000	0.000000
1983	CA	44	4829	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1984	CA	46	13808	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000155	0.000000	0.000000
1985	CA	62	29811	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001904	0.000967
1986	CA	30	9076	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003366	0.000000	0.002992	0.000000	0.005013	0.006434	0.002174	0.012389
1986	OR	1	6105	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003112	0.000000	0.000000	0.000000
1987	CA	22	10838	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000034	0.000000	0.000000	0.003135	0.000000	0.022234
1988	CA	3	834	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1989	CA	19	37000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000501	0.001392	0.000427	0.002948	0.011271	0.006338
1990	CA	26	47324	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002232	0.000119	0.000034	0.003021	0.001488	0.005631	0.013058
1990	OR	45	187973	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000103	0.000000	0.000343	0.000333	0.000751	0.000788	0.001282	0.005038
1991	CA	38	63556	0.000047	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000125	0.000008	0.000285	0.000189	0.000900	0.001018
1991	OR	41	92564	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001756	0.000021	0.000513	0.002275	0.002782
1992	CA	41	67925	0.000000	0.000000	0.000000	0.000000	0.000000	0.000152	0.000423	0.000144	0.000410	0.001589	0.005468	0.005852	0.016306	0.008295
1992	OR	47	242912	0.000000	0.000000	0.000000	0.000004	0.000009	0.000175	0.000450	0.000661	0.000291	0.002588	0.008609	0.003003	0.009580	0.014795
1993	CA	41	73461	0.000000	0.000000	0.000000	0.000000	0.000000	0.000123	0.000178	0.000065	0.000117	0.000565	0.013579	0.000864	0.003091	0.006283
1993	OR	11	61931	0.000000	0.000000	0.000000	0.000000	0.000000	0.000384	0.000378	0.000225	0.000179	0.001775	0.002979	0.003047	0.003476	0.011520
1994	CA	61	118940	0.000000	0.000000	0.000000	0.000000	0.000000	0.000035	0.000035	0.001957	0.004754	0.004349	0.020490	0.008047	0.018550	0.014950
1994	OR	1	11325	0.000000	0.000000	0.011302	0.000000	0.035585	0.010508	0.000000	0.022781	0.017042	0.051038	0.033201	0.068344	0.059426	0.103841
1995	CA	83	240561	0.000000	0.000000	0.000000	0.000000	0.000010	0.001688	0.000300	0.000130	0.000958	0.002108	0.000282	0.004678	0.010784	0.007996
1996	CA	75	213321	0.000000	0.000000	0.000000	0.000000	0.000000	0.001695	0.001325	0.000628	0.002951	0.001092	0.003182	0.014425	0.021569	0.026683
1996	OR	12	157114	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001686	0.001122	0.002165	0.003774	0.004141	0.014809
1997	CA	63	183923	0.000000	0.000000	0.000000	0.000000	0.000000	0.000089	0.000123	0.000296	0.000242	0.000166	0.000353	0.002667	0.002678	0.011128
1997	OR	112	57048	0.000000	0.000000	0.000000	0.002443	0.003962	0.005145	0.007843	0.006366	0.013067	0.007574	0.013466	0.008053	0.011944	0.021251
1998	CA	41	143798	0.000000	0.000000	0.000000	0.000000	0.004488	0.000120	0.003581	0.002569	0.004971	0.001295	0.008565	0.011956	0.028270	0.060658
1998	OR	30	13950	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000415	0.005531	0.000512	0.004503	0.000011	0.000097
1999	CA	33	100039	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000042	0.007807	0.003210	0.018143	0.017532	0.005706	0.010676	0.012512
1999	OR	40	18095	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004178	0.000230	0.004700	0.000022	0.016932
2000	CA	41	98138	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000002	0.004921	0.000062	0.000155	0.003779	0.009414	0.009554
2000	OR	33	14415	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000894	0.011144	0.000596	0.001382	0.004425
2001	CA	43	85105	0.000236	0.000000	0.000000	0.000000	0.000004	0.000071	0.000000	0.000142	0.000001	0.005094	0.018309	0.037156	0.032811	0.044131
2001	OR	42	18331	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000037	0.002909	0.004847
2001	WA	3	47266	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000402	0.000365	0.003656
2002	CA	78	166769	0.007829	0.000000	0.000015	0.000053	0.000031	0.000000	0.002501	0.001019	0.001736	0.004570	0.003133	0.007132	0.007561	0.017029
2002	OR	44	19419	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000575	0.000000	0.000014	0.000644	0.002305	0.001794
2002	WA	2	7141	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004733	0.000000	0.024083	0.086307	0.052759	0.041901	0.043181
2003	CA	56	104680	0.006615	0.000000	0.000000	0.000000	0.000000	0.000000	0.000050	0.000000	0.000000	0.000018	0.000310	0.000446	0.000705	0.002382
2003	OR	50	20188	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002054	0.000000	0.001532	0.000000	0.000915	0.003981
2003	WA	11	22807	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005437	0.011883	0.015215	0.018416	0.033500	0.042883	0.035649	0.056082
2004	CA	43	73816	0.000033	0.000000	0.000000	0.000000	0.000000	0.000000	0.005709	0.000000	0.000000	0.000044	0.009819	0.000209	0.008377	0.000863
2004	OR	32	14316	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001883	0.000000	0.003579	0.005644	0.007193	0.013868
2004	WA	3	5464	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.016297	0.064822	0.050173	0.015198	0.061352	0.113165

(Table 8 continued)

19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001412	0.000898	0.000000	0.000000	0.522599	0.000000	0.475090	0.000000	0.000000	0.000000	0.000000
0.011837	0.011364	0.004261	0.033617	0.084754	0.152936	0.150095	0.100852	0.154830	0.116004	0.068655	0.020833	0.023201	0.011837	0.016098	0.000000	0.020833
0.000000	0.005177	0.010768	0.008283	0.056533	0.090081	0.135225	0.226134	0.169600	0.137088	0.079105	0.025264	0.021951	0.008283	0.005177	0.002071	0.019259
0.000026	0.000169	0.023725	0.058220	0.090245	0.158552	0.192698	0.158750	0.115856	0.118789	0.061422	0.008934	0.002119	0.001261	0.001239	0.000000	0.007841
0.015201	0.005234	0.019621	0.051965	0.082332	0.121903	0.160787	0.194277	0.135570	0.109294	0.053382	0.023926	0.011747	0.001538	0.001979	0.000000	0.008373
0.041353	0.017357	0.034510	0.062120	0.132135	0.100223	0.136075	0.189202	0.118393	0.065586	0.039967	0.011784	0.009850	0.001660	0.000000	0.000000	0.007419
0.010975	0.000000	0.025717	0.021949	0.061425	0.080426	0.178215	0.189517	0.152826	0.097133	0.030958	0.092219	0.018509	0.020311	0.016708	0.000000	0.000000
0.000000	0.002749	0.030271	0.107273	0.115310	0.205198	0.191387	0.099462	0.118001	0.065174	0.017843	0.008008	0.013477	0.000146	0.000298	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.157355	0.101244	0.108531	0.174433	0.136619	0.186631	0.067090	0.015858	0.034155	0.000000	0.000000	0.000000	0.018085
0.012538	0.029904	0.059557	0.082124	0.168040	0.144162	0.131763	0.143355	0.106023	0.080783	0.018442	0.000189	0.000200	0.000005	0.000000	0.000000	0.000039
0.040929	0.070263	0.071490	0.096720	0.202460	0.166457	0.152978	0.081036	0.040494	0.040251	0.008906	0.002338	0.000000	0.000097	0.000000	0.000000	0.000000
0.018462	0.028733	0.027592	0.039767	0.020378	0.078076	0.105301	0.221502	0.196782	0.139768	0.052360	0.020892	0.031294	0.010107	0.000077	0.000006	0.000256
0.006509	0.005870	0.067637	0.132498	0.161589	0.117209	0.185690	0.167403	0.086406	0.034867	0.018951	0.009782	0.001314	0.001512	0.000051	0.000000	0.000139
0.008434	0.032977	0.035873	0.096837	0.177799	0.184380	0.109724	0.108461	0.102609	0.070596	0.028628	0.028740	0.006803	0.000788	0.000004	0.000000	0.000000
0.029915	0.044450	0.056733	0.116987	0.150291	0.120489	0.152042	0.120936	0.094803	0.051624	0.018269	0.001557	0.000781	0.000205	0.000016	0.000016	0.002246
0.030425	0.037105	0.078169	0.093392	0.115368	0.152468	0.151605	0.112554	0.043693	0.099135	0.008159	0.019455	0.000838	0.005636	0.000008	0.011822	0.000001
0.016398	0.057281	0.073160	0.106097	0.154927	0.199193	0.088064	0.154742	0.077209	0.023049	0.014932	0.009579	0.000285	0.000003	0.000212	0.000001	0.000000
0.010494	0.007322	0.036950	0.075646	0.105607	0.110059	0.125019	0.139062	0.186145	0.109565	0.055716	0.004048	0.004819	0.003718	0.000000	0.000000	0.000000
0.040395	0.065954	0.076517	0.100855	0.147713	0.118924	0.104038	0.106269	0.095912	0.044707	0.015342	0.007042	0.000775	0.001910	0.000478	0.000002	0.000000
0.125298	0.118587	0.110287	0.088124	0.092715	0.021634	0.013422	0.006976	0.007770	0.000000	0.002119	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
0.028621	0.056461	0.074310	0.099287	0.106378	0.117815	0.158839	0.109965	0.107439	0.058710	0.033434	0.011378	0.005295	0.000076	0.002589	0.000425	0.000044
0.038840	0.050129	0.073054	0.127676	0.106374	0.134359	0.141577	0.114932	0.070986	0.031863	0.019622	0.010287	0.005278	0.001417	0.000000	0.000005	0.000045
0.031721	0.056334	0.068639	0.161814	0.184683	0.141876	0.161064	0.071550	0.057717	0.023326	0.012695	0.000841	0.000014	0.000022	0.000006	0.000000	0.000000
0.011653	0.031661	0.067898	0.098429	0.138604	0.142092	0.162520	0.158986	0.108668	0.031189	0.021396	0.008643	0.000370	0.000047	0.000087	0.000000	0.000017
0.018142	0.040876	0.058259	0.101747	0.111817	0.144500	0.129722	0.088614	0.084316	0.050032	0.031646	0.017060	0.011098	0.002671	0.001023	0.005462	0.001834
0.070571	0.097134	0.117714	0.160220	0.138422	0.117357	0.052992	0.053118	0.035371	0.012918	0.008596	0.004704	0.002214	0.000127	0.001797	0.000027	0.000245
0.018119	0.025868	0.046475	0.084462	0.092730	0.129643	0.153592	0.179017	0.099592	0.097758	0.033210	0.021853	0.002381	0.002007	0.000000	0.000000	0.002227
0.039346	0.073259	0.074280	0.148205	0.165055	0.168333	0.094496	0.092807	0.037664	0.010471	0.008029	0.004686	0.004650	0.003064	0.000026	0.000000	0.000000
0.022420	0.047987	0.038334	0.058782	0.132145	0.142222	0.144477	0.158351	0.103705	0.067673	0.034511	0.015938	0.004061	0.001403	0.000000	0.000000	0.001929
0.022593	0.037518	0.048203	0.084070	0.138211	0.151532	0.196089	0.132601	0.075848	0.049382	0.016558	0.011393	0.002878	0.003766	0.000087	0.000052	0.001331
0.013878	0.031868	0.039430	0.080250	0.109857	0.161042	0.144241	0.134515	0.118165	0.086545	0.042580	0.002931	0.016256	0.000000	0.000001	0.000000	0.000000
0.044497	0.060425	0.090059	0.139104	0.134087	0.173502	0.057975	0.097253	0.040368	0.002834	0.021228	0.000327	0.000359	0.000011	0.000003	0.000003	0.000010
0.002066	0.017321	0.059954	0.076495	0.120544	0.134913	0.159308	0.191892	0.114522	0.076032	0.027862	0.009663	0.001344	0.000038	0.000137	0.000102	0.000013
0.028018	0.181602	0.211344	0.213892	0.168009	0.076042	0.057530	0.035068	0.019227	0.004460	0.000153	0.000000	0.000007	0.000000	0.000067	0.000089	0.000067
0.033640	0.058358	0.089890	0.101454	0.114387	0.151483	0.125482	0.123681	0.080116	0.040901	0.011461	0.005850	0.001776	0.000786	0.004583	0.003474	0.000066
0.008198	0.047560	0.079932	0.108994	0.139582	0.139075	0.129719	0.150820	0.121140	0.051518	0.008775	0.004578	0.004624	0.000070	0.000000	0.000000	0.000084
0.088064	0.125834	0.138623	0.107763	0.059527	0.106269	0.075297	0.033827	0.000000	0.011832	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
0.022455	0.034727	0.070217	0.118012	0.116754	0.212842	0.164712	0.134828	0.078393	0.027421	0.006441	0.002501	0.000169	0.000000	0.000000	0.000000	0.000000
0.006268	0.030786	0.055625	0.083115	0.115239	0.116967	0.167566	0.197448	0.110038	0.070073	0.023821	0.010768	0.001424	0.001214	0.000000	0.001164	0.000001
0.105937	0.086775	0.138165	0.126063	0.130843	0.074279	0.062966	0.028896	0.013593	0.008419	0.003376	0.000921	0.000702	0.000000	0.000000	0.000000	0.000000
0.018200	0.040109	0.077057	0.100703	0.193195	0.161521	0.185971	0.093155	0.065269	0.015101	0.021042	0.002298	0.001316	0.000000	0.000008	0.000000	0.000000
0.033293	0.049152	0.058067	0.110604	0.093426	0.168521	0.137507	0.099526	0.109709	0.063101	0.030760	0.014160	0.000000	0.000000	0.000000	0.000007	0.000000
0.046145	0.076176	0.104924	0.091923	0.098515	0.099802	0.066287	0.042116	0.033693	0.011170	0.000000	0.000000	0.008240	0.000000	0.000000	0.000000	0.000000

Table 9 : length compositions (cm length bins) of the commercial landings, by North / South fleet. The '#trips' column refers to the number of sampled trips for that year/fleet/agency combination, whereas the '#fish' column refers to the actual number of fish measured.

Year	Agency	# trips	# fish	5	6	7	8	9	10	11	12	13	14	15	16	17	18
North																	
1990	OR	39	168983	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000349	0.000338	0.000712	0.000802	0.001206	0.004983
1991	OR	38	91709	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001797	0.000021	0.000525	0.002328	0.002847
1992	OR	41	208886	0.000000	0.000000	0.000000	0.000004	0.000000	0.000158	0.000416	0.000614	0.000215	0.002549	0.008585	0.002847	0.009565	0.014818
1993	OR	8	51427	0.000000	0.000000	0.000000	0.000000	0.000000	0.001475	0.001452	0.000866	0.000687	0.006819	0.011443	0.011703	0.013350	0.039615
1996	OR	10	139540	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001711	0.001138	0.002197	0.003828	0.004113	0.014921
1997	OR	89	47748	0.000000	0.000000	0.000000	0.002618	0.004246	0.005513	0.008405	0.006822	0.014002	0.008117	0.014222	0.008629	0.012240	0.022340
1998	OR	22	10230	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001170	0.000076	0.001444	0.000000	0.000030	0.000273
1999	OR	28	13051	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006694	0.000000	0.005072	0.000036	0.012851
2000	OR	20	9300	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002692	0.000000	0.001795	0.001345	0.013330
2001	OR	25	10804	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000122	0.000258	0.015204
2001	WA	3	47266	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000402	0.000365	0.003656
2002	OR	30	12878	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000025	0.001151	0.000009	0.003206
2002	WA	2	7141	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004733	0.000000	0.024083	0.086307	0.052759	0.041901	0.043181
2003	OR	29	11037	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003672	0.000000	0.000160	0.007580
2003	WA	11	22807	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005437	0.011883	0.015215	0.018416	0.033500	0.042883	0.035649	0.056082
2004	OR	24	10626	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002515	0.000000	0.004780	0.005452	0.008425	0.017532
2004	WA	3	5464	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.016297	0.064822	0.050173	0.015198	0.061352	0.113165
South																	
1981	CA	2	39	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1982	CA	13	2112	0.005682	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.012311	0.000000	0.000000
1983	CA	44	4829	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1984	CA	46	13808	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000155	0.000000	0.000000
1985	CA	62	29811	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001904	0.000967
1986	CA	30	9076	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003366	0.000000	0.002992	0.000000	0.005013	0.006434	0.002174	0.012389
1986	OR	1	6105	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003112	0.000000	0.000000	0.000000
1987	CA	22	10838	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000034	0.000000	0.000000	0.003135	0.000000	0.022234
1988	CA	3	834	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1989	CA	19	37000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000501	0.001392	0.000427	0.002948	0.011271	0.006338
1990	CA	26	47324	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002232	0.000119	0.000034	0.003021	0.001488	0.005631	0.013058
1990	OR	6	18990	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006056	0.000000	0.000000	0.000000	0.003002	0.000000	0.005687	0.008215
1991	CA	38	63556	0.000047	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000125	0.000008	0.000285	0.000189	0.000900	0.001018
1991	OR	3	855	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000020	0.000000	0.000000	0.000000
1992	CA	41	67925	0.000000	0.000000	0.000000	0.000000	0.000000	0.000152	0.000423	0.000144	0.000410	0.001589	0.005468	0.005852	0.016306	0.008295
1992	OR	6	34026	0.000000	0.000000	0.000000	0.000031	0.001373	0.002868	0.005737	0.007919	0.012114	0.008620	0.012419	0.027250	0.011931	0.011285
1993	CA	41	73461	0.000000	0.000000	0.000000	0.000000	0.000000	0.000123	0.000178	0.000065	0.000117	0.000565	0.013579	0.000864	0.003091	0.006283
1993	OR	3	10504	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001629
1994	CA	61	118940	0.000000	0.000000	0.000000	0.000000	0.000000	0.000035	0.000035	0.001957	0.004754	0.004349	0.020490	0.008047	0.018550	0.014950
1994	OR	1	11325	0.000000	0.000000	0.011302	0.000000	0.035585	0.010508	0.000000	0.022781	0.017042	0.051038	0.033201	0.068344	0.059426	0.103841
1995	CA	83	240561	0.000000	0.000000	0.000000	0.000000	0.000010	0.001688	0.000300	0.000130	0.000958	0.002108	0.000282	0.004678	0.010784	0.007996
1996	CA	75	213321	0.000000	0.000000	0.000000	0.000000	0.000000	0.001695	0.001325	0.000628	0.002951	0.001092	0.003182	0.014425	0.021569	0.026683
1996	OR	2	17574	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006068	0.007027
1997	CA	63	183923	0.000000	0.000000	0.000000	0.000000	0.000000	0.000089	0.000123	0.000296	0.000242	0.000166	0.000353	0.002667	0.002678	0.011128
1997	OR	23	9300	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000013	0.000000	0.002922	0.000025	0.007821	0.006053
1998	CA	41	143798	0.000000	0.000000	0.000000	0.000000	0.004488	0.000120	0.003581	0.002569	0.004971	0.001295	0.008565	0.011956	0.028270	0.060658
1998	OR	8	3720	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.008524	0.000000	0.006974	0.000000	0.000000
1999	CA	33	100039	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000042	0.007807	0.003210	0.018143	0.017532	0.005706	0.010676	0.012512
1999	OR	12	5044	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000613	0.004081	0.000000	0.023708
2000	CA	41	98138	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000002	0.004921	0.000062	0.000155	0.003779	0.009414	0.009554
2000	OR	13	5115	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.016682	0.000000	0.001401	0.000000
2001	CA	43	85105	0.000236	0.000000	0.000000	0.000000	0.000004	0.000071	0.000000	0.000142	0.000001	0.005094	0.018309	0.037156	0.032811	0.044131
2001	OR	17	7527	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004050	0.000392
2002	CA	78	166769	0.007829	0.000000	0.000015	0.000053	0.000031	0.000000	0.002501	0.001019	0.001736	0.004570	0.003133	0.007132	0.007561	0.017029
2002	OR	14	6541	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001305	0.000000	0.000000	0.000000	0.005222	0.000000
2003	CA	56	104680	0.006615	0.000000	0.000000	0.000000	0.000000	0.000000	0.000050	0.000000	0.000000	0.000018	0.000310	0.000446	0.000705	0.002382
2003	OR	21	9151	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003525	0.000000	0.000000	0.000000	0.001455	0.001405
2004	CA	43	73816	0.000033	0.000000	0.000000	0.000000	0.000000	0.000000	0.005709	0.000000	0.000000	0.000044	0.009819	0.000209	0.008377	0.000863
2004	OR	8	3690	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006216	0.003522	0.002954

(Table 9 continued)

19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
0.018510	0.028924	0.027600	0.039692	0.019647	0.077377	0.104575	0.222009	0.197647	0.140727	0.052042	0.020757	0.031753	0.010174	0.000078	0.000006	0.000083
0.008630	0.033744	0.036707	0.099089	0.180493	0.187044	0.109506	0.105743	0.102223	0.068806	0.025348	0.028373	0.005966	0.000807	0.000004	0.000000	0.000000
0.030505	0.037233	0.078511	0.093562	0.115750	0.152961	0.151376	0.112400	0.043139	0.099129	0.007945	0.019379	0.000762	0.005672	0.000008	0.011898	0.000001
0.029557	0.028123	0.061562	0.090759	0.102131	0.123286	0.100458	0.097012	0.091865	0.081343	0.060925	0.015108	0.016271	0.014191	0.000000	0.000000	0.000000
0.031648	0.055775	0.068321	0.161497	0.184329	0.142664	0.162196	0.071729	0.057765	0.023168	0.012316	0.000663	0.000014	0.000000	0.000006	0.000000	0.000000
0.018853	0.042710	0.060597	0.104332	0.113737	0.144041	0.131608	0.083784	0.078325	0.046510	0.028657	0.016095	0.011835	0.002849	0.001097	0.005853	0.001966
0.015684	0.028625	0.091801	0.101557	0.124726	0.147817	0.139894	0.119487	0.110138	0.064769	0.039985	0.012371	0.000096	0.000000	0.000000	0.000000	0.000056
0.021425	0.075719	0.044883	0.071857	0.148119	0.141348	0.120351	0.137780	0.092014	0.066082	0.030239	0.015832	0.006507	0.000101	0.000000	0.000000	0.003090
0.025422	0.059438	0.055208	0.104842	0.123539	0.170892	0.087201	0.152836	0.057380	0.094675	0.035712	0.000364	0.013324	0.000000	0.000003	0.000000	0.000000
0.001457	0.005239	0.027559	0.076985	0.129125	0.108393	0.129043	0.249134	0.140590	0.092594	0.018334	0.005824	0.000000	0.000094	0.000004	0.000000	0.000042
0.028018	0.181602	0.211344	0.213892	0.168009	0.076042	0.057530	0.035068	0.019227	0.004460	0.000153	0.000000	0.000007	0.000000	0.000067	0.000089	0.000067
0.009236	0.053937	0.076690	0.121567	0.148260	0.142823	0.113495	0.176750	0.115959	0.024864	0.006537	0.001602	0.003614	0.000125	0.000000	0.000000	0.000150
0.088064	0.125834	0.138623	0.107763	0.059527	0.106269	0.075297	0.033827	0.000000	0.011832	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
0.000168	0.040702	0.092113	0.116322	0.120183	0.093423	0.171575	0.208214	0.088881	0.042290	0.013266	0.001441	0.000000	0.000009	0.000000	0.000000	0.000003
0.105937	0.086775	0.138165	0.126063	0.130843	0.074279	0.062966	0.028896	0.013593	0.008419	0.003376	0.000921	0.000702	0.000000	0.000000	0.000000	0.000000
0.042355	0.062670	0.069716	0.137837	0.110213	0.174095	0.111015	0.078078	0.086650	0.046296	0.024561	0.017802	0.000000	0.000000	0.000000	0.000009	0.000000
0.046145	0.076176	0.104924	0.091923	0.098515	0.099802	0.066287	0.042116	0.033693	0.011170	0.000000	0.000000	0.008240	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001412	0.000898	0.000000	0.000000	0.522599	0.000000	0.475090	0.000000	0.000000	0.000000	0.000000
0.011837	0.011364	0.004261	0.033617	0.084754	0.152936	0.150095	0.100852	0.154830	0.116004	0.068655	0.020833	0.023201	0.011837	0.016098	0.000000	0.020833
0.000000	0.005177	0.010768	0.008283	0.056533	0.090081	0.135225	0.226134	0.169600	0.137088	0.079105	0.025264	0.021951	0.008283	0.005177	0.002071	0.019259
0.000026	0.000169	0.023725	0.058220	0.090245	0.158552	0.192698	0.158750	0.115856	0.118789	0.061422	0.008934	0.002119	0.001261	0.001239	0.000000	0.007841
0.015201	0.005234	0.019621	0.051965	0.082332	0.121903	0.160787	0.194277	0.135570	0.109294	0.053382	0.023926	0.011747	0.001538	0.001979	0.000000	0.008373
0.041353	0.017357	0.034510	0.062120	0.132135	0.100223	0.136075	0.189202	0.118393	0.065586	0.039967	0.011784	0.009850	0.001660	0.000000	0.000000	0.007419
0.010975	0.000000	0.025717	0.021949	0.061425	0.080426	0.178215	0.189517	0.152826	0.097133	0.030958	0.092219	0.018509	0.020311	0.016708	0.000000	0.000000
0.000000	0.002749	0.030271	0.107273	0.115310	0.205198	0.191387	0.099462	0.118001	0.065174	0.017843	0.008008	0.013477	0.000146	0.000298	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.157355	0.101244	0.108531	0.174433	0.136619	0.186631	0.067090	0.015858	0.034155	0.000000	0.000000	0.000000	0.018085
0.012538	0.029904	0.059557	0.082124	0.168040	0.144162	0.131763	0.143355	0.106023	0.080783	0.018442	0.000189	0.000200	0.000005	0.000000	0.000000	0.000039
0.040929	0.070263	0.071490	0.096720	0.202460	0.166457	0.152978	0.081036	0.040494	0.040251	0.008906	0.002338	0.000000	0.000097	0.000000	0.000000	0.000000
0.015692	0.017694	0.027120	0.044128	0.062823	0.118641	0.147393	0.192101	0.146551	0.084097	0.070827	0.028752	0.004687	0.006214	0.000000	0.000000	0.010321
0.006509	0.005870	0.067637	0.132498	0.161589	0.117209	0.185690	0.167403	0.086406	0.034867	0.018951	0.009782	0.001314	0.001512	0.000051	0.000000	0.000139
0.000000	0.000000	0.000000	0.000000	0.061950	0.069828	0.119113	0.225344	0.119167	0.147569	0.169682	0.044519	0.042809	0.000000	0.000000	0.000000	0.000000
0.029915	0.044450	0.056733	0.116987	0.150291	0.120489	0.152042	0.120936	0.094803	0.051624	0.018269	0.001557	0.000781	0.000205	0.000016	0.000016	0.002246
0.018010	0.017308	0.025186	0.067130	0.055988	0.075962	0.187214	0.136515	0.129673	0.100070	0.041378	0.031261	0.012725	0.000000	0.000031	0.000000	0.000000
0.016398	0.057281	0.073160	0.106097	0.154927	0.199193	0.088064	0.154742	0.077209	0.023049	0.014932	0.009579	0.000285	0.000003	0.000212	0.000001	0.000000
0.003783	0.000000	0.028286	0.070326	0.106830	0.105403	0.133665	0.153864	0.219333	0.119500	0.053883	0.000154	0.000788	0.000031	0.000000	0.000000	0.000000
0.040395	0.065954	0.076517	0.100855	0.147713	0.118924	0.104038	0.106269	0.095912	0.044707	0.015342	0.007042	0.000775	0.001910	0.000478	0.000002	0.000000
0.125298	0.118587	0.110287	0.088124	0.092715	0.021634	0.013422	0.006976	0.007770	0.000000	0.002119	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
0.028621	0.056461	0.074310	0.099287	0.106378	0.117815	0.158839	0.109965	0.107439	0.058710	0.033434	0.011378	0.005295	0.000076	0.002589	0.000425	0.000044
0.038840	0.050129	0.073054	0.127676	0.106374	0.134359	0.141577	0.114932	0.070986	0.031863	0.019622	0.010287	0.005278	0.001417	0.000000	0.000005	0.000045
0.036826	0.095216	0.090715	0.183860	0.209284	0.087018	0.082384	0.059122	0.054349	0.034322	0.039010	0.013220	0.000000	0.001579	0.000000	0.000000	0.000000
0.011653	0.031661	0.067898	0.098429	0.138604	0.142092	0.162520	0.158986	0.108668	0.031189	0.021396	0.008643	0.000370	0.000047	0.000087	0.000000	0.000017
0.008214	0.015278	0.025629	0.065662	0.085012	0.150913	0.103413	0.156029	0.167931	0.099183	0.073359	0.030517	0.000823	0.000177	0.000000	0.000000	0.000000
0.070571	0.097134	0.117714	0.160220	0.138422	0.117357	0.052992	0.053118	0.035371	0.012918	0.008596	0.004704	0.002214	0.000127	0.001797	0.000027	0.000245
0.019454	0.024354	0.021604	0.075081	0.075173	0.119670	0.161109	0.211682	0.093805	0.115859	0.029492	0.027056	0.003635	0.003109	0.000000	0.000000	0.003418
0.039346	0.073259	0.074280	0.148205	0.165055	0.168333	0.094496	0.092807	0.037664	0.010471	0.008029	0.004686	0.004650	0.003064	0.000026	0.000000	0.000000
0.024072	0.001943	0.027461	0.037072	0.105623	0.143673	0.184534	0.192506	0.123115	0.070314	0.041604	0.016115	0.000000	0.003565	0.000000	0.000000	0.000000
0.022593	0.037518	0.048203	0.084070	0.138211	0.151532	0.196089	0.132601	0.075848	0.049382	0.016558	0.011393	0.002878	0.003766	0.000087	0.000052	0.001331
0.008142	0.018169	0.031590	0.068031	0.103058	0.156148	0.172583	0.125411	0.148368	0.082505	0.045992	0.004207	0.017713	0.000000	0.000000	0.000000	0.000000
0.044497	0.060425	0.090059	0.139104	0.134087	0.173502	0.057975	0.097253	0.040368	0.002834	0.021228	0.000327	0.000359	0.000011	0.000003	0.000003	0.000010
0.002328	0.022519	0.073891	0.076283	0.116853	0.146323	0.172329	0.167265	0.103307	0.068907	0.031961	0.011315	0.001922	0.000015	0.000194	0.000146	0.000000
0.033640	0.058358	0.089890	0.101454	0.114387	0.151483	0.125482	0.123681	0.080116	0.040901	0.011461	0.005850	0.001776	0.000786	0.004583	0.003474	0.000066
0.006879	0.039454	0.084054	0.093014	0.128553	0.134311	0.150339	0.117861	0.127726	0.085397	0.011619	0.008359	0.005908	0.000000	0.000000	0.000000	0.000000
0.022455	0.034727	0.070217	0.118012	0.116754	0.212842	0.164712	0.134828	0.078393	0.027421	0.006441	0.002501	0.000169	0.000000	0.000000	0.000000	0.000000
0.010635	0.023688	0.029505	0.059343	0.111701	0.133821	0.164697	0.189742	0.125183	0.089962	0.031377	0.017445	0.002444	0.002076	0.000000	0.001997	0.000000
0.018200	0.040109	0.077057	0.100703	0.193195	0.161521	0.185971	0.093155	0.065269	0.015101	0.021042	0.002298	0.001316	0.000000	0.000008	0.000000	0.000000
0.006299	0.008886	0.023369	0.029484	0.043426	0.151921	0.216420	0.163413	0.178395	0.113158	0.049225	0.003312	0.000000	0.000000	0.000000	0.000000	0.000000

Table 10 : Standardized logbook CPUE indices for longspine thornyhead (Brodziak, unpublished manuscript) for 1978-1988. Indices are based on analyses which considered a) tows which caught longspine, and b) tows which caught any of the four DTS species (deepwater complex column). The CV of 0.25 is not a result of the standardization procedure.

Year	longspine effort	dwc effort	CV
1978	0.67	0.63	0.25
1979	1.18	1.05	0.25
1980	1.25	0.99	0.25
1981	1.96	1.57	0.25
1982	1.7	1.67	0.25
1983	1.29	0.95	0.25
1984	1.03	0.83	0.25
1985	1	1	0.25
1986	1.12	0.93	0.25
1987	1.1	0.65	0.25

Table 11 : Biomass estimates (coastwide totals and by INPFC area) for the combined slope survey and separate AFSC and NWFSC FRAM slope surveys as developed by Helser et al. (2005). INPFC area totals are a summation of results over the two depth strata for each area. The data for the 1992 "super-year" did not cover the Conception area, and those for the 1996 "super-year" did not cover the Monterey or Conception INPFC areas.

Year	Total		Vancouver		Columbia		Eureka		Monterey		Conception	
	Median (mt)	CV	Median (mt)	CV	Median (mt)	CV	Median (mt)	CV	Median (mt)	CV	Median (mt)	CV
Combined												
1992	69,250	0.07	16,429	0.15	10,403	0.11	18,869	0.10	23,548	0.15	-	-
1996	40,800	0.07	11,853	0.13	12,023	0.11	16,924	0.11	-	-	-	-
1997	85,246	0.08	11,493	0.21	12,073	0.16	19,728	0.19	24,578	0.15	17,374	0.19
1998	65,271	0.07	10,816	0.19	8,862	0.14	15,230	0.15	17,160	0.12	13,202	0.20
1999	81,313	0.05	12,719	0.12	11,194	0.11	17,844	0.11	23,129	0.10	16,428	0.14
2000	84,171	0.05	13,941	0.13	11,571	0.11	19,652	0.11	21,412	0.10	17,595	0.14
2001	85,424	0.05	12,461	0.12	11,474	0.11	18,674	0.12	24,000	0.10	18,815	0.14
2002	87,139	0.06	12,937	0.16	12,080	0.13	22,460	0.13	23,372	0.11	16,292	0.17
2003	104,273	0.10	16,690	0.13	13,497	0.13	22,345	0.15	24,039	0.17	27,703	0.31
2004	96,814	0.09	11,454	0.23	12,952	0.18	20,845	0.17	32,044	0.18	19,518	0.17
AFSC												
1992	85,297	0.05	20,312	0.12	12,880	0.08	22,550	0.08	29,107	0.11	-	-
1996	48,669	0.05	13,962	0.11	14,326	0.09	20,217	0.09	-	-	-	-
1997	99,258	0.07	13,231	0.19	13,988	0.14	22,407	0.17	28,403	0.12	20,219	0.18
1999	95,401	0.07	14,645	0.15	14,221	0.14	21,672	0.17	24,266	0.12	19,712	0.17
2000	94,582	0.07	14,523	0.15	13,222	0.14	22,301	0.17	26,925	0.11	16,249	0.17
2001	95,246	0.07	11,970	0.15	13,676	0.14	22,262	0.17	28,767	0.11	17,546	0.16
NWFSC												
1998	67,403	0.07	11,226	0.20	9,151	0.14	15,698	0.15	17,798	0.12	13,530	0.19
1999	85,201	0.07	13,096	0.15	11,130	0.13	18,687	0.13	25,386	0.13	16,902	0.21
2000	91,796	0.07	16,040	0.19	12,020	0.13	20,544	0.14	20,652	0.12	22,540	0.19
2001	93,180	0.07	15,510	0.18	11,250	0.14	18,701	0.14	23,737	0.12	23,982	0.19
2002	88,725	0.06	13,319	0.15	12,389	0.13	23,001	0.14	23,571	0.11	16,445	0.16
2003	106,957	0.10	17,460	0.13	13,929	0.12	23,206	0.14	25,225	0.16	27,137	0.34
2004	101,832	0.09	11,980	0.21	14,063	0.17	22,248	0.17	33,348	0.19	20,193	0.17

Table 12 : Length composition data (cm length bins) for the NWFSC FRAM and AFSC slope surveys, based on weighting to the combined slope survey GLMM analysis (Table 11).

Year	# tows	# fish	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NWFSC																
1998	162	23,880	0.000443	0.001493	0.007461	0.018866	0.030567	0.035161	0.038396	0.046507	0.045355	0.046456	0.045373	0.042381	0.048414	0.057484
1999	209	27,121	0.000095	0.002380	0.012105	0.021193	0.022115	0.028747	0.032414	0.040445	0.045103	0.045647	0.047138	0.043325	0.048334	0.053517
2000	196	22,652	0.000291	0.002150	0.006026	0.013823	0.023689	0.023498	0.027852	0.036820	0.046554	0.050380	0.057717	0.052250	0.051279	0.055991
2001	213	24,382	0.000433	0.001288	0.007978	0.014920	0.016741	0.028038	0.025396	0.032058	0.037034	0.046777	0.048742	0.052442	0.052884	0.054980
2002	281	34,054	0.000398	0.002681	0.008461	0.012463	0.018207	0.020574	0.024707	0.028053	0.035795	0.042652	0.051591	0.060005	0.062661	0.061937
2003	200	15,590	0.000133	0.000977	0.005675	0.012240	0.015254	0.019518	0.019996	0.023086	0.028114	0.028593	0.041266	0.047490	0.065468	0.062848
2004	158	11,703	0.000518	0.004926	0.015494	0.025757	0.024491	0.026146	0.024018	0.029135	0.029392	0.036982	0.047253	0.044065	0.054175	0.059060
AFSC																
1997	134		0.000514	0.000589	0.005419	0.012663	0.029094	0.038177	0.043234	0.051071	0.050960	0.056627	0.055809	0.055877	0.061333	0.063013
1999	146		0.000071	0.000135	0.004449	0.013569	0.022932	0.026820	0.037618	0.042457	0.046752	0.047089	0.051636	0.049614	0.051521	0.058621
2000	159		0.000189	0.001150	0.007553	0.009831	0.020916	0.030021	0.037286	0.044469	0.052363	0.048357	0.058231	0.055421	0.060379	0.051953
2001	160		0.000000	0.000140	0.003653	0.016007	0.022028	0.028831	0.036737	0.044166	0.051884	0.049958	0.050300	0.059187	0.051451	0.055152

19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
0.059834	0.059647	0.064216	0.065115	0.066560	0.069682	0.056030	0.044026	0.026831	0.012330	0.008292	0.002259	0.000397	0.000270	0.000039	0.000030	0.000087
0.057340	0.062213	0.064403	0.070241	0.077180	0.071815	0.062115	0.040429	0.028009	0.014110	0.007585	0.001248	0.000433	0.000196	0.000128	0.000000	0.000000
0.063520	0.062732	0.065806	0.070124	0.070818	0.070396	0.056775	0.041082	0.028082	0.012544	0.006594	0.002097	0.000592	0.000403	0.000082	0.000020	0.000015
0.066915	0.066817	0.071826	0.076156	0.072963	0.071662	0.061279	0.041770	0.028638	0.013392	0.005402	0.002511	0.000666	0.000179	0.000017	0.000000	0.000094
0.072391	0.074138	0.075131	0.073803	0.070451	0.069087	0.055890	0.036627	0.025049	0.010582	0.004360	0.001673	0.000366	0.000248	0.000020	0.000000	0.000000
0.068546	0.070545	0.072833	0.071983	0.080892	0.089336	0.066096	0.049263	0.032961	0.014776	0.008517	0.002185	0.001033	0.000171	0.000095	0.000077	0.000032
0.069467	0.069784	0.077390	0.080735	0.069890	0.070444	0.057954	0.037718	0.024329	0.013100	0.005268	0.002001	0.000120	0.000206	0.000049	0.000000	0.000132
0.067693	0.066593	0.074722	0.069415	0.055269	0.048247	0.039109	0.026014	0.016685	0.007681	0.002242	0.001271	0.000487	0.000118	0.000041	0.000033	0.000003
0.059407	0.066246	0.074459	0.073614	0.068878	0.067309	0.054795	0.039621	0.020807	0.012381	0.004910	0.003197	0.000884	0.000155	0.000023	0.000012	0.000020
0.066525	0.069085	0.064136	0.067459	0.065539	0.061165	0.048748	0.036793	0.021671	0.011890	0.005519	0.002179	0.001002	0.000134	0.000037	0.000000	0.000000
0.064308	0.064874	0.064631	0.076856	0.069849	0.063130	0.047572	0.038198	0.021570	0.011689	0.004809	0.002131	0.000634	0.000186	0.000070	0.000000	0.000000

Table 13 : The parameters of the stock assessment model. Parameter values in the 'fixed values' column indicate parameters pre-specified (fixed) to those values. An X in the 'Estimated' column indicates that the parameter was estimated within the model framework. Catchability for the logbook CPUE was only included in the relevant sensitivity analysis for these data. Shaded retention parameters correspond to the alternative discard scenarios. X* indicates that this parameter was estimated in discard scenarios 3 and 4. Slope survey parameters were duplicated for models which used two slope survey biomass series. Asterisks in parameter descriptions indicate that sensitivity tests explored the implications of uncertainty associated with these parameters.

Parameter	Fixed Value	Estimated
Biological parameters		
Age and growth		
maximum age	80	
M , rate of natural mortality (yr^{-1})*		X
mean length at age 3 (cm)	8.6	
mean length at age 40 (cm)	29.1	
CV of length at age 3	0.13	
CV of length at age 40	0.05	
Von Bertalanffy *K*	0.064	
a - length-weight parameter	4.30E-06	
b - length-weight parameter	3.352	
Maturity at length		
length at 50% maturity (cm)*	17.8	
slope of maturity at length ogive*	-1.79	
Stock-recruitment parameters		
R_0 , expected recruitment at virgin spawning biomass		X
h , steepness of stock-recruit relationship*	0.75	
fraction of expected recruitment at equilibrium	1	
σ_R, standard deviation of recruitment residuals*	0.6	
annual recruitment residuals, years 1980-2002*		X
Trawl fishery parameters		
initial exploitation rate at equilibrium*	0	
q , catchability of logbook CPUE		X
selectivity parameters		
length (double logistic)		
length (cm) at highest selectivity	25.5	
selectivity of smallest length bin	0.00001	
inflection of ascending limb (logit space)		X
slope of ascending limb		X
selectivity of largest length bin (logit space)		X
inflection of descending limb (logit space)		X
slope of descending limb		X
width of selectivity peak (cm)		X
age (logistic)		
age at 50% selectivity (yrs)	1.5	
slope of logistic function	40	
retention parameters (logistic)		
length at 50% retention		X
slope of retention curve		X
length at 50% retention 1964-1977	33	X*
length at 50% retention 1978-1987	25	X*
slope of retention curve 1964-1987		X
length at 50% retention 1988-1994		X
slope of retention curve 1988-1995		X
length at 50% retention 1995-2004		X
slope of retention curve 1995-2004		X
Slope survey parameters		
q , catchability of slope survey*		μ=0.7, CV=0.2
selectivity parameters		
length (double logistic)		
length (cm) at highest selectivity		X
selectivity of smallest length bin		X
inflection of ascending limb (logit space)		X
slope of ascending limb		X
selectivity of largest length bin (logit space)		X
inflection of descending limb (logit space)		X
slope of descending limb		X
width of selectivity peak (cm)		X
age (logistic)		
age at 50% selectivity (yrs)	1.5	
slope of logistic function	40	

Table 14 : Summaries of the results, and contributions to the negative log-likelihood function of the various data sources, for different versions of the base-case scenarios which explore the model structure. Not all models are comparable using AIC due to differences in the data and log-likelihood function. Shading in the column 'AIC' indicates which models can be compared to each other using AIC. B_0 and SB_0 are the unfished equilibrium values estimated for total and spawning biomass, respectively. SB_{2005} is the spawning biomass in 2005, and 2005 depletion is SB_{2005} expressed relative to SB_0. 'e' indicates that the relevant parameter was estimated, 'pe' indicates that the parameter was estimated but with a constraining penalty.

	fleet / survey designation	fleet selectivity	survey selectivity	*M*	q	# pars	fishery length comps	discard rates	avg. weights	biomass indices	survey length comps	recruitment	penalties	total nLL	AIC	B_0 (mt)	SB_0 (mt)	SB_{2005} (mt)	2005 depletion
	base-case																		
1	coast-wide fleet, combined slope survey	dome-shaped	dome-shaped	e 0.06	pe 1.03	42	201.44	-30.47	-24.57	-10.96	14.56	-9.74	1.65	141.90	367.8	228,275	105,157	75,049	0.71
2	""	dome-shaped	dome-shaped	0.06	1	40	201.56	-30.44	-24.59	-10.94	14.58	-9.83	-	140.34	360.7	236,391	108,818	78,487	0.72
3	""	dome-shaped	asymptotic	0.06	1	34	198.40	-28.09	-22.11	-11.76	40.29	0.26	-	176.99	422.0	156,266	71,934	53,850	0.75
4	""	asymptotic	dome-shaped	0.06	1	36	242.69	-28.76	-22.32	-12.39	16.13	2.22	-	197.56	467.1	172,723	79,510	63,695	0.80
5	""	asymptotic	asymptotic	0.06	1	30	212.98	-29.02	-23.81	-10.64	35.02	-8.58	-	175.95	411.9	161,898	67,146	47,618	0.71
6	"" (fishery length data as North / South split)	dome-shaped	dome-shaped	0.06	1	40	213.97	-30.40	-24.58	-10.98	14.59	-9.74	-	152.86	385.7	235,540	108,426	78,250	0.72
7	coast-wide fleet, separate slope surveys	dome-shaped	dome-shaped	0.06	1	47	205.31	-30.14	-24.11	-17.00	11.83	-9.99	-	135.91	365.8	226,581	103,481	74,594	0.72
8	""	dome-shaped	asymptotic	0.06	1	35	197.89	-28.53	-20.75	-18.07	26.29	-0.88	-	155.95	381.9	166,199	75,904	58,209	0.77
9	""	asymptotic	dome-shaped	0.06	1	44	226.87	-29.27	-22.81	-17.39	11.73	-5.11	-	164.03	416.1	197,539	90,217	67,968	0.75
10	2 fleets, combined slope survey	dome-shaped	dome-shaped	0.06	1	48	217.15	-55.56	-38.58	-11.12	14.76	-9.49	-	117.16	330.3	236,193	108,727	78,542	0.72
11	""	asymptotic	dome-shaped	0.06	1	40	257.49	-53.49	-36.62	-12.23	15.76	0.85	-	171.77	423.5	182,157	83,853	65,898	0.79

Table 15 : Base-case estimated time-series of derived quantities, the number of recruits, and the exploitation rate.

Year	Total Biomass (mt)	Spawning Biomass (mt)	Spawning Depletion	Recruits	Total Catch (mt)	Fishing Mortality Rate
1964	228,275	105,157	1.00	108,272	15	0.0001
1965	228,260	105,150	1.00	108,271	35	0.0003
1966	228,226	105,134	1.00	108,270	24	0.0002
1967	228,202	105,122	1.00	108,269	12	0.0001
1968	228,192	105,117	1.00	108,268	12	0.0001
1969	228,181	105,111	1.00	108,268	33	0.0003
1970	228,149	105,096	1.00	108,267	48	0.0004
1971	228,103	105,073	1.00	108,265	51	0.0005
1972	228,055	105,050	1.00	108,263	94	0.0009
1973	227,964	105,005	1.00	108,259	107	0.0010
1974	227,862	104,955	1.00	108,254	89	0.0008
1975	227,780	104,914	1.00	108,251	114	0.0011
1976	227,674	104,862	1.00	108,246	62	0.0006
1977	227,621	104,836	1.00	108,244	117	0.0011
1978	227,515	104,784	1.00	108,240	216	0.0020
1979	227,313	104,685	1.00	108,231	303	0.0028
1980	226,996	104,545	0.99	84,200	411	0.0038
1981	226,590	104,355	0.99	98,044	129	0.0012
1982	226,468	104,303	0.99	122,462	474	0.0044
1983	225,992	104,086	0.99	132,625	340	0.0032
1984	225,629	103,937	0.99	113,058	426	0.0040
1985	225,210	103,749	0.99	111,566	839	0.0079
1986	224,411	103,364	0.98	111,968	845	0.0080
1987	223,630	102,975	0.98	104,365	1380	0.0131
1988	222,340	102,315	0.97	94,335	3180	0.0305
1989	219,283	100,767	0.96	86,669	3671	0.0359
1990	215,762	98,971	0.94	87,002	6857	0.0687
1991	209,106	95,667	0.91	97,190	3449	0.0363
1992	205,876	94,063	0.89	115,061	6376	0.0685
1993	199,778	91,142	0.87	124,704	6250	0.0702
1994	193,835	88,360	0.84	99,103	5381	0.0632
1995	188,807	86,052	0.82	68,420	6541	0.0796
1996	182,731	83,222	0.79	82,276	5752	0.0734
1997	177,469	80,768	0.77	67,444	4720	0.0626
1998	173,254	78,789	0.75	55,319	2671	0.0365
1999	171,073	77,767	0.74	52,265	2136	0.0294
2000	169,413	77,012	0.73	66,946	1797	0.0248
2001	168,021	76,466	0.73	59,009	1438	0.0198
2002	166,956	76,164	0.72	88,962	2287	0.0313
2003	164,976	75,518	0.72	87,572	1869	0.0256
2004	163,355	75,079	0.71	87,515	912	0.0125
2005	162,642	75,049	0.71	87,511	-	-

Table 16 : Base-case estimated numbers at age. *Note that age 45 is not the plus group; rather individuals older than 45 are accumulated at age 45 for presentation purposes.

Year	Numbers at age																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1964	108,272	102,001	96,093	90,528	85,285	80,345	75,692	71,308	67,178	63,287	59,622	56,169	52,916	49,851	46,964	44,244	41,681	39,267	36,993	34,850	32,832	30,930	29,139	27,451
1965	108,271	102,001	96,093	90,528	85,284	80,345	75,691	71,307	67,177	63,286	59,620	56,167	52,913	49,848	46,961	44,241	41,678	39,264	36,989	34,847	32,828	30,927	29,135	27,448
1966	108,270	102,000	96,093	90,527	85,283	80,343	75,689	71,305	67,174	63,282	59,616	56,163	52,909	49,843	46,955	44,235	41,671	39,257	36,982	34,839	32,820	30,919	29,128	27,440
1967	108,269	101,999	96,093	90,527	85,283	80,342	75,688	71,304	67,173	63,281	59,614	56,160	52,906	49,841	46,952	44,231	41,668	39,253	36,978	34,834	32,815	30,914	29,122	27,435
1968	108,268	101,998	96,092	90,527	85,284	80,343	75,689	71,304	67,173	63,281	59,614	56,160	52,906	49,840	46,952	44,231	41,667	39,252	36,977	34,833	32,814	30,912	29,121	27,433
1969	108,268	101,998	96,091	90,526	85,284	80,344	75,689	71,304	67,173	63,281	59,615	56,160	52,906	49,840	46,952	44,230	41,667	39,251	36,976	34,832	32,813	30,911	29,119	27,431
1970	108,267	101,997	96,090	90,524	85,282	80,342	75,688	71,303	67,171	63,279	59,612	56,157	52,903	49,836	46,948	44,226	41,662	39,246	36,971	34,827	32,807	30,905	29,113	27,425
1971	108,265	101,996	96,090	90,524	85,280	80,340	75,686	71,301	67,169	63,276	59,608	56,153	52,898	49,831	46,942	44,219	41,655	39,238	36,962	34,818	32,798	30,895	29,103	27,416
1972	108,263	101,994	96,089	90,523	85,279	80,338	75,684	71,299	67,167	63,273	59,605	56,149	52,893	49,826	46,936	44,213	41,648	39,231	36,954	34,810	32,789	30,886	29,094	27,407
1973	108,259	101,992	96,087	90,521	85,277	80,335	75,679	71,293	67,161	63,267	59,597	56,140	52,883	49,815	46,924	44,200	41,633	39,215	36,937	34,792	32,771	30,868	29,076	27,388
1974	108,254	101,989	96,085	90,519	85,274	80,332	75,675	71,288	67,154	63,260	59,590	56,132	52,873	49,803	46,911	44,186	41,618	39,199	36,920	34,773	32,751	30,847	29,055	27,368
1975	108,251	101,985	96,082	90,518	85,273	80,330	75,674	71,286	67,151	63,256	59,586	56,127	52,868	49,797	46,904	44,177	41,609	39,188	36,908	34,761	32,738	30,833	29,040	27,352
1976	108,246	101,981	96,078	90,514	85,271	80,328	75,671	71,282	67,147	63,250	59,579	56,119	52,860	49,787	46,893	44,165	41,596	39,174	36,893	34,744	32,720	30,815	29,021	27,333
1977	108,244	101,977	96,075	90,512	85,269	80,329	75,672	71,283	67,148	63,251	59,579	56,120	52,860	49,788	46,893	44,165	41,595	39,173	36,891	34,741	32,717	30,810	29,015	27,326
1978	108,240	101,975	96,071	90,507	85,265	80,324	75,669	71,280	67,144	63,247	59,574	56,113	52,852	49,780	46,884	44,155	41,583	39,160	36,877	34,727	32,701	30,794	28,998	27,309
1979	108,231	101,971	96,069	90,500	85,256	80,315	75,658	71,270	67,132	63,233	59,558	56,095	52,831	49,756	46,859	44,128	41,553	39,128	36,843	34,691	32,664	30,756	28,960	27,270
1980	84,200	101,963	96,065	90,496	85,247	80,303	75,645	71,253	67,115	63,212	59,535	56,069	52,802	49,723	46,822	44,088	41,510	39,081	36,793	34,638	32,609	30,700	28,904	27,215
1981	98,044	79,323	96,057	90,489	85,238	80,288	75,626	71,232	67,089	63,185	59,502	56,032	52,761	49,677	46,771	44,032	41,450	39,017	36,724	34,565	32,533	30,622	28,826	27,138
1982	122,462	92,366	74,729	90,490	85,243	80,295	75,630	71,236	67,095	63,190	59,510	56,039	52,768	49,684	46,778	44,038	41,455	39,021	36,727	34,566	32,532	30,618	28,819	27,128
1983	132,625	115,370	87,016	70,390	85,230	80,281	75,614	71,213	67,067	63,159	59,474	56,000	52,724	49,635	46,724	43,978	41,390	38,951	36,653	34,488	32,451	30,535	28,734	27,043
1984	113,058	124,944	108,688	81,967	66,302	80,276	75,610	71,209	67,058	63,147	59,460	55,984	52,706	49,615	46,701	43,953	41,362	38,919	36,617	34,450	32,409	30,490	28,687	26,994
1985	111,566	106,510	117,707	102,378	77,205	62,445	75,600	71,198	67,046	63,129	59,439	55,959	52,678	49,585	46,667	43,915	41,320	38,873	36,567	34,396	32,352	30,431	28,625	26,930
1986	111,968	105,104	100,341	110,859	96,411	72,694	58,787	71,156	66,998	63,074	59,372	55,884	52,594	49,491	46,565	43,803	41,199	38,743	36,429	34,250	32,202	30,278	28,472	26,778
1987	104,365	105,483	99,017	94,503	104,396	90,777	68,434	55,331	66,957	63,028	59,319	55,820	52,521	49,411	46,476	43,706	41,092	38,627	36,305	34,118	32,064	30,135	28,327	26,633
1988	94,335	98,320	99,374	93,238	88,971	98,262	85,419	64,373	52,027	62,932	59,210	55,697	52,381	49,254	46,304	43,519	40,890	38,409	36,072	33,874	31,811	29,877	28,068	26,377
1989	86,669	88,872	92,626	93,517	87,704	83,644	92,317	80,188	60,377	48,748	58,900	55,348	51,993	48,825	45,834	43,008	40,339	37,820	35,450	33,226	31,147	29,208	27,405	25,728
1990	87,002	81,650	83,724	87,150	87,942	82,422	78,544	86,609	75,151	56,517	45,571	54,981	51,583	48,371	45,335	42,464	39,749	37,187	34,777	32,520	30,417	28,466	26,662	24,996
1991	97,190	81,963	76,921	78,683	81,819	82,460	77,168	73,408	80,781	69,933	52,459	42,180	50,734	47,437	44,313	41,354	38,553	35,910	33,428	31,117	28,979	27,016	25,223	23,588
1992	115,061	91,561	77,216	72,372	73,991	76,889	77,430	72,394	68,793	75,611	65,370	48,964	39,307	47,194	44,039	41,048	38,213	35,533	33,012	30,658	28,478	26,477	24,653	22,999
1993	124,704	108,397	86,258	72,566	67,946	69,379	71,990	72,368	67,524	64,019	70,185	60,510	45,185	36,150	43,239	40,177	37,272	34,527	31,947	29,543	27,325	25,300	23,465	21,816
1994	99,103	117,481	102,119	81,059	68,123	63,704	64,948	67,270	67,484	62,819	59,403	64,938	55,810	41,530	33,097	39,414	36,447	33,641	31,005	28,552	26,294	24,238	22,386	20,731
1995	68,420	93,363	110,677	95,988	76,122	63,900	59,673	60,740	62,794	62,861	58,379	55,062	60,023	51,425	38,134	30,271	35,893	33,040	30,358	27,860	25,561	23,469	21,587	19,909
1996	82,276	64,458	87,956	103,972	90,067	71,323	59,768	55,700	56,562	58,319	58,208	53,882	50,639	54,984	46,899	34,604	27,319	32,205	29,474	26,935	24,602	22,485	20,586	18,901
1997	67,444	77,511	60,724	82,645	97,589	84,426	66,749	55,829	51,916	52,590	54,076	53,812	49,649	46,492	50,274	42,685	31,337	24,608	28,856	26,277	23,909	21,761	19,838	18,133
1998	55,319	63,537	73,022	57,080	77,614	91,544	79,088	62,428	52,118	48,364	48,879	50,132	49,748	45,757	42,699	45,993	38,884	28,417	22,215	25,940	23,536	21,351	19,390	17,652
1999	52,265	52,115	59,858	68,703	53,676	72,937	85,959	74,193	58,502	48,781	45,207	45,620	46,714	46,273	42,476	39,548	42,495	35,834	26,121	20,371	23,737	21,500	19,480	17,677
2000	66,946	49,238	49,096	56,332	64,629	50,465	68,531	80,705	69,599	54,825	45,666	42,270	42,601	43,560	43,079	39,473	36,679	39,331	33,097	24,079	18,747	21,815	19,739	17,873
2001	59,009	63,068	46,386	46,212	53,003	60,783	47,437	64,377	75,758	65,279	51,375	42,750	39,527	39,788	40,629	40,120	36,700	34,044	36,441	30,615	22,242	17,297	20,111	18,188
2002	88,962	55,591	59,416	43,669	43,492	49,866	57,160	44,587	60,474	71,119	61,237	48,156	40,036	36,982	37,187	37,926	37,402	34,166	31,649	33,834	28,393	20,609	16,016	18,614
2003	87,572	83,810	52,371	55,912	41,075	40,886	46,846	53,655	41,814	56,655	66,551	57,231	44,943	37,308	34,403	34,527	35,140	34,577	31,517	29,135	31,090	26,053	18,890	14,671
2004	87,515	82,500	78,956	49,293	52,606	38,628	38,429	44,002	50,360	39,213	53,081	62,288	53,504	41,964	34,786	32,028	32,088	32,598	32,019	29,136	26,894	28,666	24,000	17,393

(Table 16 continued)

Year	Numbers at age																					
	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45+*
1964	25,861	24,364	22,953	21,623	20,371	19,191	18,079	17,032	16,046	15,117	14,241	13,416	12,639	11,907	11,218	10,568	9,956	9,379	8,836	8,324	7,842	127,559
1965	25,858	24,361	22,950	21,621	20,368	19,189	18,077	17,031	16,044	15,115	14,240	13,415	12,638	11,906	11,217	10,567	9,955	9,378	8,836	8,324	7,842	127,559
1966	25,851	24,354	22,943	21,614	20,363	19,184	18,073	17,026	16,040	15,111	14,236	13,412	12,635	11,904	11,214	10,565	9,953	9,377	8,835	8,324	7,842	127,559
1967	25,846	24,349	22,939	21,610	20,359	19,180	18,069	17,023	16,037	15,109	14,234	13,410	12,633	11,902	11,213	10,563	9,952	9,375	8,834	8,324	7,842	127,559
1968	25,844	24,347	22,936	21,608	20,357	19,178	18,067	17,021	16,036	15,107	14,233	13,409	12,632	11,901	11,212	10,563	9,951	9,375	8,832	8,322	7,841	127,559
1969	25,842	24,345	22,934	21,606	20,355	19,176	18,066	17,020	16,034	15,106	14,231	13,407	12,631	11,900	11,211	10,562	9,950	9,374	8,832	8,321	7,840	127,558
1970	25,836	24,338	22,928	21,600	20,349	19,171	18,061	17,015	16,030	15,102	14,228	13,404	12,628	11,897	11,208	10,560	9,948	9,372	8,831	8,320	7,839	127,556
1971	25,826	24,329	22,920	21,592	20,341	19,164	18,054	17,009	16,024	15,097	14,223	13,400	12,624	11,893	11,205	10,556	9,945	9,370	8,829	8,320	7,838	127,554
1972	25,817	24,320	22,911	21,583	20,333	19,156	18,047	17,002	16,018	15,091	14,218	13,395	12,620	11,889	11,201	10,553	9,942	9,367	8,827	8,318	7,838	127,550
1973	25,799	24,303	22,894	21,567	20,318	19,142	18,034	16,990	16,007	15,081	14,208	13,386	12,612	11,882	11,195	10,547	9,937	9,362	8,824	8,316	7,836	127,547
1974	25,779	24,283	22,875	21,549	20,301	19,126	18,019	16,976	15,994	15,069	14,197	13,376	12,603	11,874	11,187	10,540	9,930	9,356	8,820	8,313	7,834	127,542
1975	25,763	24,268	22,860	21,535	20,287	19,112	18,006	16,964	15,983	15,058	14,188	13,367	12,595	11,866	11,180	10,534	9,925	9,351	8,814	8,309	7,832	127,536
1976	25,744	24,248	22,841	21,516	20,269	19,095	17,990	16,949	15,969	15,045	14,176	13,356	12,584	11,857	11,172	10,526	9,918	9,344	8,809	8,304	7,828	127,527
1977	25,736	24,240	22,832	21,507	20,260	19,086	17,981	16,940	15,960	15,038	14,168	13,349	12,578	11,851	11,166	10,521	9,913	9,340	8,803	8,299	7,823	127,515
1978	25,718	24,222	22,814	21,489	20,243	19,069	17,965	16,925	15,946	15,024	14,156	13,338	12,567	11,841	11,157	10,513	9,905	9,333	8,799	8,293	7,818	127,500
1979	25,681	24,185	22,778	21,455	20,210	19,038	17,936	16,898	15,920	15,000	14,134	13,317	12,549	11,824	11,142	10,498	9,892	9,321	8,793	8,290	7,813	127,481
1980	25,626	24,132	22,727	21,406	20,164	18,995	17,895	16,860	15,885	14,967	14,103	13,289	12,523	11,800	11,120	10,478	9,874	9,304	8,781	8,283	7,809	127,458
1981	25,551	24,059	22,657	21,339	20,101	18,935	17,839	16,808	15,837	14,923	14,062	13,252	12,488	11,769	11,090	10,452	9,849	9,282	8,765	8,273	7,804	127,433
1982	25,538	24,045	22,641	21,323	20,083	18,917	17,821	16,790	15,820	14,907	14,047	13,237	12,474	11,756	11,079	10,441	9,839	9,272	8,744	8,258	7,793	127,404
1983	25,455	23,964	22,563	21,247	20,011	18,850	17,758	16,731	15,765	14,855	13,999	13,193	12,434	11,718	11,044	10,409	9,810	9,246	8,735	8,238	7,779	127,367
1984	25,404	23,912	22,512	21,197	19,962	18,802	17,712	16,688	15,724	14,817	13,963	13,160	12,403	11,690	11,018	10,385	9,788	9,225	8,710	8,229	7,760	127,319
1985	25,339	23,847	22,447	21,134	19,901	18,743	17,656	16,634	15,673	14,770	13,919	13,119	12,365	11,654	10,985	10,355	9,760	9,200	8,691	8,206	7,753	127,256
1986	25,191	23,703	22,308	21,001	19,775	18,625	17,545	16,531	15,577	14,680	13,836	13,042	12,294	11,590	10,926	10,300	9,710	9,153	8,667	8,187	7,731	127,189
1987	25,047	23,562	22,171	20,869	19,650	18,506	17,433	16,425	15,479	14,589	13,752	12,964	12,222	11,523	10,864	10,243	9,657	9,105	8,623	8,165	7,713	127,106
1988	24,796	23,319	21,938	20,648	19,440	18,309	17,249	16,254	15,320	14,442	13,616	12,839	12,107	11,417	10,767	10,154	9,575	9,030	8,578	8,124	7,692	127,011
1989	24,170	22,722	21,373	20,117	18,945	17,849	16,823	15,862	14,959	14,111	13,312	12,560	11,851	11,183	10,552	9,956	9,394	8,863	8,507	8,081	7,653	126,901
1990	23,458	22,037	20,723	19,503	18,369	17,313	16,326	15,403	14,536	13,722	12,955	12,233	11,551	10,908	10,300	9,725	9,182	8,668	8,350	8,014	7,613	126,761
1991	22,098	20,738	19,493	18,349	17,293	16,314	15,403	14,552	13,755	13,005	12,298	11,631	11,000	10,402	9,836	9,300	8,791	8,309	8,166	7,866	7,550	126,592
1992	21,500	20,141	18,908	17,782	16,750	15,799	14,918	14,099	13,333	12,614	11,937	11,298	10,694	10,122	9,579	9,064	8,575	8,110	7,828	7,693	7,411	126,372
1993	20,337	19,011	17,820	16,745	15,770	14,879	14,059	13,300	12,592	11,930	11,307	10,718	10,161	9,632	9,129	8,650	8,195	7,761	7,640	7,374	7,247	126,035
1994	19,259	17,953	16,792	15,757	14,828	13,987	13,221	12,516	11,862	11,253	10,680	10,140	9,628	9,141	8,678	8,235	7,813	7,409	7,311	7,198	6,947	125,563
1995	18,425	17,116	15,964	14,946	14,042	13,234	12,504	11,838	11,226	10,658	10,127	9,627	9,153	8,703	8,273	7,863	7,470	7,094	6,980	6,888	6,781	124,835
1996	17,418	16,119	14,984	13,992	13,121	12,351	11,663	11,044	10,479	9,959	9,474	9,020	8,591	8,182	7,793	7,419	7,061	6,716	6,683	6,576	6,489	123,993
1997	16,635	15,330	14,195	13,210	12,354	11,605	10,944	10,356	9,825	9,341	8,894	8,477	8,085	7,712	7,357	7,016	6,688	6,372	6,327	6,296	6,195	122,925
1998	16,124	14,792	13,638	12,640	11,778	11,031	10,379	9,804	9,293	8,832	8,410	8,020	7,655	7,311	6,982	6,668	6,366	6,074	6,003	5,961	5,931	121,642
1999	16,086	14,694	13,484	12,438	11,537	10,759	10,085	9,498	8,981	8,521	8,105	7,725	7,373	7,043	6,731	6,433	6,147	5,872	5,722	5,655	5,615	120,184
2000	16,214	14,755	13,481	12,376	11,423	10,602	9,894	9,282	8,748	8,279	7,860	7,482	7,136	6,815	6,514	6,228	5,956	5,693	5,532	5,391	5,327	118,514
2001	16,464	14,936	13,594	12,425	11,412	10,539	9,788	9,140	8,580	8,092	7,662	7,279	6,933	6,616	6,321	6,045	5,782	5,531	5,364	5,211	5,079	116,668
2002	16,831	15,236	13,824	12,585	11,507	10,574	9,770	9,078	8,482	7,966	7,517	7,121	6,768	6,449	6,156	5,884	5,628	5,385	5,211	5,053	4,909	114,696
2003	17,045	15,412	13,955	12,667	11,539	10,558	9,710	8,979	8,349	7,808	7,339	6,930	6,569	6,248	5,957	5,690	5,441	5,207	5,074	4,909	4,760	112,678
2004	13,504	15,689	14,189	12,852	11,672	10,639	9,741	8,964	8,294	7,718	7,222	6,792	6,418	6,087	5,792	5,525	5,280	5,051	4,906	4,780	4,625	110,637

Table 17 : Results and contributions by various data sources to the negative log-likelihood function for the sensitivity analyses.

#	Sensitivity analysis	# pars	logbook CPUE	M young	M old	q	fishery length comps	discard rates	avg. weights	biomass indices	survey length comps	recruitment	penalties	total nLL	B_0 (mt)	SB_0 (mt)	SB_{2005} (mt)	2005 depletion
	Base-case	42	NA	e 0.06		pe 1.03	201.44	-30.47	-24.57	-10.96	14.56	-9.74	1.65	141.90	228,275	105,157	75,049	0.714
	Discards																	
1	# 2: time-varying retention	45	NA	e 0.071		pe 0.81	179.38	-27.67	-25.96	-10.63	14.29	-10.30	0.37	119.48	260,614	117,128	86,132	0.74
2	# 3: time-varying retention, discard time series A	47	NA	e 0.071		pe 0.85	183.34	-89.96	-24.97	-10.33	14.43	-10.57	0.55	62.48	245,853	110,274	81,575	0.74
3	# 4: time-varying retention, discard time series B	46	NA	e 0.066		pe 0.79	180.87	-72.80	-24.91	-10.82	14.40	-10.36	0.30	76.70	279,203	126,838	94,830	0.75
4	# 2: time-varying retention	44	NA	e 0.071		1	178.95	-28.13	-25.86	-10.72	14.47	-10.36	-	118.36	224,055	100,969	70,149	0.69
5	# 3: time-varying retention, discard time series A	46	NA	e 0.071		1	182.56	-90.07	-24.95	-10.62	14.60	-10.39	-	61.14	216,860	97,407	68,893	0.71
6	# 4: time-varying retention, discard time series B	46	NA	e 0.065		1	180.22	-72.98	-24.78	-10.90	14.56	-10.43	-	75.69	237,000	107,890	76,216	0.71
	Recruitment																	
7	σ_R = 0.8, residuals 1980-2002	42	NA	e 0.05		pe 0.95	198.98	-30.17	-24.55	-12.39	14.62	2.82	1.18	150.48	267,249	125,520	97,009	0.77
8	σ_R = 1.0, residuals 1980-2002	42	NA	e 0.045		pe 0.93	197.29	-29.85	-24.66	-13.49	15.37	10.61	1.01	156.28	275,882	130,794	105,777	0.81
9	σ_R = 0.6, residuals 1995-2002	27	NA	e 0.058		pe 0.99	200.58	-30.70	-25.00	-12.10	15.95	-3.59	1.56	146.70	243,320	112,532	83,070	0.74
10	σ_R = 0.6, residuals 1992-2002	24	NA	e 0.055		pe 0.97	201.00	-30.75	-24.92	-12.08	15.13	-4.73	1.32	144.97	259,574	120,771	90,618	0.75
11	σ_R = 0.6, residuals 1964-2002	60	NA	e 0.044		pe 0.76	186.33	-29.71	-25.60	-14.69	15.25	-15.60	0.11	116.09	420,593	199,834	147,096	0.74
12	no recruitment variability	19	NA	e 0.060		pe 1.03	199.97	-30.73	-25.34	-12.69	20.84	0.00	1.88	153.92	231,284	106,538	77,835	0.73
	Slope survey catchability																	
13	q=0.5	41	NA	e 0.057		0.5	205.96	-30.23	-24.60	-11.11	14.30	-8.73	-	145.60	427,711	197,956	167,154	0.84
14	q = 0.7	41	NA	e 0.06		0.7	203.57	-30.24	-24.51	-11.23	14.95	-8.77	-	143.79	302,570	139,322	109,796	0.79
15	q = 0.7	40	NA	0.1		0.7												
16	q = 1	41	NA	e 0.066		1	202.90	-30.29	-23.87	-10.99	14.91	-9.76	-	142.92	214,855	97,604	69,340	0.71
17	q estimated (MPD for q = 2.55)	42	NA	e 0.047		e 2.55	193.06	-30.92	-24.99	-9.30	15.92	-9.95	-	133.63	158,526	74,859	41,853	0.56
18	different penalty (μ=0.7, CV=0.3)	42	NA	e 0.055		pe 1.51	197.65	-30.63	-24.63	-10.75	14.88	-9.92	3.29	139.89	189,246	87,989	56,850	0.65
19	different penalty (μ=0.5, CV=0.3)	42	NA	e 0.066		pe 1.27	200.57	-30.36	-23.84	-10.97	14.93	-9.89	4.82	145.25	184,214	83,762	55,592	0.66
20	different penalty (μ=0.5, CV=0.2)	42	NA	e 0.03		pe 0.61	203.28	-30.01	-24.00	-10.80	12.89	-7.30	0.50	144.57	654,182	317,760	280,452	0.88
	Natural Mortality																	
21	M = 0.1	40	NA	0.1		1	204.91	-30.42	-23.86	-12.12	16.95	-10.16	-	145.31	187,947	78,035	55,859	0.72
22	M = 0.015	40	NA	0.015		1	201.26	-30.41	-23.93	-10.66	12.78	-6.66	-	142.37	916,071	452,450	407,904	0.90
23	M = 0.15	40	NA	0.15		1	238.60	-30.31	-23.87	-12.16	19.23	-10.37	-	181.12	410,580	143,057	118,118	0.83
24	young M = 0.2 old M = 0.05	40	NA	0.2	0.05	1	198.77	-30.51	-24.92	-10.99	13.02	-9.27	-	136.10	242,540	107,861	89,569	0.83
25	young M = 0.1 old M = 0.03	40	NA	0.1	0.03	1	201.70	-30.39	-24.33	-11.28	13.16	-6.80	-	142.05	401,392	192,982	163,807	0.85
26	young M = 0.1 old M = 0.015	40	NA	0.1	0.015	1	202.46	-30.34	-24.40	-10.96	13.16	-6.20	-	143.73	847,879	416,848	385,651	0.93
27	young and old M's estimated	42	NA	e 0.25	e 0.062	1	198.85	-30.55	-25.07	-11.53	13.45	-9.47	-	135.69	212,411	87,443	74,076	0.85
28	young and old M's estimated	42	NA	e 0.24	e 0.065	0.7	201.95	-30.36	-24.87	-11.42	13.66	-9.19	-	139.78	269,495	110,570	100,848	0.91

(Table 17 continued)

#	Sensitivity analysis	# pars	logbook CPUE	M young	M old	q	fishery length comps	discard rates	avg. weights	biomass indices	survey length comps	recruitment	penalties	total nLL	B_0 (mt)	SB_0 (mt)	SB_{2005} (mt)	2005 depletion
	Steepness																	
29	h estimated (MPD for h = 1.0)	43	NA	e 0.057		pe 1.01	201.19	-30.48	-24.60	-11.09	14.57	-9.71	1.72	141.60	242,865	112,490	81,676	0.73
	Logbook CPUE																	
30	longspine effort	43	-7.7073	e 0.057		pe 1.01	201.44	-30.47	-24.57	-10.96	14.56	-9.74	1.66	134.20	245,155	113,559	82,477	0.73
31	dwc effort	43	-6.69619	e 0.057		pe 1.01	201.40	-30.47	-24.57	-10.96	14.56	-9.74	1.69	135.21	244,389	113,199	82,133	0.73
	Landings																	
32	1900-2004, discard #1, foreign catches 1965-1976	46	NA	e 0.058		pe 1.01	201.21	-30.45	-24.57	-10.97	14.57	-9.74	1.72	141.76	239,042	110,432	79,597	0.72
33	1900-2004, discard #2, foreign catches 1965-1976	46	NA	e 0.07		pe 1.00	179.49	-27.59	-25.96	-10.69	14.27	-10.29	0.37	119.60	261,903	117,842	86,066	0.73
	Slope survey biomass estimates																	
34	coastwide expansion	41	NA	e 0.044		1	211.14	-29.73	-24.78	-15.82	26.70	-10.15	-	157.37	509,915	242,170	204,531	0.84
35	coastwide expansion	40	NA	0.1		1	210.42	-29.93	-23.71	-15.97	28.38	-10.63	-	158.56	325,319	135,071	108,673	0.80
36	no Conception area	41	NA	e 0.038		0.7	193.23	-30.32	-24.29	-12.91	12.95	-7.04	-	131.61	353,058	169,371	138,542	0.82
37	no Conception area	41	NA	e 0.061		1	192.45	-30.76	-24.95	-13.29	14.79	-9.55	-	128.68	181,600	83,340	56,544	0.68
	Length data																	
38	slope survey N=200	42	NA	e 0.059		pe 1.01	201.44	-30.43	-24.57	-10.92	17.07	-9.64	1.67	144.62	238,041	109,817	79,268	0.72
39	fishery & slope survey N=200	42	NA	e 0.031		pe 2.84	1536.50	-30.83	-15.60	-14.32	26.44	13.66	24.58	1540.43	179,502	87,005	56,175	0.65
	Maturity at length																	
40	maturity ogive by Ianelli et al. (1994)	42	NA	e 0.057		pe 1.00	201.46	-30.48	-24.57	-10.96	14.56	-9.75	1.65	141.91	245,766	97,762	69,592	0.71

Table 18 : Estimated total catch from the four discard scenarios, with *M* estimated and penalised estimation of *q* (base-case and model #'s 1-3 from Table 17).

Year	Total Catch (mt) discard scenario 1	2	3	4
1964	15	90	41	28
1965	35	209	96	65
1966	24	146	67	45
1967	12	69	32	21
1968	12	69	32	21
1969	33	202	93	63
1970	48	293	135	91
1971	51	308	141	96
1972	94	574	264	179
1973	107	651	300	203
1974	89	539	248	168
1975	114	694	319	216
1976	62	379	174	118
1977	117	716	329	223
1978	216	355	271	411
1979	303	498	379	575
1980	411	676	515	781
1981	129	212	161	245
1982	474	781	594	902
1983	340	559	425	646
1984	426	702	534	810
1985	839	1,384	1,053	1,597
1986	845	1,394	1,060	1,609
1987	1,380	2,277	1,731	2,628
1988	3,180	3,221	3,024	3,037
1989	3,671	3,718	3,490	3,503
1990	6,857	6,943	6,516	6,539
1991	3,449	3,491	3,275	3,286
1992	6,376	6,451	6,050	6,071
1993	6,250	6,321	5,925	5,945
1994	5,381	5,438	5,094	5,112
1995	6,541	6,505	6,473	6,486
1996	5,752	5,713	5,686	5,698
1997	4,720	4,681	4,660	4,671
1998	2,671	2,646	2,634	2,641
1999	2,136	2,115	2,106	2,112
2000	1,797	1,778	1,771	1,776
2001	1,438	1,422	1,417	1,422
2002	2,287	2,263	2,255	2,263
2003	1,869	1,849	1,843	1,849
2004	912	902	899	902

Table 19 : Estimated landings of longspine thornyhead for years 1964-1976, with inclusion of estimates of foreign catches, as derived from Rogers (2001).

Year	Landings (mt)
1964	13
1965	32
1966	89
1967	96
1968	151
1969	42
1970	54
1971	64
1972	127
1973	232
1974	109
1975	171
1976	78

Table 20 : Estimated longspine thornyhead landings (mt) for 1900-1976 derived from sablefish catch and by inclusion of estimated foreign catches for years 1965-1976.

Year	Landings (mt)	Year	Landings (mt)	Year	Landings (mt)
1900	0	1926	3	1952	15
1901	0	1927	3	1953	6
1902	0	1928	3	1954	11
1903	0	1929	3	1955	11
1904	0	1930	3	1956	66
1905	1	1931	3	1957	24
1906	1	1932	3	1958	25
1907	1	1933	4	1959	34
1908	1	1934	4	1960	40
1909	1	1935	4	1961	37
1910	1	1936	4	1962	52
1911	1	1937	4	1963	32
1912	1	1938	5	1964	13
1913	1	1939	5	1965	32
1914	2	1940	7	1966	89
1915	2	1941	9	1967	96
1916	2	1942	10	1968	151
1917	2	1943	23	1969	42
1918	2	1944	33	1970	54
1919	2	1945	39	1971	64
1920	2	1946	18	1972	127
1921	2	1947	4	1973	232
1922	2	1948	13	1974	109
1923	2	1949	14	1975	171
1924	3	1950	13	1976	78
1925	3	1951	26		

Table 21 : Slope survey biomass estimates for the combined, AFSC, and NWFSC GLMM analyses which used a coastwide expansion, including the area south of Point Conception.

Year	Total		Vancouver		Columbia		Eureka		Monterey		Conception	
	Median (mt)	CV	Median (mt)	CV	Median (mt)	CV	Median (mt)	CV	Median (mt)	CV	Median (mt)	CV
Combined												
1992	70,346	0.09	16,679	0.15	10,590	0.11	19,017	0.11	24,101	0.15	-	-
1996	41,515	0.09	11,943	0.13	12,164	0.11	17,164	0.11	-	-	-	-
1997	147,969	0.12	11,543	0.23	12,153	0.16	19,659	0.19	24,416	0.15	78,480	0.19
1998	114,290	0.13	10,737	0.20	8,788	0.14	15,415	0.16	17,309	0.12	61,021	0.20
1999	140,302	0.10	12,726	0.12	11,261	0.11	17,750	0.12	23,133	0.10	74,772	0.15
2000	147,965	0.10	14,098	0.13	11,672	0.11	19,728	0.12	21,438	0.10	80,143	0.14
2001	157,467	0.09	12,612	0.13	11,646	0.11	19,038	0.11	24,196	0.10	89,504	0.13
2002	139,368	0.08	12,992	0.16	12,216	0.13	22,641	0.13	23,602	0.11	67,266	0.11
2003	140,299	0.09	17,017	0.13	13,524	0.13	22,902	0.15	24,789	0.16	61,112	0.16
2004	148,746	0.10	11,483	0.23	12,934	0.18	21,088	0.18	32,338	0.18	68,965	0.12
AFSC												
1992	85,394	0.06	20,398	0.12	12,844	0.08	22,545	0.08	29,322	0.12	-	-
1996	48,413	0.05	13,971	0.11	14,288	0.09	20,049	0.09	-	-	-	-
1997	172,865	0.10	13,059	0.20	13,846	0.15	22,684	0.17	28,252	0.13	92,957	0.18
1999	166,600	0.10	14,547	0.15	14,243	0.15	21,333	0.17	24,295	0.13	91,038	0.17
2000	152,409	0.09	14,666	0.14	13,113	0.14	22,170	0.17	26,943	0.12	73,674	0.17
2001	159,997	0.09	11,846	0.15	13,657	0.14	22,330	0.17	28,759	0.11	81,771	0.16
NWFSC												
1998	116,887	0.12	11,119	0.19	9,185	0.14	15,738	0.16	17,894	0.11	61,544	0.20
1999	145,685	0.12	13,155	0.15	11,127	0.13	18,604	0.14	25,041	0.12	77,118	0.21
2000	175,294	0.13	15,773	0.18	12,117	0.13	20,482	0.14	20,670	0.12	104,827	0.20
2001	187,109	0.13	15,501	0.17	11,263	0.14	18,837	0.14	23,802	0.12	116,369	0.19
2002	140,855	0.08	13,602	0.16	12,579	0.13	23,150	0.13	23,735	0.11	67,765	0.12
2003	142,948	0.09	17,575	0.13	14,017	0.12	23,510	0.14	25,664	0.17	60,955	0.15
2004	152,378	0.09	12,081	0.22	13,624	0.18	22,102	0.17	33,401	0.17	70,301	0.12

Table 22 : Forecasts to 2016 for the base-case model under the PFMC's $F_{50\%}$ control rule. No 40:10 adjustment was necessary as the stock is well above the management target.

Year	Total Biomass (mt)	Age 2+ Biomass (mt)	Spawning Biomass (mt)	Spawning Depletion	Recruitment	Exploitation rate	ABC	=	OY
2005	162,642	162,395	75,049	0.71	87,511	1.7%	2,838		2,838
2006	160,037	159,768	74,012	0.70	104,604	1.8%	2,831		2,831
2007	157,441	157,147	72,853	0.69	104,414	2.5%	3,953		3,953
2008	153,786	153,492	71,031	0.68	104,104	2.5%	3,860		3,860
2009	150,302	150,009	69,149	0.66	103,769	2.5%	3,766		3,766
2010	147,020	146,728	67,259	0.64	103,416	2.5%	3,671		3,671
2011	143,964	143,673	65,419	0.62	103,055	2.5%	3,577		3,577
2012	141,150	140,860	63,684	0.61	102,698	2.5%	3,483		3,483
2013	138,589	138,300	62,089	0.59	102,355	2.5%	3,391		3,391
2014	136,287	135,999	60,657	0.58	102,034	2.4%	3,304		3,304
2015	134,240	133,952	59,398	0.56	101,740	2.4%	3,225		3,225
2016	132,439	132,153	58,319	0.55	101,480	2.4%	3,155		3,155

Table 23 : Projection results for the base-case model and the analyses which used different values for *M* and *q*.

									Harvest regime			
									Avg. catch for last 5 yrs		base-case ABC	
	M	*q*	objective function	B_0 (mt)	SB_0 (mt)	SB_{2005} (mt)	2005 depletion	MSY (F50%)	SB 2016	2016 depletion	SB 2016	2016 depletion
base-case	**0.06**	**1.03**	**142.1**	**228,277**	**105,159**	**75,050**	**0.71**	**3306**	**67,437**	**0.64**	**61,992**	**0.56**
	0.05	0.79	140.1	334,903	157,280	122,982	0.78	3771	111,492	0.71	101,452	0.65
	0.07	1.34	138.7	173,646	78,165	50,274	0.64	2971	45,408	0.58	36,615	0.47
	0.05	1.34	137.8	222,019	104,266	71,540	0.69	2607	63,433	0.61	53,099	0.51
	0.07	0.79	143.8	267,089	120,228	90,175	0.75	4265	79,133	0.68	70,114	0.60

Table 24 : Decision table and forecast harvest projections to 2016 for the base-case model and 'best' and 'worst' alternative states of nature under two different harvest regimes: the catch expected from applying the F_{MSY} proxy, $F_{50\%}$., to the results from the base case model, and the average total catch over the last 5 years (2000-2004) calculated from the base-case model. Catches in years 2005 and 2006 were set to approximate the current ABC for both the northern Conception area and the rest of the coast (2,850 mt) for the $F_{50\%}$ projection. As the stock is estimated to be well above the management target of $SB_{40\%}$, there was no adjustment of harvest due to the 40:10 rule under this regime.

				"Worst" q=0.79 M=0.05		Base q = 1.03 (based on prior) est. M = 0.06		"Best" q=1.34 M=0.07	
Management action	Year	Catch (mt)	Landings (mt)	Spawning Biomass	Depletion	Spawning Biomass	Depletion	Spawning Biomass	Depletion
Average of last 5 years	2005	1,640	1,410	50,274	0.64	75,049	0.71	122,513	0.78
	2006	1,640	1,410	49,942	0.64	74,578	0.71	121,828	0.78
	2007	1,640	1,410	49,519	0.63	73,987	0.70	120,997	0.77
	2008	1,640	1,410	49,004	0.63	73,271	0.70	120,009	0.77
	2009	1,640	1,410	48,419	0.62	72,452	0.69	118,886	0.76
	2010	1,640	1,410	47,807	0.61	71,572	0.68	117,677	0.75
	2011	1,640	1,410	47,217	0.60	70,687	0.67	116,443	0.74
	2012	1,640	1,410	46,686	0.60	69,845	0.66	115,244	0.74
	2013	1,640	1,410	46,233	0.59	69,082	0.66	114,125	0.73
	2014	1,640	1,410	45,865	0.59	68,419	0.65	113,115	0.72
	2015	1,640	1,410	45,589	0.58	67,868	0.65	112,233	0.72
	2016	1,640	1,410	45,408	**0.58**	67,437	**0.64**	111,492	**0.71**
OY - F50% for base model	2005	2,838	2,423	50,274	0.64	75,049	0.71	122,982	0.78
	2006	2,831	2,423	49,386	0.63	74,012	0.70	121,722	0.77
	2007	3,953	3,390	48,410	0.62	72,853	0.69	120,308	0.76
	2008	3,859	3,316	46,816	0.60	70,989	0.68	118,185	0.75
	2009	3,765	3,239	45,205	0.58	69,067	0.66	115,965	0.74
	2010	3,671	3,159	43,624	0.56	67,137	0.64	113,700	0.72
	2011	3,576	3,075	42,127	0.54	65,259	0.62	111,460	0.71
	2012	3,482	2,990	40,754	0.52	63,487	0.60	109,309	0.69
	2013	3,391	2,903	39,523	0.51	61,858	0.59	107,292	0.68
	2014	3,304	2,818	38,443	0.49	60,391	0.57	105,440	0.67
	2015	3,224	2,737	37,517	0.48	59,101	0.56	103,773	0.66
	2016	3,154	2,664	36,746	**0.47**	57,990	**0.55**	102,301	**0.65**

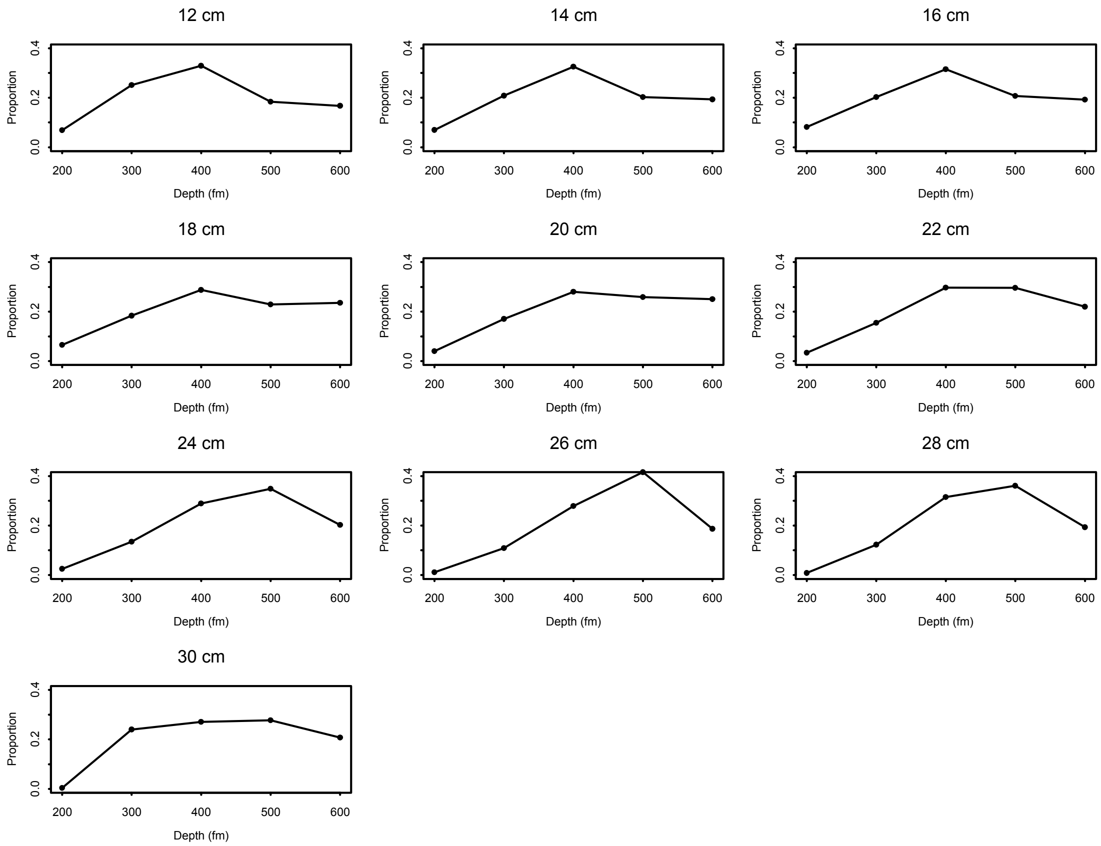


Figure 1 : Average depth distributions for longspine thornyhead (modified from Jacobson *et al.* 2001).

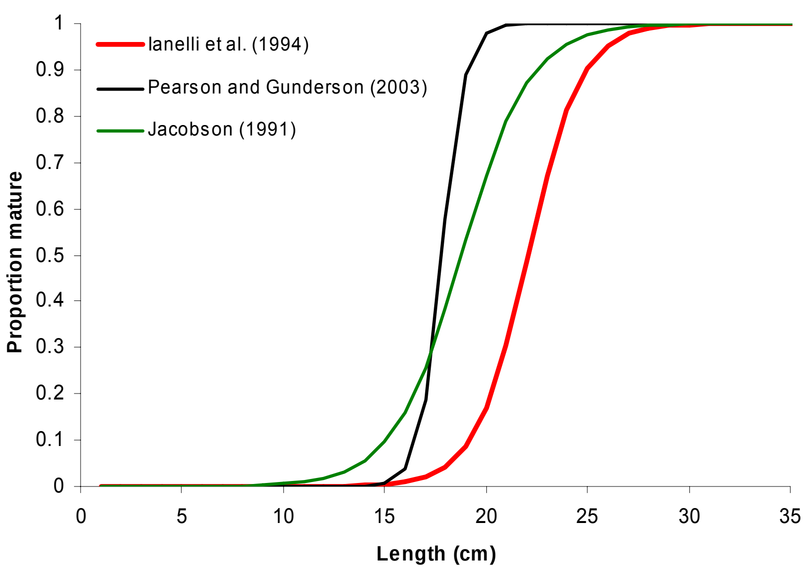


Figure 2 : Maturity at length for longspines.

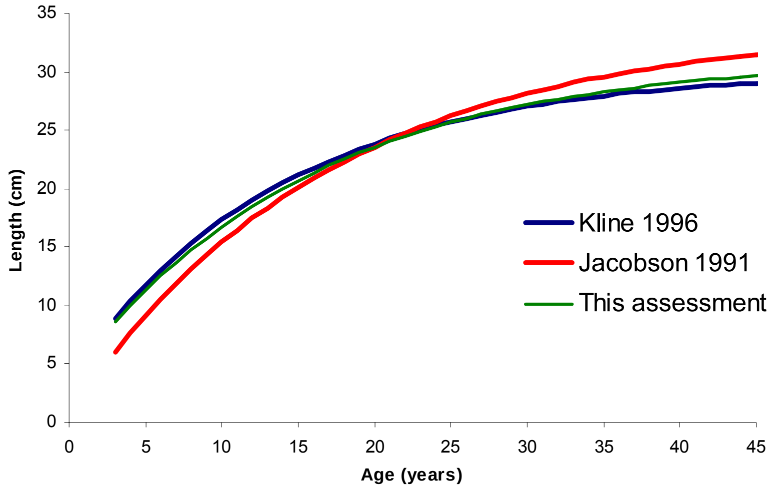


Figure 3 : Von Bertalanffy growth curves for longspine thornyhead showing estimates of mean length at age.

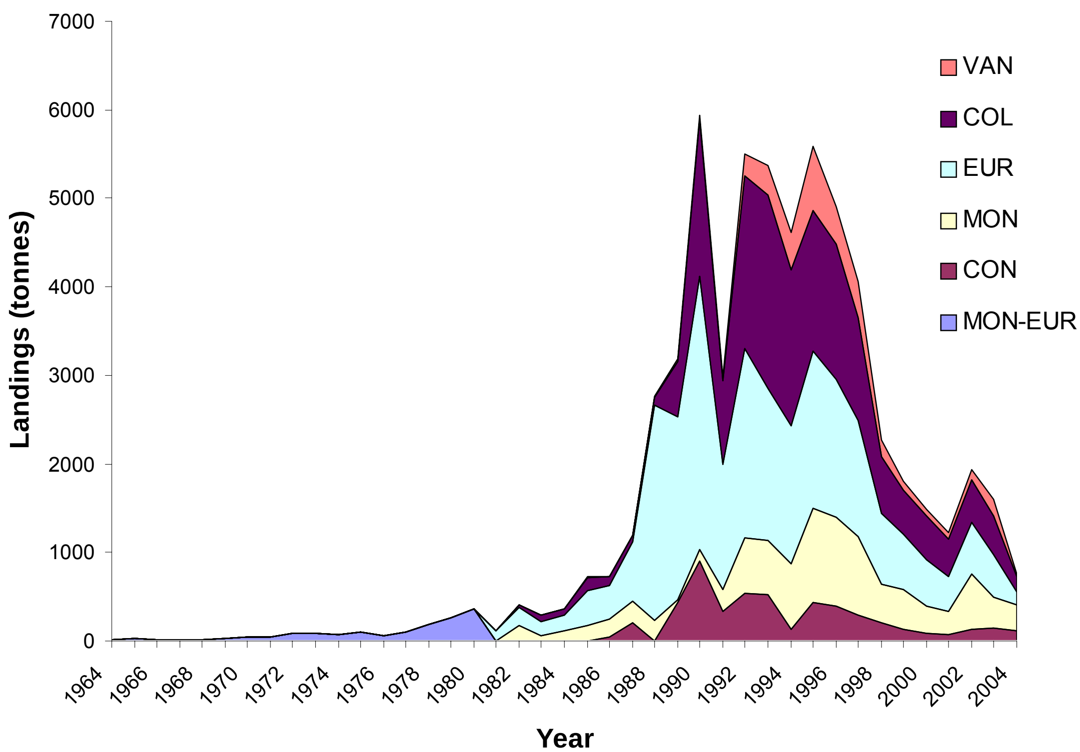


Figure 4 : Estimated total landings of longspine thornyhead by INPFC area for the period 1964-2004.

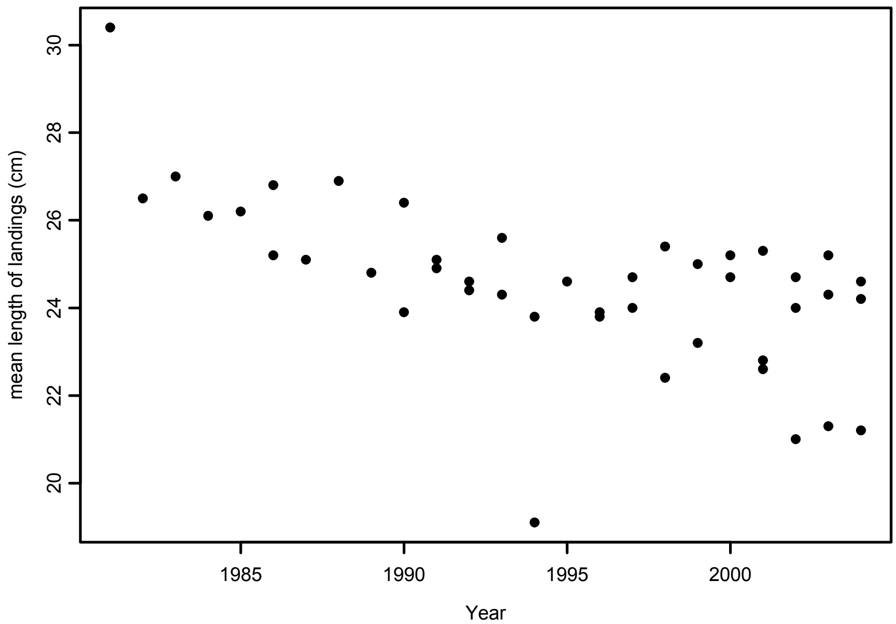


Figure 5 : Mean length over time of the commercial length composition data.

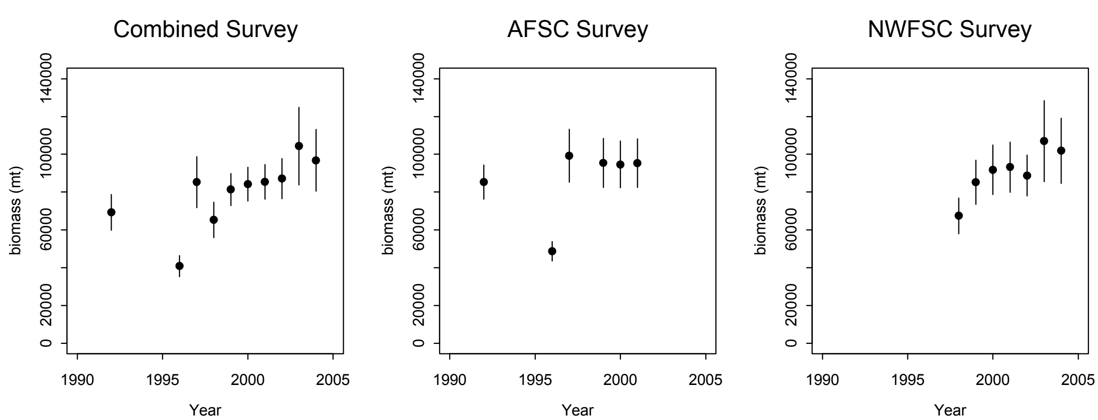


Figure 6 : Biomass estimates (median ± 1 standard error) from the GLMM analysis (Helser et al. 2005) of the data from the AFSC and NWFSC FRAM slope surveys, with the Conception area expanded to only include the region north of Point Conception. 1992 and 1996 are "Super years" – 1992 excludes Conception biomass, and 1996 excludes Monterey and Conception biomass.

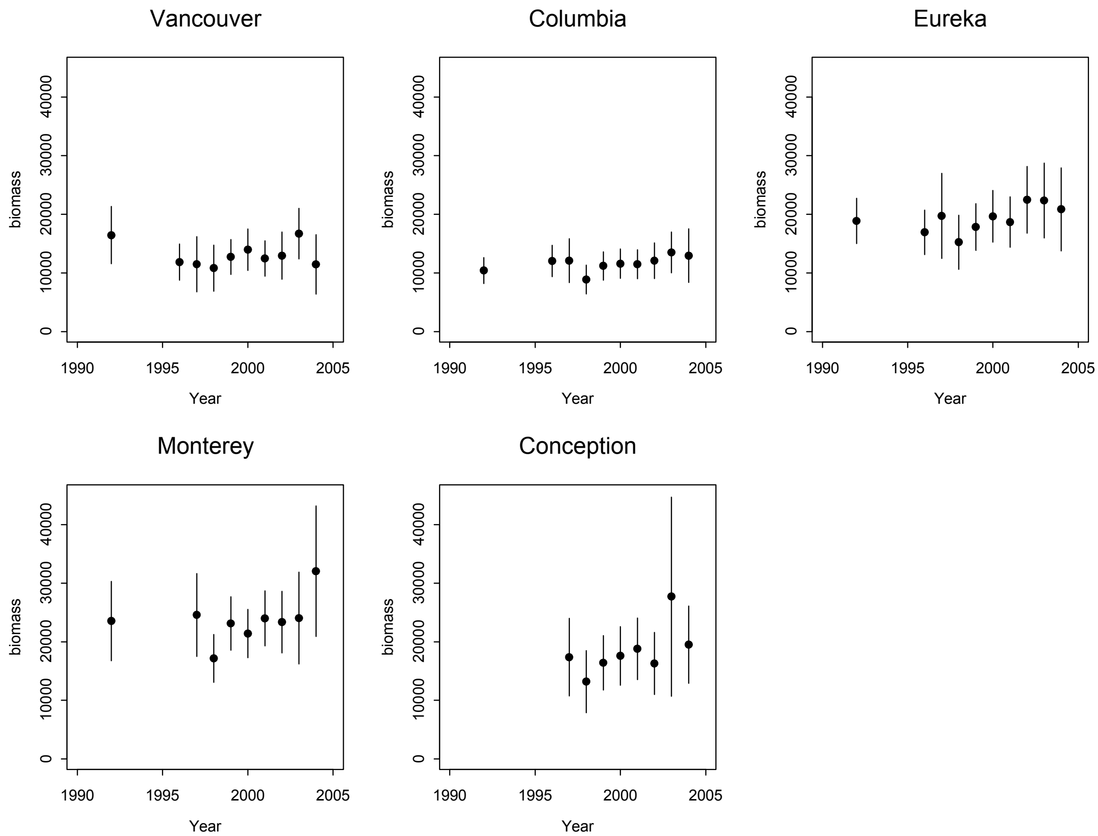


Figure 7 : Biomass estimates by INPFC area from the combined slope survey GLMM. The Conception area biomass is based on an expansion of the Conception area north of Point Conception.

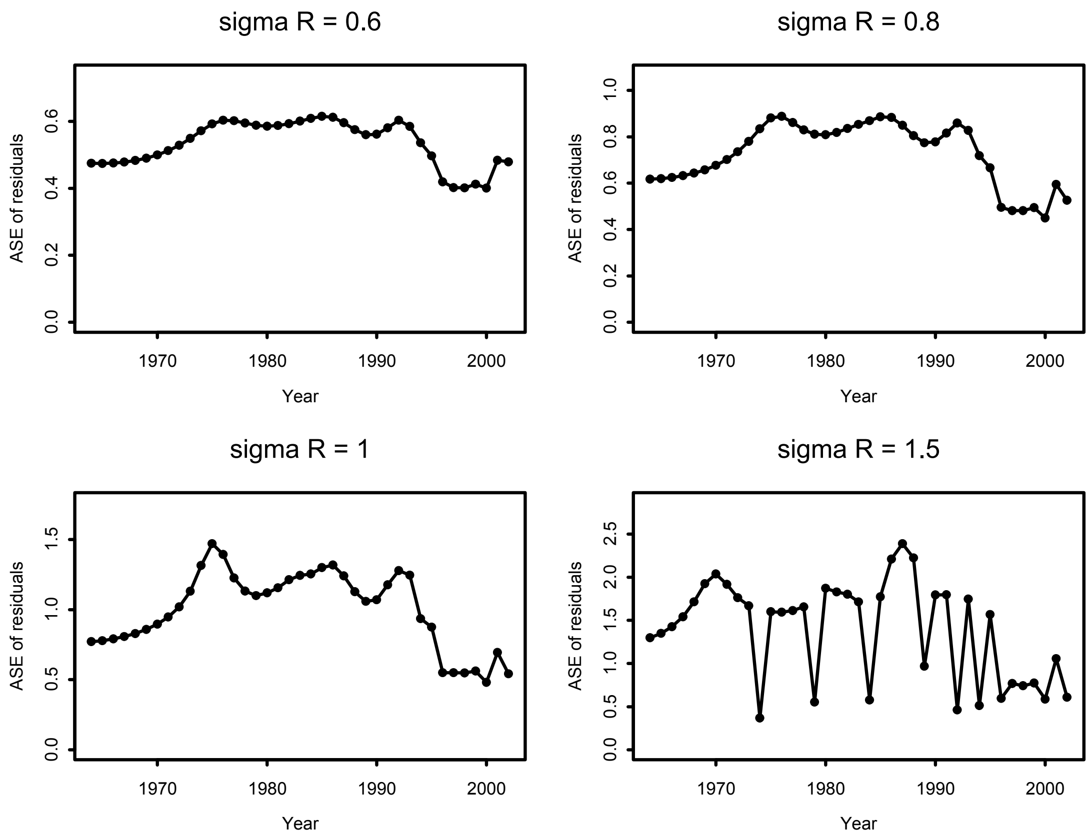


Figure 8 : Asymptotic standard errors of the recruitment residuals for four different levels of recruitment variability. Residuals were estimated for years 1964-2002.

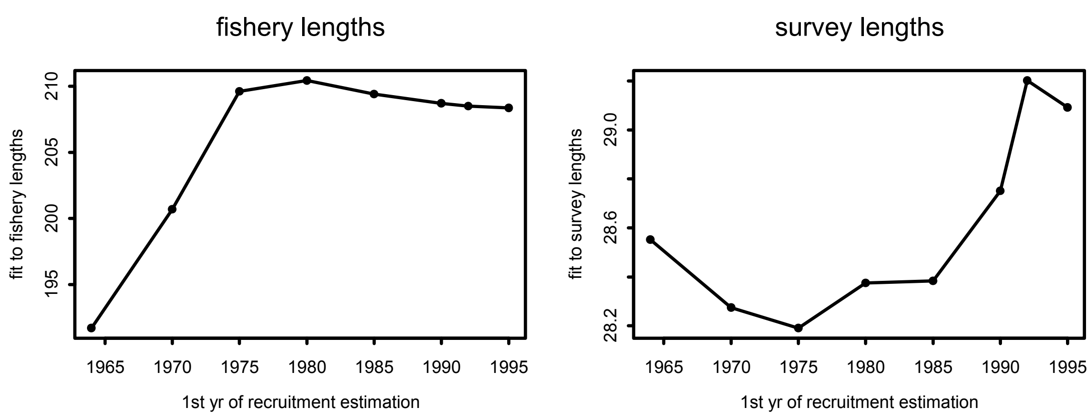


Figure 9 : Change in fit (negative log-likelihood) to the length composition data for the fishery and the survey with number of recruitment residuals estimated. Base-case assumptions, σ_R = 0.6.

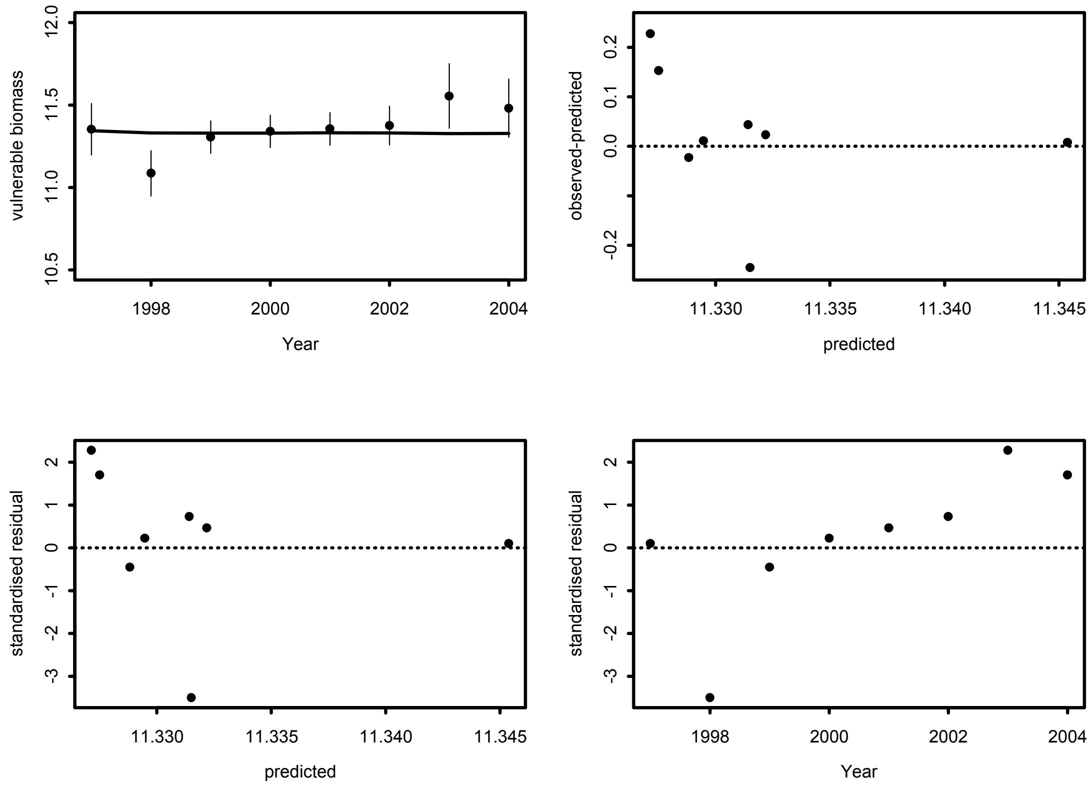


Figure 10 : Base-case model fits and residual plots for the combined slope survey biomass index data. Error bars on the natural logarithm of the GLMM estimates in the top-left panel correspond to ± 1.96 standard deviations, equivalent to the CV of the observations given in Table 11.

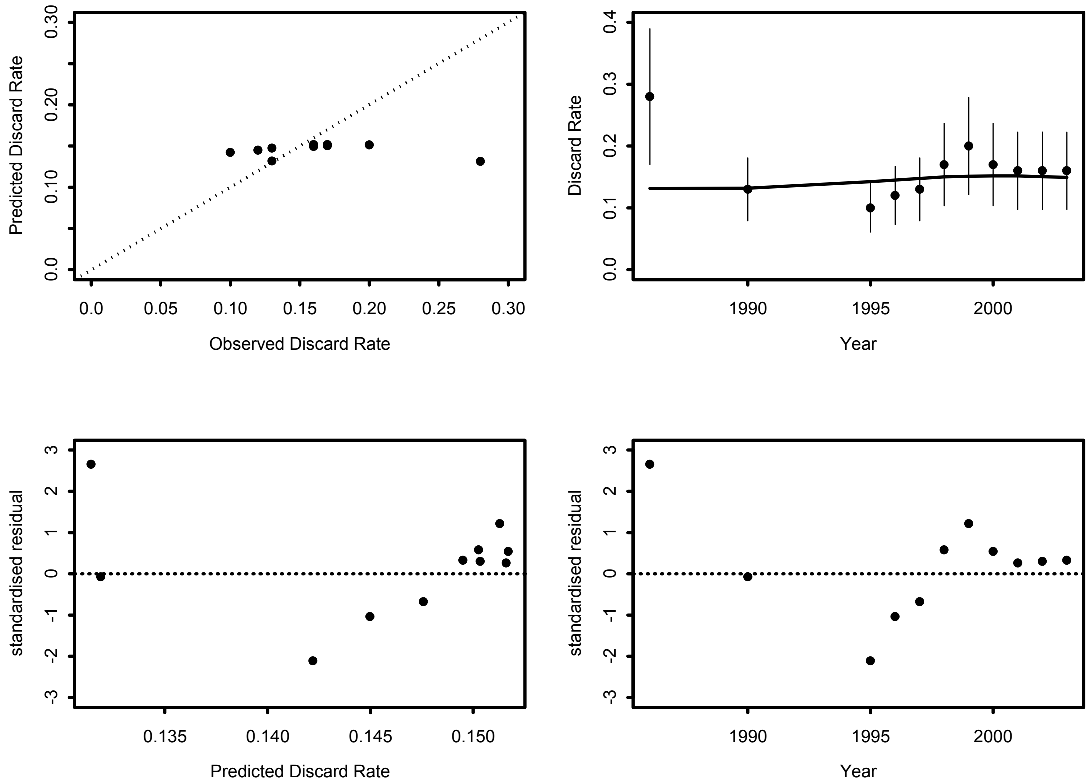


Figure 11 : Base-case model fits and plots of standardized residuals for the discard rate data. Error bars on the observations in the top-right panel correspond to ±1.96 standard deviations. Standardized residuals are plotted against both the predicted values, and time.

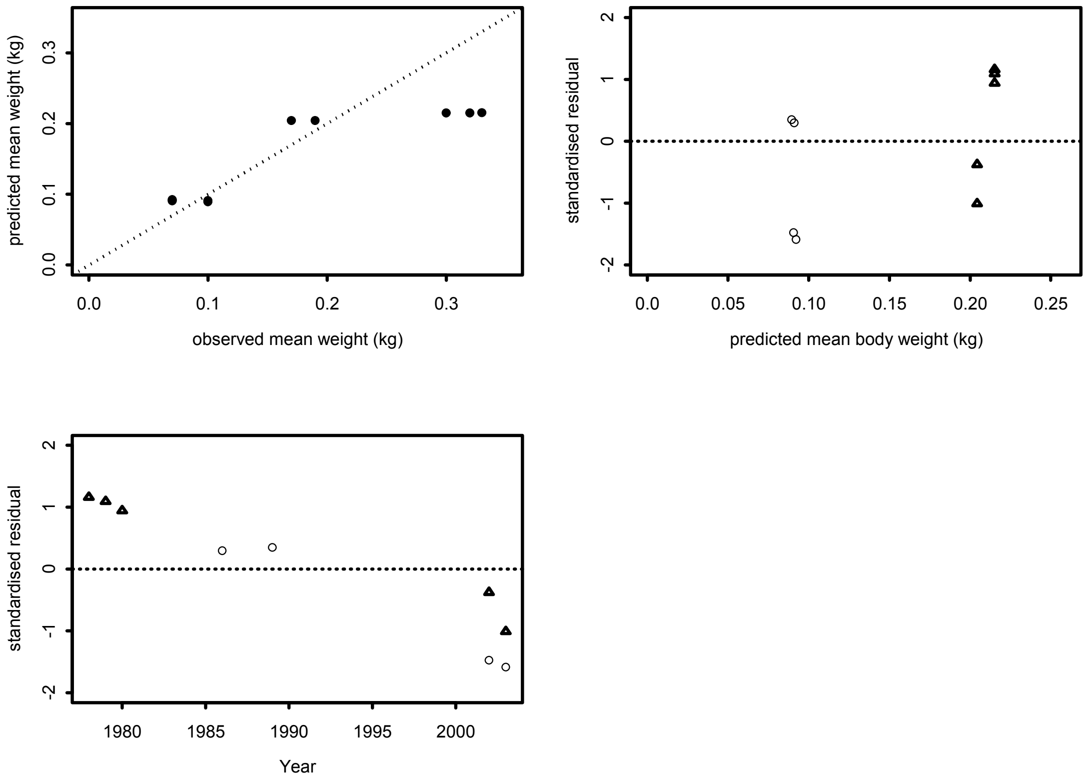


Figure 12 : Base-case model fits and standardized residuals for the mean body weight data. Triangles in the residual plots represent data for the retained catch, circles that of the discards.

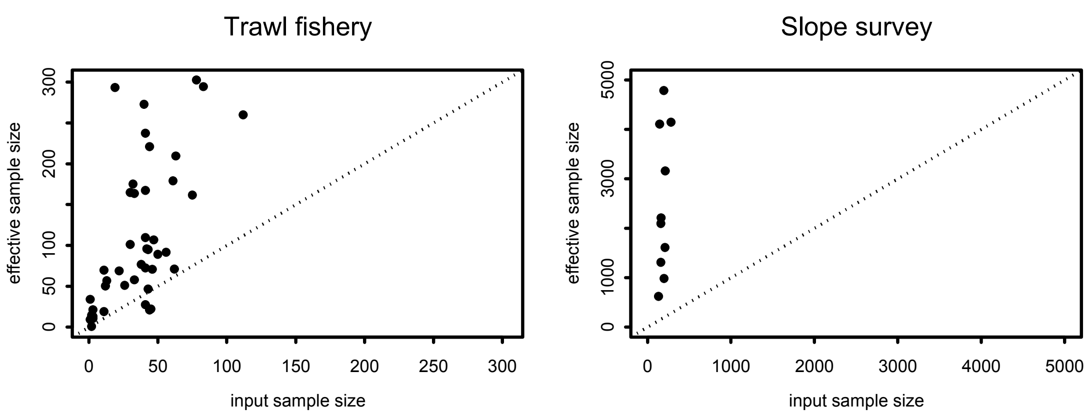


Figure 13 : Input sample size for the length compositions compared to the effective sample sizes outputted from the model in the base-case analysis.

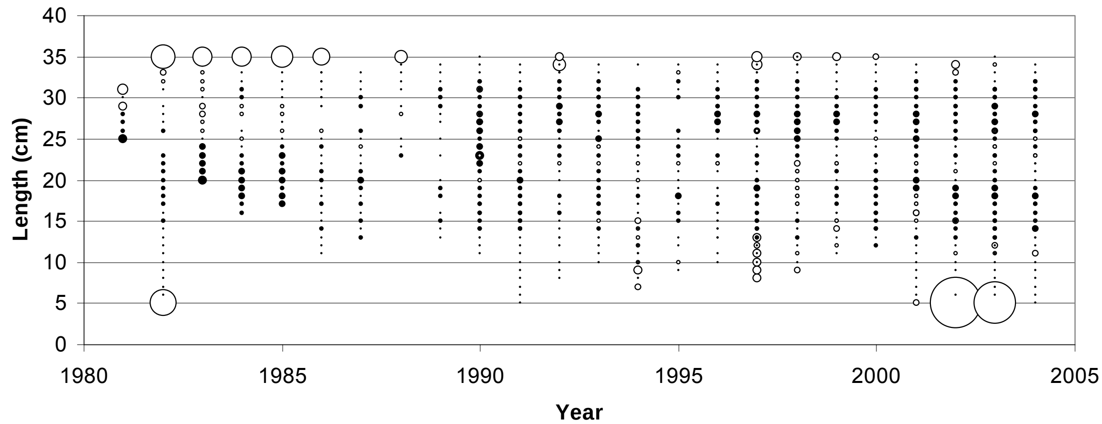


Figure 14 : Pearson residuals for the base-case fits to the commercial length composition data. Solid circles represent negative residuals.

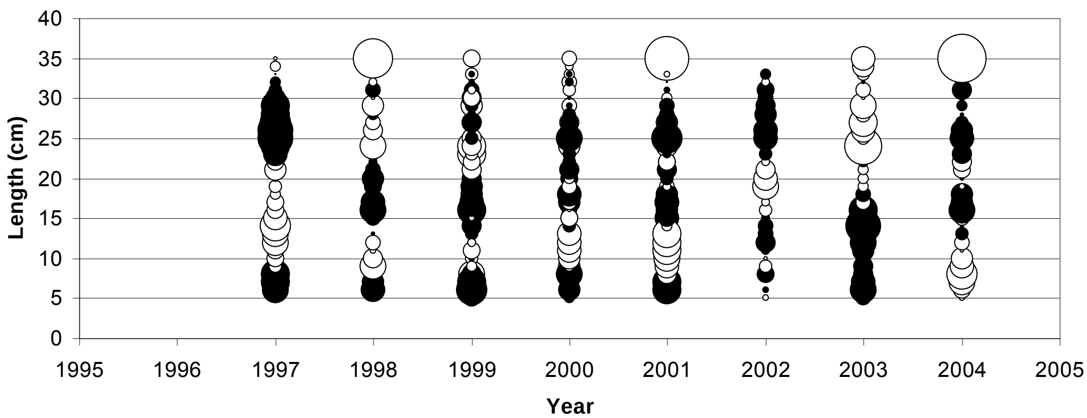


Figure 15 : Pearson residuals for the base-case fits to the slope survey length composition data. Solid circles represent negative residuals.

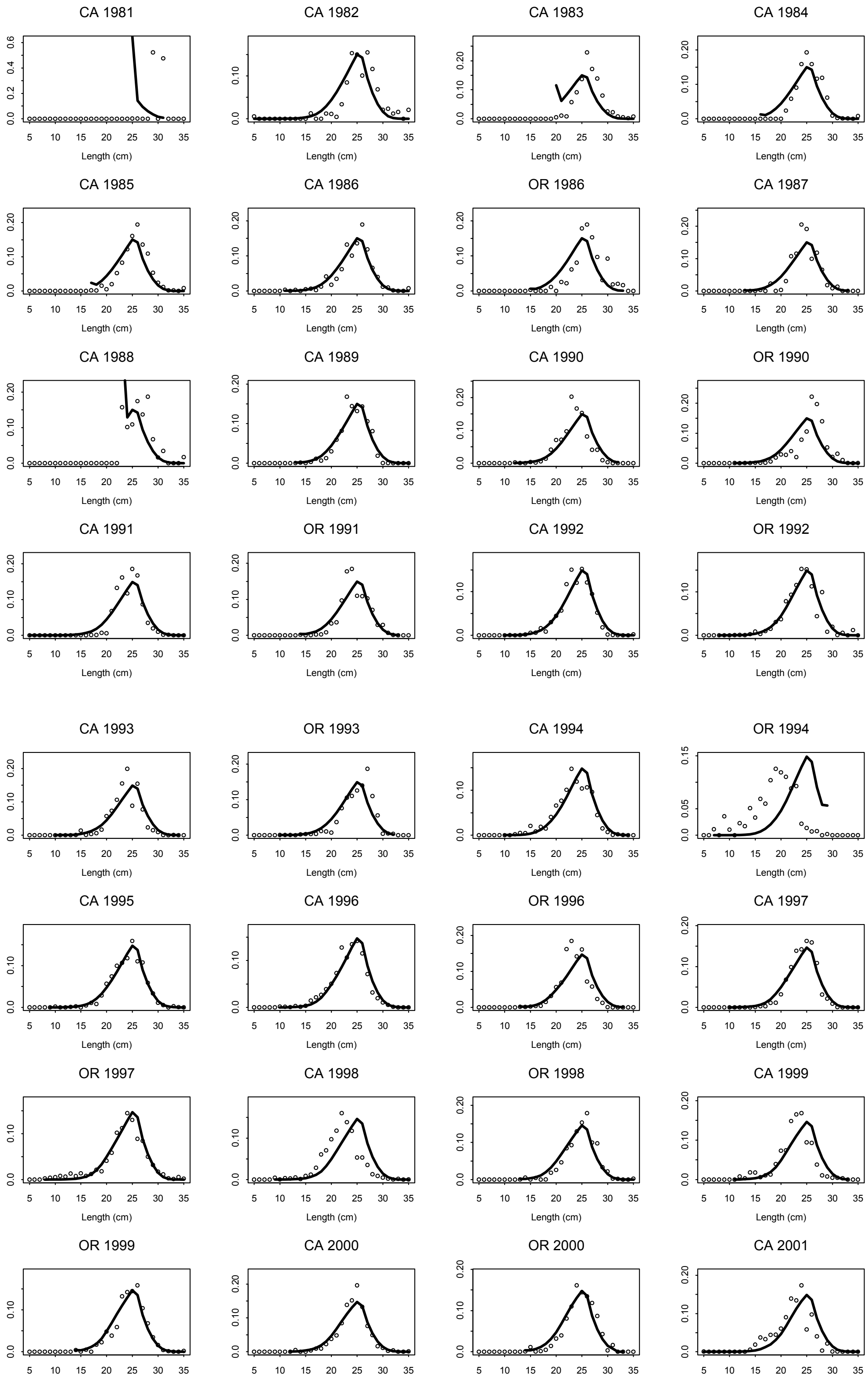
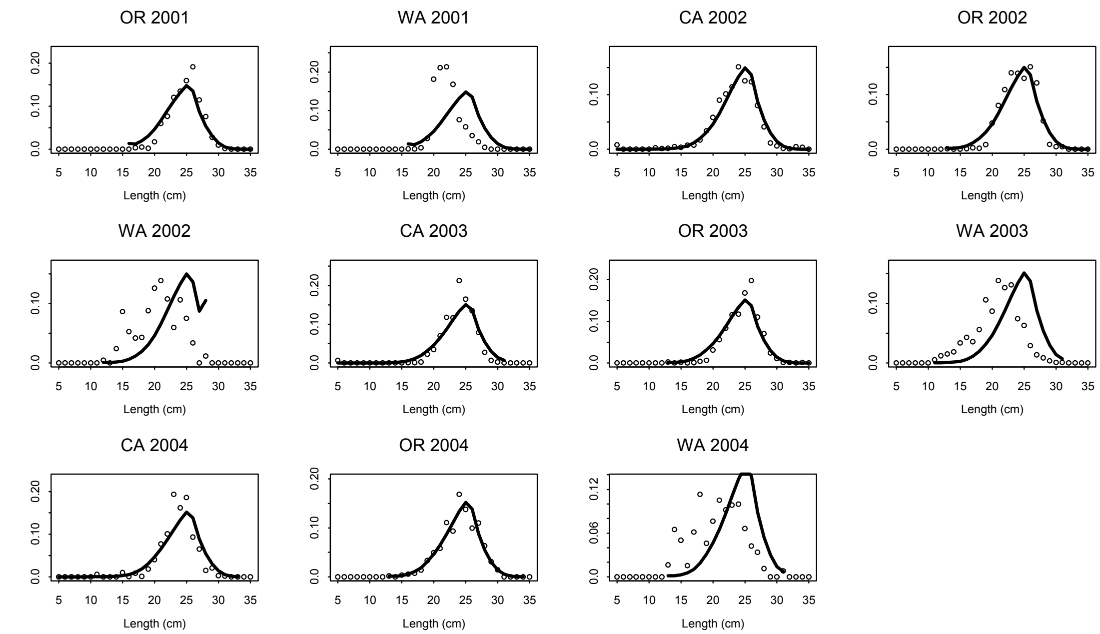


Figure 16 : Base-case fits to the trawl fishery length composition data.



(Figure 16 continued)

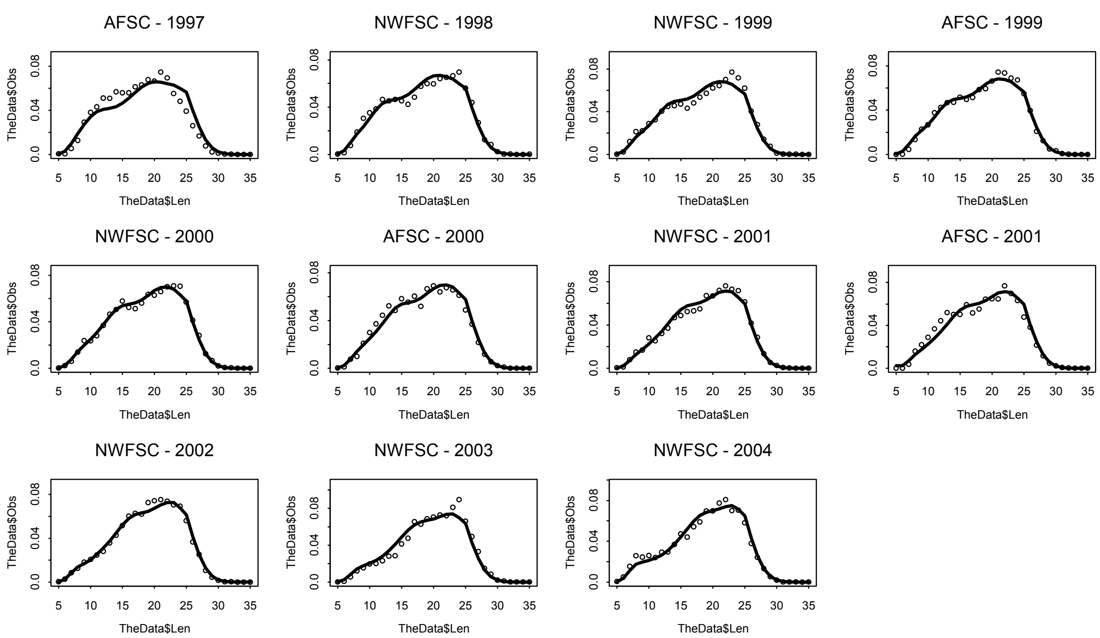


Figure 17 : Base-case fits to the slope survey length composition data.

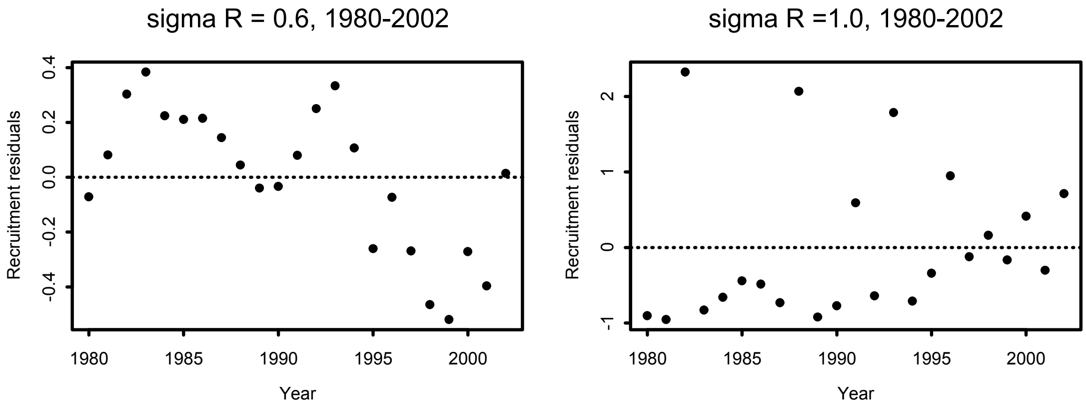


Figure 18 : recruitment residuals for the base-case model and for a sensitivity analysis in which the extent of recruitment variability is increased.

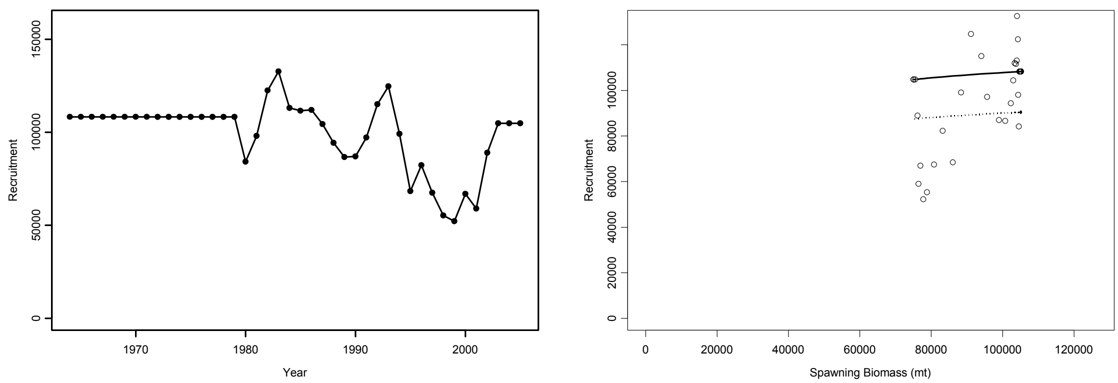


Figure 19 : Recruitment time-series, and the distribution of recruitment around the stock-recruitment curve (the solid line represents the expected (mean) recruitment and the dashed line indicates median recruitment without the log-bias adjustment).

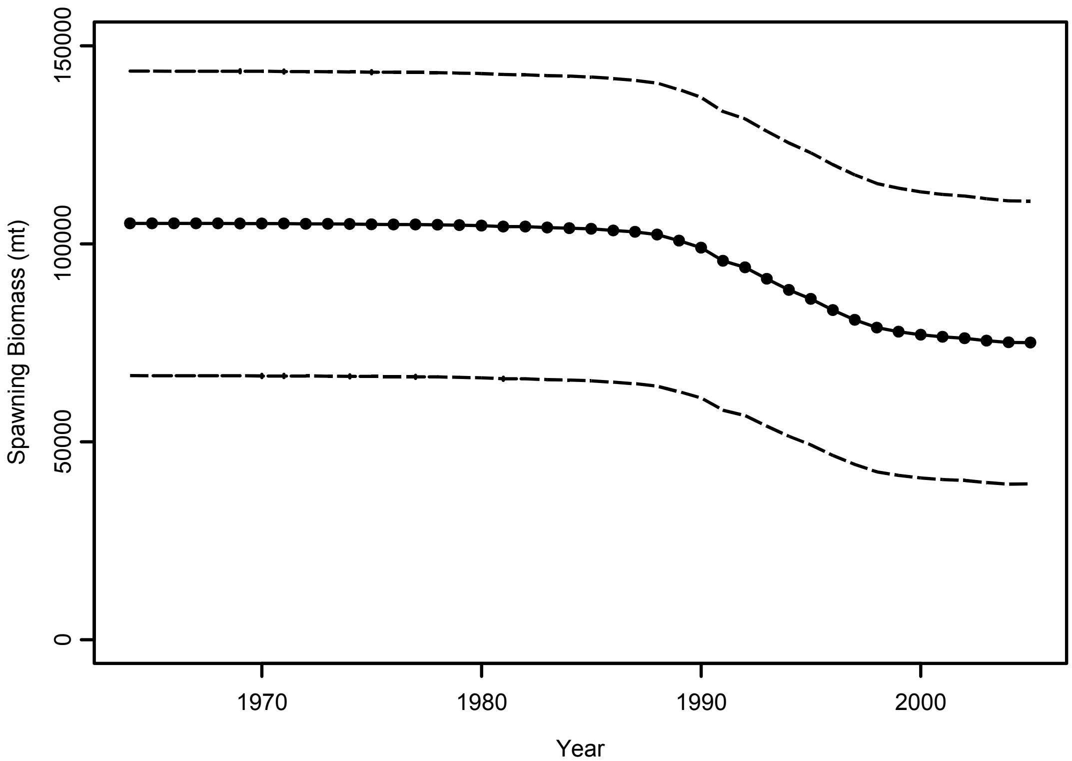


Figure 20 : Time-series of spawning biomass for the base-case analysis. The dashed lines represent upper and lower bounds of the asymptotic 95% confidence interval.

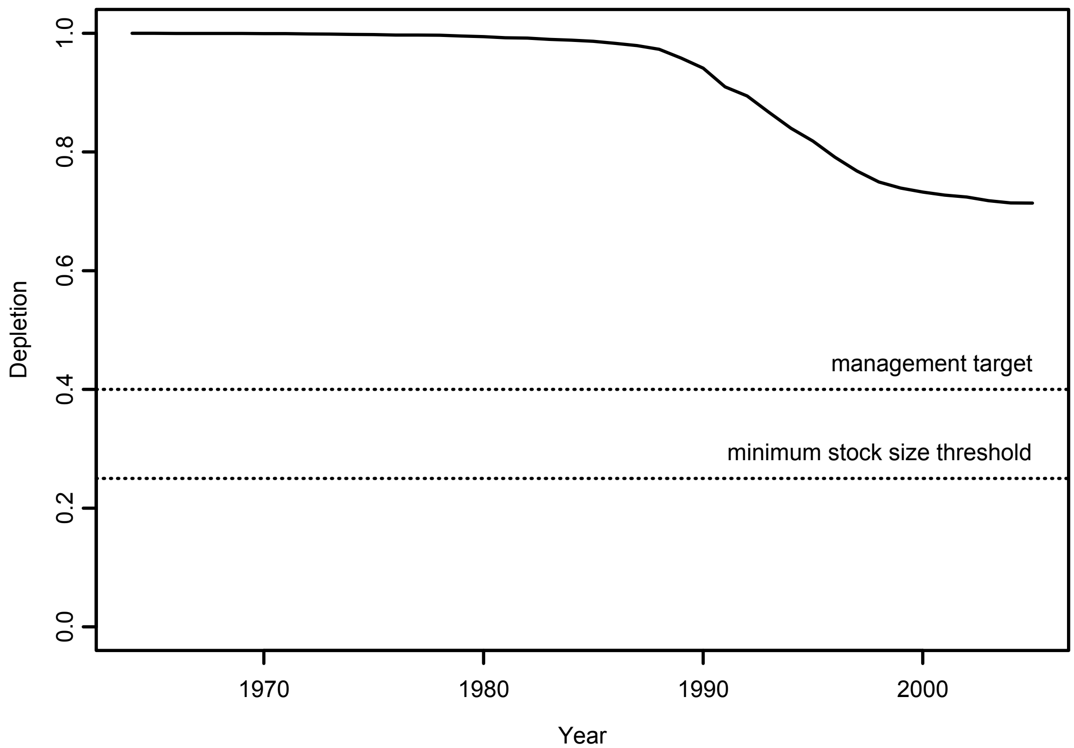


Figure 21 : Base-case estimate of the time-series of depletion, relative to SB_0, the virgin spawning biomass. Dashed lines refer to the target depletion ($SB_{40\%}$) and overfishing level ($SB_{25\%}$).

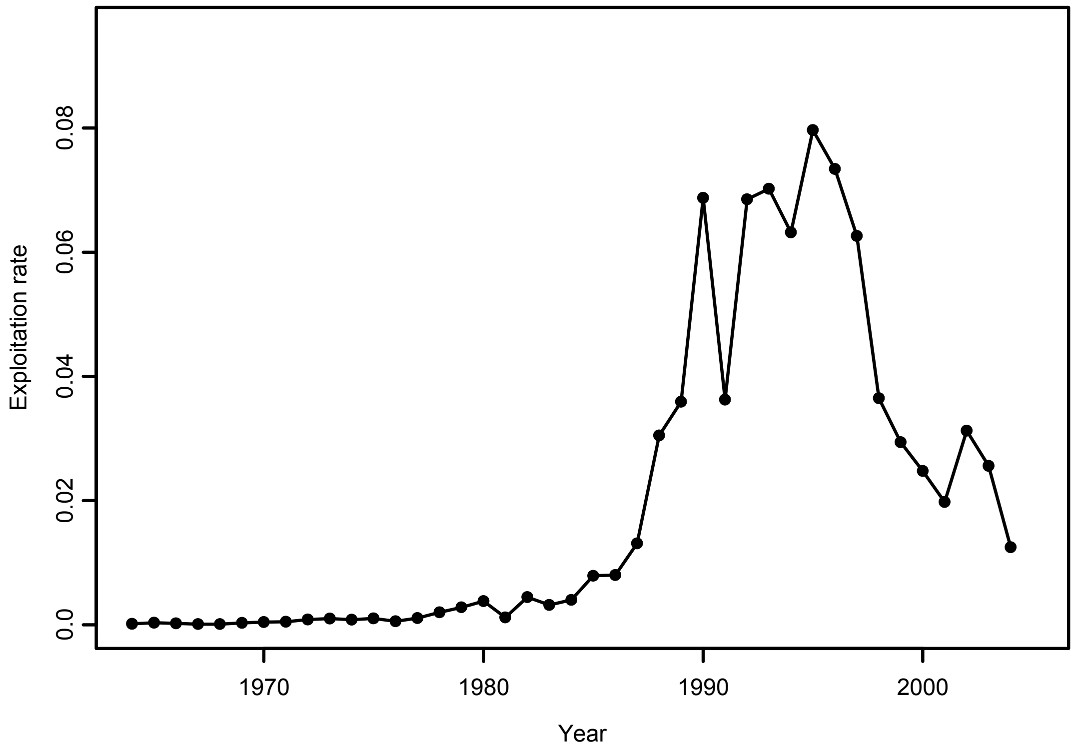


Figure 22 : Estimated total exploitation rates for the trawl fishery in the base-case analysis.

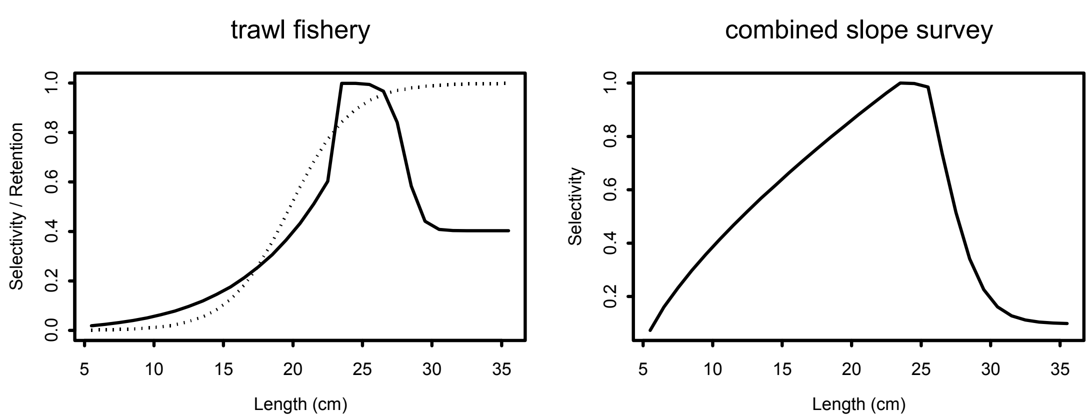


Figure 23 : Estimated selectivity at length for both the trawl fishery and the combined slope survey in the base-case model. The estimated retention curve (dotted line) in the trawl fishery panel indicates proportion at length retained in the landed catch.

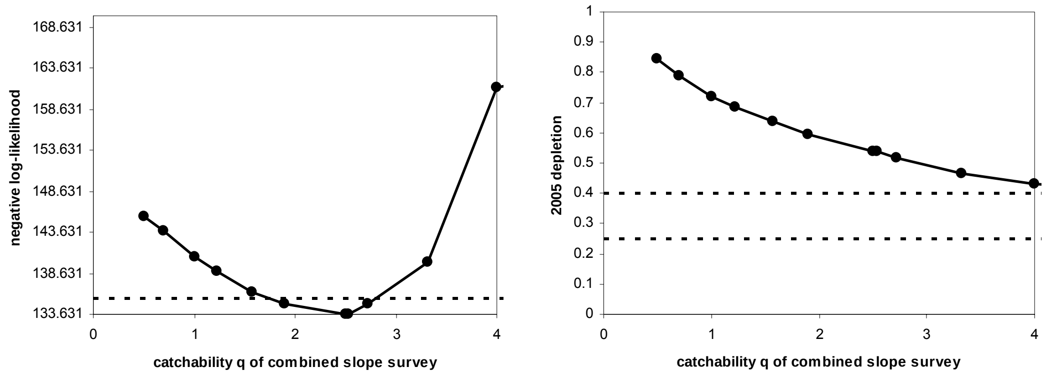


Figure 24 : Likelihood profile for the slope survey catchability coefficient, *q*, and the resulting predicted 2005 depletion level associated with different values for *q*. The dashed line on left panel represents an approximate 95% confidence interval for this parameter and the dashed lines on right panel correspond to the target ($SB_{40\%}$) and the minimum stock size threshold ($SB_{25\%}$).

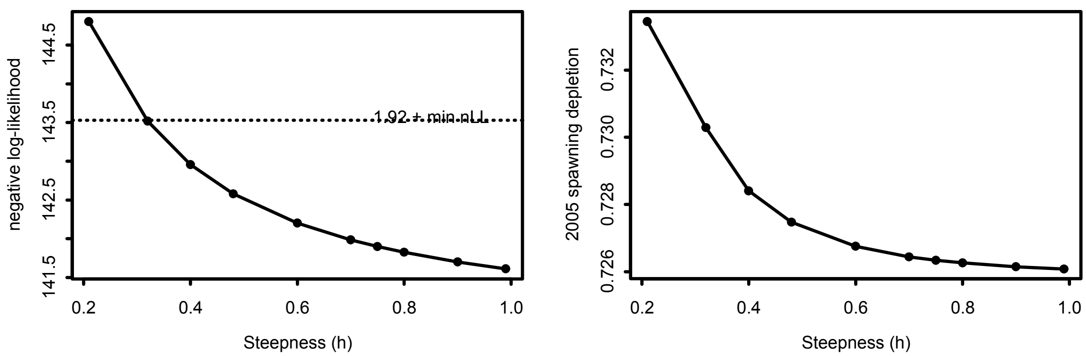


Figure 25 : Likelihood profile over the value for the steepness parameter (*h*) for the base-case model.

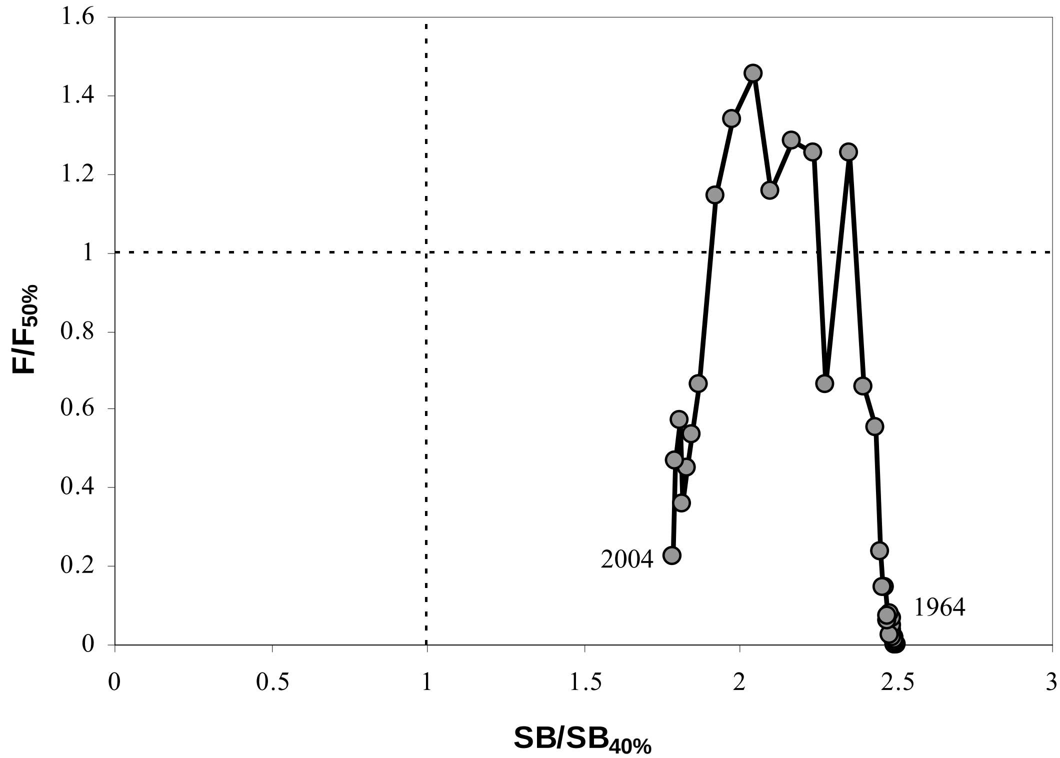


Figure 26 : Changes over time in fishing mortality relative to F_{MSY} versus changes in spawning biomass relative to the target spawning biomass.

Appendix A
Estimation of Von Bertalanffy growth curve for Longspine Thornyhead

A.1 Methods
Growth of longspine thornyhead was modelled according to a von Bertalanffy growth curve with mean length-at-age given by:

$$\bar{L}_a = L_\infty \left(1-\exp\left(-k\left[a-t_0\right]\right)\right) \qquad \text{(A.1)}$$

where $\bar{L}_a$ is the mean length (in centimetres) of a fish of age a, and
L_∞, k, and t_0 are the parameters of the growth curve.

The distribution of length-at-age was assumed to be log-normal with standard deviation σ_a, given by:

$$\sigma_a = \bar{L}_a CV_a \qquad \text{(8.B.2)}$$

with

$$\sigma_a = \sigma_{L_1} + \left(\frac{\sigma_{L_x} - \sigma_{L_1}}{\bar{L}_x - \bar{L}_1}\right)\left(\bar{L}_a - \bar{L}_1\right) \qquad \text{(8.B.3)}$$

where σ_{L_1} is the standard deviation of the mean length of fish of age 1, and
σ_{L_x} is the standard deviation of the mean length at the maximum age *x*.

The values for the parameters of the model (L_∞, k, t_0, CV_{L_1}, and CV_{L_x}) were estimated by minimizing the negative of the logarithm of the likelihood function, which, ignoring constants which are independent of the values for the model parameters, is defined as:

$$-\ln L = \sum_{i=1}^{n}\left(\ln CV_i + \frac{\left[\ln(L_i) - \ln(\bar{L}_i)\right]^2}{2CV_i^2}\right) \qquad \text{(8.B.5)}$$

where $\bar{L}_i$ is the model-estimate of the length of the ith fish in the sample, and
n is the total number of age-length observations.

The model was fitted using the AD Model Builder software package (Otter Consulting). The data set of age-length observations was provided by Donna E. Kline (Moss Landing Marine Laboratory, pers. comm.) totalling 815 pairs of observations, with a maximum age (*x*) in the sample of 46 yr.

A.2 Results
The maximum likelihood estimates (MLEs) of the growth curve parameters were: L_∞ = 31.2 cm, k = 0.064, and t_0 = -2.02. Table A.1 lists the estimates of mean length-at-age,

standard deviation of length-at-age, and CV of the length at age obtained from the analysis.

Table A.1 : Estimates of mean length-at-age, standard deviation of the mean length-at-age, and CV of length-at-age corresponding to the MLEs of the model parameters.

Age	Mean length at age (cm)	σ_a	CV_a	Age	Mean length at age (cm)	σ_a	CV_a
1	5.5	0.74	0.14	24	25.3	2.20	0.09
2	7.1	0.94	0.13	25	25.7	2.18	0.08
3	8.6	1.12	0.13	26	26.0	2.15	0.08
4	10.0	1.28	0.13	27	26.3	2.13	0.08
5	11.3	1.43	0.13	28	26.6	2.10	0.08
6	12.5	1.56	0.12	29	26.9	2.06	0.08
7	13.7	1.68	0.12	30	27.2	2.03	0.07
8	14.8	1.78	0.12	31	27.4	1.99	0.07
9	15.8	1.87	0.12	32	27.7	1.95	0.07
10	16.7	1.95	0.12	33	27.9	1.90	0.07
11	17.6	2.01	0.11	34	28.1	1.86	0.07
12	18.5	2.07	0.11	35	28.3	1.81	0.06
13	19.3	2.12	0.11	36	28.5	1.76	0.06
14	20.0	2.16	0.11	37	28.6	1.72	0.06
15	20.7	2.19	0.11	38	28.8	1.66	0.06
16	21.3	2.21	0.10	39	28.9	1.61	0.06
17	22.0	2.23	0.10	40	29.1	1.56	0.05
18	22.5	2.24	0.10	41	29.2	1.51	0.05
19	23.1	2.25	0.10	42	29.3	1.45	0.05
20	23.6	2.25	0.10	43	29.4	1.40	0.05
21	24.0	2.24	0.09	44	29.6	1.34	0.05
22	24.5	2.23	0.09	45	29.7	1.28	0.04
23	24.9	2.22	0.09	46	29.8	1.22	0.04

10. Appendix B

SS2 data file (lst.dat) and control file (lst.ctl) for the base-case model.

10.1 Data file

```
#*****************************************
#base-case longspine thornyhead datafile
#lst.dat
#G.Fay August 2005
#*****************************************
1964	#_styr
2004	#_endyr
1	#_nseas
	12	#_months/season
1	#_spawn_seas
1	#_Nfleet
1	#_Nsurv
Comm_Trawl%Combined_Slope
0.5	0.5#_surveytiming_in_season
1	#_Ngenders
80	#_Nages
0#_init_equil_catch_for_each_fishery
#_catch_biomass(mtons):_columns_are_fisheries,_rows_are_year*season
13
30
21
10
10
29
42
44
82
93
77
99
54
102
188
263
357
112
412
295
370
729
734
1198
2760
3183
5937
2979
5497
5374
4613
5593
4904
4013
2266
1811
1523
1219
1941
1588
776

8	#_N_cpue_and_surveyabundance_observations
#_year	seas	index	obs	se(log)
1997	1	2	85246	0.08
1998	1	2	65271	0.07
1999	1	2	81313	0.05
```

2000	1	2	84171	0.05
2001	1	2	85424	0.05
2002	1	2	87139	0.06
2003	1	2	104273	0.10
2004	1	2	96814	0.09

2	#_discard_type			
11	#_N_discard_obs			
#Yr	seas	Type	Value	CV
1986	1	1	0.28	0.2
1990	1	1	0.13	0.2
1995	1	1	0.1	0.2
1996	1	1	0.12	0.2
1997	1	1	0.13	0.2
1998	1	1	0.17	0.2
1999	1	1	0.2	0.2
2000	1	1	0.17	0.2
2001	1	1	0.16	0.2
2002	1	1	0.16	0.2
2003	1	1	0.16	0.2

9	#_N_meanbodywt_obs				
#Yr	seas	Type	Part	Value	CV
1978	1	1	2	0.33	0.3
1979	1	1	2	0.32	0.3
1980	1	1	2	0.30	0.3
1986	1	1	1	0.10	0.3
1989	1	1	1	0.10	0.3
2002	1	1	2	0.19	0.2
2002	1	1	1	0.07	0.2
2003	1	1	2	0.17	0.2
2003	1	1	1	0.07	0.2

0.000001	#_comp_tail_compression										
0.0000001	#_add_to_comp										
31	#_N_LengthBins										
5	6	7	8	9	10	11	12	13	14	15	16
	17	18	19	20	21	22	23	24	25	26	27
	28	29	30	31	32	33	34	35			
54 #_N_Length_obs											
#Yr	Seas	Flt/Svy	Gender	Part	Nsamp	datavector(female-male)					
#commerical length comps											
1981	1	1	0	2	2	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0.001412	0.000898	0	0	0.522599	0	0.47509	0
	0	0	0								
1982	1	1	0	2	13	0.005682	0	0	0	0	0
	0	0	0	0	0	0.012311	0	0	0.011837	0.011364	0.004261
	0.033617	0.084754	0.152936	0.150095	0.100852	0.15483	0.116004	0.068655	0.020833	0.023201	0.011837
	0.016098	0	0.020833								
1983	1	1	0	2	44	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0.005238	0.010895
	0.00838	0.057197	0.091138	0.136811	0.228787	0.17159	0.138697	0.080034	0.02556	0.022208	0.00838
	0.005238	0.002095	0.007752								
1984	1	1	0	2	46	0	0	0	0	0	0
	0	0	0	0	0	0.000155	0	0	0.000026	0.000169	0.023725
	0.05822	0.090245	0.158552	0.192698	0.15875	0.115856	0.118789	0.061422	0.008934	0.002119	0.001261
	0.001239	0	0.007841								
1985	1	1	0	2	62	0	0	0	0	0	0
	0	0	0	0	0	0	0.001904	0.000967	0.015201	0.005234	0.019621
	0.051965	0.082332	0.121903	0.160787	0.194277	0.13557	0.109294	0.053382	0.023926	0.011747	0.001538
	0.001979	0	0.008373								
1986	1	1	0	2	30	0	0	0	0	0	0
	0.003366	0	0.002992	0	0.005013	0.006434	0.002174	0.012389	0.041353	0.017357	0.03451
	0.06212	0.132135	0.100223	0.136075	0.189202	0.118393	0.065586	0.039967	0.011784	0.00985	0.00166
	0	0	0.007419								
1986	1	1	0	2	1	0	0	0	0	0	0
	0	0	0	0	0.003112	0	0	0	0.010975	0	0.025717

	0.021949	0.061425	0.080426	0.178215	0.189517	0.152826	0.097133	0.030958	0.092219	0.018509	0.020311
	0.016708	0	0								
1987	1	1	0	2	22	0	0	0	0	0	0
	0	0	0.000034	0	0	0.003135	0	0.022234	0	0.002749	0.030271
	0.107273	0.11531	0.205198	0.191387	0.099462	0.118001	0.065174	0.017843	0.008008	0.013477	0.000146
	0.000298	0	0								
1988	1	1	0	2	3	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0
	0	0.157548	0.101368	0.108664	0.174646	0.136786	0.186859	0.067171	0.015877	0.034196	0
	0	0	0.016886								
1989	1	1	0	2	19	0	0	0	0	0	0
	0	0	0.000501	0.001392	0.000427	0.002948	0.011271	0.006338	0.012538	0.029904	0.059557
	0.082124	0.16804	0.144162	0.131763	0.143355	0.106023	0.080783	0.018442	0.000189	0.0002	0.000005
	0	0	0.000039								
1990	1	1	0	2	26	0	0	0	0	0	0
	0	0.002232	0.000119	0.000034	0.003021	0.001488	0.005631	0.013058	0.040929	0.070263	0.07149
	0.09672	0.20246	0.166457	0.152978	0.081036	0.040494	0.040251	0.008906	0.002338	0	0.000097
	0	0	0								
1990	1	1	0	2	45	0	0	0	0	0	0
	0.000103	0	0.000343	0.000333	0.000751	0.000788	0.001282	0.005038	0.018463	0.028734	0.027593
	0.039768	0.020379	0.078078	0.105303	0.221508	0.196787	0.139771	0.052362	0.020893	0.031295	0.010107
	0.000077	0.000006	0.000237								
1991	1	1	0	2	38	0.000047	0	0	0	0	0
	0	0	0.000125	0.000008	0.000285	0.000189	0.0009	0.001018	0.00651	0.00587	0.067641
	0.132505	0.161597	0.117214	0.1857	0.167411	0.08641	0.034869	0.018952	0.009783	0.001314	0.001512
	0.000051	0	0.000089								
1991	1	1	0	2	41	0	0	0	0	0	0
	0	0	0	0.001756	0.000021	0.000513	0.002275	0.002782	0.008434	0.032977	0.035873
	0.096837	0.177799	0.18438	0.109724	0.108461	0.102609	0.070596	0.028628	0.02874	0.006803	0.000788
	0.000004	0	0								
1992	1	1	0	2	41	0	0	0	0	0	0.000152
	0.000423	0.000144	0.00041	0.001589	0.005468	0.005853	0.016307	0.008296	0.029916	0.044451	0.056735
	0.116992	0.150297	0.120494	0.152048	0.120941	0.094807	0.051625	0.01827	0.001557	0.000781	0.000205
	0.000016	0.000016	0.002209								
1992	1	1	0	2	47	0	0	0	0.000004	0.000009	0.000175
	0.00045	0.000661	0.000291	0.002588	0.008609	0.003003	0.00958	0.014795	0.030425	0.037105	0.078169
	0.093392	0.115368	0.152468	0.151605	0.112554	0.043693	0.099135	0.008159	0.019455	0.000838	0.005636
	0.000008	0.011822	0.000001								
1993	1	1	0	2	41	0	0	0	0	0	0.000123
	0.000178	0.000065	0.000117	0.000565	0.013579	0.000864	0.003091	0.006283	0.016398	0.057281	0.07316
	0.106097	0.154927	0.199193	0.088064	0.154742	0.077209	0.023049	0.014932	0.009579	0.000285	0.000003
	0.000212	0.000001	0								
1993	1	1	0	2	11	0	0	0	0	0	0.000385
	0.000379	0.000226	0.000179	0.001779	0.002985	0.003053	0.003482	0.011541	0.010513	0.007336	0.037019
	0.075787	0.105804	0.110265	0.125253	0.139322	0.186493	0.10977	0.055821	0.004055	0.004828	0.003725
	0	0	0								
1994	1	1	0	2	61	0	0	0	0	0	0.000035
	0.000035	0.001957	0.004754	0.004349	0.02049	0.008047	0.01855	0.01495	0.040395	0.065954	0.076517
	0.100855	0.147713	0.118924	0.104038	0.106269	0.095912	0.044707	0.015342	0.007042	0.000775	0.00191
	0.000478	0.000002	0								
1994	1	1	0	2	1	0	0	0.011302	0	0.035585	0.010508
	0	0.022781	0.017042	0.051038	0.033201	0.068344	0.059426	0.103841	0.125298	0.118587	0.110287
	0.088124	0.092715	0.021634	0.013422	0.006976	0.00777	0	0.002119	0	0	0
	0	0	0								
1995	1	1	0	2	83	0	0	0	0	0.00001	0.001688
	0.0003	0.00013	0.000958	0.002108	0.000282	0.004678	0.010784	0.007996	0.028621	0.056461	0.074311
	0.099287	0.106379	0.117816	0.15884	0.109966	0.10744	0.05871	0.033434	0.011378	0.005295	0.000076
	0.002589	0.000425	0.000038								
1996	1	1	0	2	75	0	0	0	0	0	0.001695
	0.001325	0.000628	0.002951	0.001092	0.003182	0.014425	0.021569	0.026683	0.038841	0.050129	0.073054
	0.127677	0.106375	0.13436	0.141578	0.114933	0.070986	0.031863	0.019622	0.010287	0.005278	0.001417
	0	0.000005	0.000044								
1996	1	1	0	2	12	0	0	0	0	0	0
	0	0	0.001686	0.001122	0.002165	0.003774	0.004141	0.014809	0.031721	0.056334	0.068639
	0.161814	0.184683	0.141876	0.161064	0.07155	0.057717	0.023326	0.012695	0.000841	0.000014	0.000022
	0.000006	0	0								
1997	1	1	0	2	63	0	0	0	0	0	0.000089
	0.000123	0.000296	0.000242	0.000166	0.000353	0.002667	0.002678	0.011128	0.011653	0.031661	0.067898
	0.098429	0.138604	0.142092	0.16252	0.158986	0.108668	0.031189	0.021396	0.008643	0.00037	0.000047
	0.000087	0	0.000017								

1997	1	1	0	2	112	0	0	0	0.002443	0.003963	0.005145
	0.007843	0.006366	0.013068	0.007574	0.013467	0.008054	0.011945	0.021252	0.018143	0.040878	0.058263
	0.101754	0.111824	0.14451	0.129731	0.08862	0.084322	0.050035	0.031648	0.017061	0.011099	0.002671
	0.001023	0.005462	0.001834								
1998	1	1	0	2	41	0	0	0	0	0.004488	0.00012
	0.003581	0.002569	0.004971	0.001295	0.008566	0.011957	0.028272	0.060663	0.070577	0.097142	0.117724
	0.160233	0.138433	0.117367	0.052996	0.053122	0.035373	0.012919	0.008597	0.004704	0.002215	0.000127
	0.001797	0.000027	0.000165								
1998	1	1	0	2	30	0	0	0	0	0	0
	0	0	0.000415	0.005531	0.000512	0.004503	0.000011	0.000097	0.018119	0.025868	0.046475
	0.084462	0.09273	0.129643	0.153592	0.179017	0.099592	0.097758	0.03321	0.021853	0.002381	0.002007
	0	0	0.002227								
1999	1	1	0	2	33	0	0	0	0	0	0
	0.000042	0.007807	0.00321	0.018143	0.017532	0.005706	0.010676	0.012512	0.039346	0.073259	0.07428
	0.148205	0.165055	0.168333	0.094496	0.092807	0.037664	0.010471	0.008029	0.004686	0.00465	0.003064
	0.000026	0	0								
1999	1	1	0	2	40	0	0	0	0	0	0
	0	0	0	0.004178	0.00023	0.0047	0.000022	0.016932	0.02242	0.047987	0.038334
	0.058782	0.132145	0.142222	0.144477	0.158351	0.103705	0.067673	0.034511	0.015938	0.004061	0.001403
	0	0	0.001929								
2000	1	1	0	2	41	0	0	0	0	0	0
	0	0.000002	0.004921	0.000062	0.000155	0.003779	0.009415	0.009554	0.022594	0.037518	0.048203
	0.084071	0.138212	0.151534	0.196091	0.132603	0.075849	0.049382	0.016558	0.011393	0.002878	0.003766
	0.000087	0.000052	0.001322								
2000	1	1	0	2	33	0	0	0	0	0	0
	0	0	0	0.000894	0.011144	0.000596	0.001382	0.004425	0.013878	0.031868	0.03943
	0.08025	0.109857	0.161042	0.144241	0.134515	0.118165	0.086545	0.04258	0.002931	0.016256	0
	0.000001	0	0								
2001	1	1	0	2	43	0.000236	0	0	0	0.000004	0.000071
	0	0.000142	0.000001	0.005094	0.018309	0.037156	0.032811	0.044131	0.044497	0.060425	0.090059
	0.139104	0.134087	0.173502	0.057975	0.097253	0.040368	0.002834	0.021228	0.000327	0.000359	0.000011
	0.000003	0.000003	0.00001								
2001	1	1	0	2	42	0	0	0	0	0	0
	0	0	0	0	0	0.000037	0.002909	0.004847	0.002066	0.017321	0.059954
	0.076495	0.120544	0.134913	0.159308	0.191892	0.114522	0.076032	0.027862	0.009663	0.001344	0.000038
	0.000137	0.000102	0.000013								
2001	1	1	0	2	3	0	0	0	0	0	0
	0	0	0	0	0	0.000402	0.000365	0.003656	0.028018	0.181602	0.211344
	0.213892	0.168009	0.076042	0.05753	0.035068	0.019227	0.00446	0.000153	0	0.000007	0
	0.000067	0.000089	0.000067								
2002	1	1	0	2	78	0.007829	0	0.000015	0.000053	0.000031	0
	0.002501	0.001019	0.001736	0.00457	0.003133	0.007132	0.007561	0.017029	0.03364	0.058358	0.08989
	0.101454	0.114387	0.151484	0.125482	0.123682	0.080116	0.040901	0.011461	0.00585	0.001776	0.000786
	0.004583	0.003474	0.000066								
2002	1	1	0	2	44	0	0	0	0	0	0
	0	0	0.000575	0	0.000014	0.000644	0.002305	0.001794	0.008198	0.04756	0.079932
	0.108994	0.139582	0.139075	0.129719	0.15082	0.12114	0.051518	0.008775	0.004578	0.004624	0.00007
	0	0	0.000084								
2002	1	1	0	2	2	0	0	0	0	0	0
	0	0.004733	0	0.024083	0.086307	0.052759	0.041901	0.043181	0.088064	0.125834	0.138623
	0.107763	0.059527	0.106269	0.075297	0.033827	0	0.011832	0	0	0	0
	0	0	0								
2003	1	1	0	2	56	0.006615	0	0	0	0	0
	0.00005	0	0	0.000018	0.00031	0.000446	0.000705	0.002382	0.022455	0.034727	0.070217
	0.118012	0.116754	0.212842	0.164712	0.134828	0.078393	0.027421	0.006441	0.002501	0.000169	0
	0	0	0								
2003	1	1	0	2	50	0	0	0	0	0	0
	0	0	0.002054	0	0.001532	0	0.000915	0.003981	0.006268	0.030786	0.055625
	0.083115	0.115239	0.116967	0.167566	0.197448	0.110038	0.070073	0.023821	0.010768	0.001424	0.001214
	0	0.001164	0.000001								
2003	1	1	0	2	11	0	0	0	0	0	0
	0.005437	0.011883	0.015215	0.018416	0.0335	0.042883	0.035649	0.056082	0.105937	0.086775	0.138165
	0.126063	0.130843	0.074279	0.062966	0.028896	0.013593	0.008419	0.003376	0.000921	0.000702	0
	0	0	0								
2004	1	1	0	2	43	0.000033	0	0	0	0	0
	0.005709	0	0	0.000044	0.009819	0.000209	0.008377	0.000863	0.0182	0.040109	0.077057
	0.100703	0.193195	0.161521	0.185971	0.093155	0.065269	0.015101	0.021042	0.002298	0.001316	0
	0.000008	0	0								
2004	1	1	0	2	32	0	0	0	0	0	0
	0	0	0.001883	0	0.003579	0.005644	0.007193	0.013868	0.033293	0.049152	0.058067

0.110604 0.093426 0.168521 0.137507 0.099526 0.109709 0.063101 0.03076 0.01416 0 0
0 0.000007 0
2004 1 1 0 2 3 0 0 0 0 0 0
0 0 0.016297 0.064822 0.050173 0.015198 0.061352 0.113165 0.046145 0.076176 0.104924
0.091923 0.098515 0.099802 0.066287 0.042116 0.033693 0.01117 0 0 0.00824 0
0 0 0
#Slope survey
1997 1 2 1 2 134 5.14E-04 0.000588902 0.005418882
0.012662516 0.029093812 0.038177054 0.043234368 0.051071046
0.050959955 0.056626599 0.055808501 0.05587681 0.061332996
0.063013302 0.06769315 0.066592583 0.074721699 0.069414801
0.055269084 0.048247228 0.039108641 0.026013608 0.016684797
0.00768141 0.002241899 0.001271015 0.000486514 0.000117955 4.06E-05
3.32E-05 2.87E-06
1998 1 2 0 0 162 0.000443 0.001493 0.007461 0.018866 0.030567 0.035161
0.038396 0.046507 0.045355 0.046456 0.045373 0.042381 0.048414 0.057484 0.059834 0.059647 0.064216
0.065115 0.06656 0.069682 0.05603 0.044026 0.026831 0.01233 0.008292 0.002259 0.000397 0.00027
0.000039 0.00003 0.000087
1999 1 2 1 2 146 7.06E-05 1.35E-04 0.004448753 0.013568931
0.022931732 0.026819785 0.037618423 0.042457185 0.046751954
0.047089441 0.051635577 0.049614272 0.051521233 0.058620793
0.059406643 0.066246011 0.074458557 0.073614372 0.068877793
0.06730934 0.054795467 0.039621069 0.020806643 0.01238085
0.004910219 0.003196582 0.000884331 0.000154524 2.27E-05 1.19E-05 1.98E-05
1999 1 2 0 0 209 0.000095 0.00238 0.012105 0.021193 0.022115 0.028747
0.032414 0.040445 0.045103 0.045647 0.047138 0.043325 0.048334 0.053517 0.05734 0.062213 0.064403
0.070241 0.07718 0.071815 0.062115 0.040429 0.028009 0.01411 0.007585 0.001248 0.000433 0.000196
0.000128 0 0
2000 1 2 1 2 159 1.89E-04 1.15E-03 0.007553044 0.009831313
0.020916429 0.030021117 0.037285851 0.04446878 0.052362718
0.048356791 0.058230604 0.055421034 0.060379297 0.051953422
0.066524855 0.069085122 0.064135852 0.067458711 0.065539376
0.061164513 0.048748383 0.036793193 0.0216709 0.011890311 0.005519054
0.002179206 0.001001794 0.000133723 3.65E-05 0 0
2000 1 2 0 0 196 0.000291 0.00215 0.006026 0.013823 0.023689 0.023498
0.027852 0.03682 0.046554 0.05038 0.057717 0.05225 0.051279 0.055991 0.06352 0.062732 0.065806
0.070124 0.070818 0.070396 0.056775 0.041082 0.028082 0.012544 0.006594 0.002097 0.000592 0.000403
0.000082 0.00002 0.000015
2001 1 2 1 2 160 0 0.00013966 0.003652816
0.016006625 0.022027735 0.028830889 0.036736967 0.04416575
0.051884093 0.049958341 0.050299556 0.059187253 0.051450712
0.055152298 0.064308155 0.064874179 0.06463139 0.076855551
0.069849363 0.063129985 0.047572298 0.038197959 0.021570113
0.011688765 0.004808515 0.002130849 0.000634234 0.000186303 6.96E-05
0 0
2001 1 2 0 0 213 0.000433 0.001288 0.007978 0.01492 0.016741 0.028038
0.025396 0.032058 0.037034 0.046777 0.048742 0.052442 0.052884 0.05498 0.066915 0.066817 0.071826
0.076156 0.072963 0.071662 0.061279 0.04177 0.028638 0.013392 0.005402 0.002511 0.000666 0.000179
0.000017 0 0.000094
2002 1 2 0 0 281 0.000398 0.002681 0.008461 0.012463 0.018207 0.020574
0.024707 0.028053 0.035795 0.042652 0.051591 0.060005 0.062661 0.061937 0.072391 0.074138 0.075131
0.073803 0.070451 0.069087 0.05589 0.036627 0.025049 0.010582 0.00436 0.001673 0.000366 0.000248
0.00002 0 0
2003 1 2 0 0 200 0.000133 0.000977 0.005675 0.01224 0.015254 0.019518
0.019996 0.023086 0.028114 0.028593 0.041266 0.04749 0.065468 0.062848 0.068546 0.070545 0.072833
0.071983 0.080892 0.089336 0.066096 0.049263 0.032961 0.014776 0.008517 0.002185 0.001033 0.000171
0.000095 0.000077 0.000032
2004 1 2 0 0 158 0.000518 0.004926 0.015494 0.025757 0.024491 0.026146
0.024018 0.029135 0.029392 0.036982 0.047253 0.044065 0.054175 0.05906 0.069467 0.069784 0.07739
0.080735 0.06989 0.070444 0.057954 0.037718 0.024329 0.0131 0.005268 0.002001 0.00012 0.000206
0.000049 0 0.000132

0 #_N_age_bins

0 #_N_ageerror_definitions

0 #_N_Agecomp_obs
#Yr Seas Flt/Svy Gender Part Ageerr Lbin_lo Lbin_hi Nsamp datavector(female-male)

```
0       #_N_MeanSize-at-Age_obs
#Yr     Seas    Flt/Svy Gender  Part    Ageerr  Ignore  datavector(female-male)
#       samplesize(female-male)

0       #_N_environ_variables
0       #_N_environ_obs

999
```

10.2 CONTROL FILE

```
#******************************************
#base-case longspine thornyhead control file
#lst.ctl
#G.Fay August 2005
#******************************************
#  lst.ctl
#  datafile:_lst.dat
1       #_N_growthmorphs

#_assign_sex_to  each_morph_(1=female;_2=male)
1

1       #_N_Areas_(populations)

#_each_fleet/survey_operates_in_just_one_area
#_but_different_fleets/surveys_can be assigned_to_share_same_selex
1       1#area_for_each_fleet/survey

0       #do_migration_(0/1)

1       #_N_Block_Designs
1       #_N_Blocks_per_Design(Block_1_always_starts_in_styr)
1964    2004    #_Block_Design_1


#Natural_mortality_and_growth_parameters_for_each_morph
11      #_Last_age_for_natmort_young
12      #_First_age_for_natmort_old
3       #_age_for_growth_Lmin
40      #_age_for_growth_Lmax
-4      #_MGparm_dev_phase
#LO     HI      INIT    PRIOR   PR_type SD      PHASE   env-variable    use_dev dev_minyr dev_maxyr
        dev_stddev
0.001   0.3     0.06    0.1     0       99      4       0       0       0       0       0.5
        0       0       #M1_natM_young
-1.001  3       0       0       0       99      -5      0       0       0       0       0.5
        0       0       #M1_natM_old_as_exponential_offset(rel_young)
5       25      8.573   10      0       99      -2      0       0       0       0       0.5
        0       0       #M1_Lmin
5       40      29.08   30      0       99      -2      0       0       0       0       0.5
        0       0       #M1_Lmax
0.05    0.2     0.064   0.1     0       99      -3      0       0       0       0       0.5
        0       0       #M1_VBK
0.015   0.25    0.131   0.1     0       99      -6      0       0       0       0       0.5
        0       0       #M1_CV-young
-3      5       -0.892  0       0       99      -6      0       0       0       0       0.5
        0       0       #M1_CV-old_as_exponential_offset(rel_young)

# Add 2+2*gender lines to read the wt-Len and mat-Len parameters
-3      3       4.3E-06 4.4E-06 0       99      -3      0       0       0       0       0.5
        0       0       #Female wt-len-1
-3      8       3.352   3.34694 0       99      -3      0       0       0       0       0.5
        0       0       #Female wt-len-2
0.001   40      17.826  20      0       99      -3      0       0       0       0       0.5
        0       0       #Female mat-len-1
-3      3       -1.79   -0.8    0       99      -3      0       0       0       0       0.5
        0       0       #Female mat-len-2
```

```
-3	3	1.	1.	0	99	-3	0	0	0	0	0.5
	0	0	#Female eggs/gm intercept
-3	3	0.	0.	0	99	-3	0	0	0	0	0.5
	0	0	#Female eggs/gm slope

# pop*gmorph lines For the proportion of each morph in each area
0	1	1.0	1.0	0	99	-3	0	0	0	0	0.5
	0	0	#frac of morph 1 in area 1

# pop lines For the proportion assigned to each area
0	1	1	1	0	99	-3	0	0	0	0	0.5
	0	0	#frac to area 1

#_custom-env_read
0	#_	0=read_one_setup_and_apply_to_all_env_fxns; 1=read_a_setup_line_for_each_MGparm_with_Env-var>0

#_custom-block_read
0	#_	0=read_one_setup_and_apply_to_all_MG-blocks;	1=read_a_setup_line_for_each_block x
MGparm_with_block>0

#	LO	HI	INIT	PRIOR	Pr_type	SD	PHASE

#_Spawner-Recruitment_parameters
1	# SR_fxn:  1=Beverton-Holt
#LO	HI	INIT	PRIOR	Pr_type	SD	PHASE
3	31	12.	9.3	0	99	1	#Ln(R0)
0.2	1	0.75	0.71	2	99	-4	#steepness
0	2	0.6	0.65	0	99	-4	#SD_recruitments
-5	5	0	0	0	99	-3	#Env_link
-5	5	0	0	0	99	-4	#init_eq
0	#env-var_for_link
#	recruitment_residuals
#	start_rec_year	end_rec_year	Lower_limit	Upper_limit	phase
#	2008	2012	-15	15	-5
	1980	2002	-15	15	4

#init_F_setupforeachfleet
#LO	HI	INIT	PRIOR	PR_type	SD	PHASE
0	1	0.00	0.01	0	99	-1

#_Qsetup
#_add_parm_row_for_each_positive_entry_below(row_then_column)
#-Float(0/1)	#Do-power(0/1)	#Do-env(0/1)	#Do-dev(0/1)  #env-Var	#Num/Bio(0/1)	for
	each	fleet	and	survey
0	0	0	0	0	1
1	0	0	0	0	1
#LO	HI	INIT	PRIOR	PR_type	SD	PHASE	env-variable
-2	2	-0.356675	-0.356675	0	0.2	5	#Q for combined slope survey
#-2	2	0	0	0	0.2	5	#Q for combined slope survey

#_SELEX_&_RETENTION_PARAMETERS
#Pattern	Retention(0/1)	Male(0/1)  Special
# Size_selex
2	1	0	0	#_Comm. Trawl
7	0	0	0	#_Combined Slope survey
#_Age_selex
11	0	0	0	#_Comm. Trawl
11	0	0	0	#_combined Slope survey

#LO	HI	INIT	PRIOR	PR_type	SD	PHASE	env-variable	use_dev	dev_minyr dev_maxyr
	dev_stddev	Block_Pattern
#Size-Selectivity for Comm. Trawl (double logistic)
#5	70	24	45	0	99	2	0	0	0	0	0.5
	0	0	#infl_for_logistic
#0.00001	60	5	15	0	99	2	0	0	0	0	0.5
	0	0	#95%width_for_logistic
5	35	23	24	0	99	-2	0	0	0	0	0.5
	0	0	#peak
0.00001	0.1	0.0001	0	0	99	-5	0	0	0	0	0.5
	0	0	#init
```

```
-10.    50.  0.0     0.0     0       99      2       0       0       0       0       0.5     0
             0       #infl
0.0000001 10 0.3     0.3     0       99      2       0       0       0       0       0.5
             0       0       #slope
-5           15      -1.     -1      0       99      3       0       0       0       0       0.5
             0       0       #final
-10.          5      0.0     0.0     0       99      3       0       0       0       0       0.5
             0       0       #infl2
0.00001      100     0.3     .3      0       99      3       0       0       0       0       0.5
             0       0       #slope2
0.           10      0.1     0       0       99      4       0       0       0       0       0.5
             0       0       #width of top
#Retention for Comm. Trawl
5            70      10      19      0       99      3       0       0       0       0       0.5
             0       0       #infl_for_logistic
0.00001      60      10      10      0       99      3       0       0       0       0       0.5
             0       0       #95%width_for_logistic
0.0001       1.      1.      1       0       99      -4      0       0       0       0       0.5
             0       0       #final
-10.          5      0.0     0.0     0       99      -4      0       0       0       0       0.5
             0       0
#Size selectivity for slope survey
#5           70      15      25      0       99      2       0       0       0       0       0.5
             0       0       #infl_for_logistic
#0.00001     60      5       15      0       99      2       0       0       0       0       0.5
             0       0       #95%width_for_logistic
5            35      23.5    24      0       99      2       0       0       0       0       0.5
             0       0       #peak
0.000001     0.5     0.001   0       0       99      4       0       0       0       0       0.5
             0       0       #init
-10.    5    0.0     0.0     0       99      2       0       0       0       0       0.5     0
             0       #infl
0.000001     100     0.3     0.3     0       99      2       0       0       0       0       0.5
             0       0       #slope
-15          15      -1.     9       0       99      3       0       0       0       0       0.5
             0       0       #final
-10.         15      0.0     0.0     0       99      3       0       0       0       0       0.5
             0       0       #infl2
0.00001      10      0.3     .3      0       99      3       0       0       0       0       0.5
             0       0       #slope2
0.           10      0.1     4       0       99      4       0       0       0       0       0.5
             0       0       #width of top
#Age selectivity for comm. trawl
0.01         10      1.5     25      0       99      -5      0       0       0       0       0.5
             0       0       #infl_for_logistic
0.00001      60      40      15      0       99      -5      0       0       0       0       0.5
             0       0       #95%width_for_logistic#Size-Selectivity for Combined Slope survey (logistic)
#Age selectivity for slope survey
0.01         10      1.5     25      0       99      -5      0       0       0       0       0.5
             0       0       #infl_for_logistic
0.00001      60      40      15      0       99      -5      0       0       0       0       0.5
             0       0       #95%width_for_logistic


#_custom-env_read
1            #_      0=read_one_setup_and_apply_to_all;_1=Custom_so_read_1_each;

#_custom-block_read
1            #_      0=read_one_setup_and_apply_to_all;_1=Custom_so_see_detailed_instructions_for_N_rows_in_Custom_setup
#-10 10 0 0 0 99 4
#            LO      HI      INIT    PRIOR   PR_type SD      PHASE

-4           #_phase_for_selex_parm_devs

1            #_max_lambda_phases:_read_this_Number_of_values_for_each_componentxtype_below
1            #_include (1) or not (0) the constant offset For Log(s) in the Log(like) calculation
#_survey_lambdas
0            1
#_discard_lambdas
1            0
```

```
#_meanbodywt
1
#_lenfreq_lambdas
1           1
#_age_freq_lambdas
0           0
#_size@age_lambdas
0           0
#_initial_equil_catch
0
#_recruitment_lambda
1
#_parm_prior_lambda
1
#_parm_dev_timeseries_lambda
0
# crashpen lambda
100
#max F
0.9

999         #_end-of-file
```