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EXECUTIVE SUMMARY

Doonan, I.J.; McMillan, P.J.; Coburn, R.P.; Hart, A.C. (2008). Assessment of OEO 4 smooth oreo for 2006–07.

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The biomass of smooth oreo in OEO 4 was estimated with Bayesian methods using a CASAL age-structured population model. Input data included research and observer-collected length data, three absolute abundance estimates from research acoustic surveys carried out in 1998 (TAN9812), 2001 (TAN0117, AEX0101), and 2005 (TAN0514, SWA0501), and relative abundance indices from standardised catch per unit effort analyses. Biomass estimates were made separately for the west and east parts of OEO 4 divided at 178° 20' W. This separation was based on an analysis of commercial catch, standardised CPUE, and research trawl and acoustic results which suggested distinct fisheries and fish distribution patterns for the west and east parts of OEO 4. The base case used the east/west split, the 1998, 2001, and 2005 acoustic abundance estimates, three standardised CPUE indices, the observer length data, the 2001 and 2005 acoustic survey length data, separate stocks in the east and west parts, and a fixed M (0.063) and growth. Only the left-hand limb (up to the peak of curve) of the observer and acoustic survey length frequency distributions were fitted in the model, unlike the 2003 assessment model where all the length distribution data were fitted.

For the base case, the median estimate of B_0 for the mature fish for OEO 4 was 202 000 t (90% confidence interval of 178 000–231 000 t). The estimate of $B_{current}$ was 115 000 t (90% confidence interval of 91 600–144 000 t), 57% of B_0.

These results suggest that there are no immediate sustainability issues for OEO 4 smooth oreo, but there are problems with the inputs to the assessment analysis that were not resolved in this study. The main concern is the use of the three acoustic survey abundance estimates as absolute values. In particular, the large proportion of the smooth oreo acoustic abundance from all surveys that came from the Layer ("Low" in 1998 and 2001) plus Background mark-types, i.e., 50% in the 1998, 74% in the 2001, and 48% in the 2005 surveys. Determining the exact mixture of species in the Layer marks had unmeasured uncertainty that may have resulted in an overestimate of the smooth oreo abundance. Layers are not normally fished by the commercial fleet, but within the model the vulnerable selectivity allocated part of the Layer abundance to the fished population because the selectivity was based on length distributions. There is more confidence assigned to the acoustic abundance estimated for the School mark-types because these marks were composed mostly of smooth oreo and they are fished. Other uncertainties in the biomass estimates are due to the sensitivity to the target strength of smooth oreo and the use of deterministic recruitment.

1. INTRODUCTION

1.1 Overview

This work addresses the following objectives in MFish project "Oreo stock assessment" (OEO2006/02).

Overall objective

1. To carry out a stock assessment of black oreo (*Allocyttus niger*) and smooth oreo (*Pseudocyttus maculatus*), including estimating biomass and sustainable yields.

Specific objective

4. To carry out a stock assessment, including reviewing and summarising historical biological data from the MFish observer programme, and estimating biomass and sustainable yields for the following areas: smooth oreo in OEO 4.

A new stock assessment for smooth oreo in OEO 4 (Figure 1) is presented based on a new absolute abundance estimate derived from a research acoustic survey carried out in 2005 (TAN0514, SWA0501), plus two previous absolute abundance estimate from 1998 (TAN9812) and 2001 (TAN0117, AEX0101), and relative abundance indices from revised and updated standardised CPUE analyses.

Early major stock assessments in 1997 and 2001 aimed to estimate virgin and current biomass (Doonan et al. 1997a, 2001) using a stock reduction analysis (PMOD). The 1997 assessment used relative abundance estimates from standardised CPUE, and relative abundance estimates from past trawl surveys (1991–93, 1995) with q values constrained. That assessment was considered uncertain because of the problems with the trawl survey catchabilities (Doonan et al. 1997a). The 2001 assessment used the single 1998 absolute abundance estimate as well as the relative abundance estimates from standardised CPUE (base case) and estimated a 95% confidence interval of 100 000 to 148 000 t for B_0, and long-term MCY of 1600–2400 t compared to catch levels of about 6200 t (1989–90 to 1998–99).

In 2003, the stock assessment was updated using a CASAL age-structured population model (Bull et al. 2002). This took account of the sex and maturity status of the fish and allowed inclusion of length frequency data. The assessment modelled separate west and east fisheries as well as a combined area fishery (OEO 4). Initial model runs gave poor fits to the data and indicated that there were major conflicts between the absolute abundance estimates, the observer collected length data, and previous estimates (Doonan et al. 1997b) of growth and natural mortality (M) (Doonan et al. 2003a).

For the 2003 base case, the median estimate for the mature fish B_0 for OEO 4 was 172 000 t (90% confidence interval of 147 000–209 000 t). The estimate of $MCY_{long\text{-}term}$ was 4200 t and the mid-year vulnerable biomass B_{MCY} was 37 000 t. The CAY estimate was 7700 t and CSP was 3500 t. The smooth oreo catch in OEO 4 from 2001–02 was 4284 t, about the same as the long-term MCY. These results suggested that there were no immediate sustainability issues, but there were problems with the inputs to the assessment that were not resolved in that study

Smooth oreo are caught throughout the year by bottom trawling at depths of 800–1300 m in southern New Zealand waters. The OEO 4 south Chatham Rise fishery is the largest oreo fishery in the EEZ and operates between 176° E and about 172° W, mostly on undulating terrain (short plateaus, terraces, and "drop-offs") at the west end, and mostly on hills in the east. Most smooth oreo is caught as a bycatch to orange roughy fishing. Black oreo is the other main species caught and has been a small bycatch from 1994–95. There is no known recreational or Maori customary catch of oreos.

Smooth oreo are thought to be slow-growing and long-lived with the larger females reaching maximum sizes of around 50 cm TL at about 80 years and males reaching 45 cm and 70 years (Doonan et al. 1997b). Age estimates for New Zealand fish are unvalidated but similar results were reported by

Australian workers (D.C. Smith and B.D. Stewart, Victorian Fisheries Research Institute, unpublished). They are a schooling species and form localised aggregations to feed (all year) or to spawn (October-December).

Stock structure of Australian and New Zealand samples of smooth oreo were examined using genetic (allozyme and mitochondrial DNA) and morphological counts (fin rays, etc.). No differences between New Zealand and Australian smooth oreo samples were found using these techniques (Ward et al. 1996). A broad scale stock is suggested by these results, but this seems unlikely given the large distance between New Zealand and Australia. A New Zealand pilot study examined smooth oreo stock relationships using samples from four management areas (OEO 1, OEO 3A, OEO 4, and OEO 6) of the New Zealand EEZ. Techniques used included genetic (nuclear and mitochondrial DNA), lateral line scale counts, settlement zone counts, parasites, otolith microchemistry, and otolith shape. Otolith shape from OEO 1 and OEO 6 was different from that from OEO 3A and OEO 4 samples. Weak evidence from parasite data, one gene locus, and otolith microchemistry suggested that OEO 3A samples were different from those from other areas. Lateral line scale and otolith settlement zone counts showed no differences between areas (Smith et al. 1999).

Observations available for stock assessment analysis include biological data from research trawl surveys (1991–93, 1995, *Tangaroa*) but relative abundance estimates from these surveys are considered unreliable because of catchability issues (Doonan et al. 1997a). Absolute abundance estimates were made using acoustic methods in 1998, 2001, and 2005. Annual observer length/catch data are available from 1990–91 on, although sampling was erratic and was influenced by the progression of fishing from west to east with time and possibly by a trend from flat to hill fishing in the east.

Catch history data are available from the late 1970s although the early data and some subsequent data required reconstruction of species catch from known species proportions because of the use of the aggregated species code (OEO) (see 1.2 below). Dumping of unwanted or small fish and accidental loss of fish (lost or ripped codends) were features of oreo fisheries in the early years. These sources of mortality were likely to have been substantial in the early years, but they are now thought to be relatively small. No estimate of mortality from these sources has been made because of lack of data and because they now appear to be small. Estimates of discards of oreos were made for 1994–95 and 1995–96 from MFish observer data. This involved calculating the ratio of discarded oreo catch to retained oreo catch and then multiplying the annual total oreo catch from the New Zealand EEZ by this ratio. Estimates were 207 and 270 t for 1994–95 and 1995–96 respectively (Clark et al. 2000).

1.2 TACCs, catch, and landings data

Oreos are managed as a group that includes black oreo (*Allocyttus niger*, BOE), smooth oreo (*Pseudocyttus maculatus*, SSO), and spiky oreo (*Neocyttus rhomboidalis*, SOR). The last species is not sought by the commercial fleet and is a minor bycatch in some areas, e.g., the Ritchie Bank orange roughy fishery. The management areas used since October 1986 are shown in Figure 1.

Separate catch statistics for each oreo species were not requested in the version of the catch statistics logbook used when the New Zealand EEZ was formalised in April 1978, so the catch for 1978–79 was not reported by species (the generic code OEO was used instead). From 1979–80 onwards the species were listed and recorded separately. When the ITQ scheme was introduced in 1986, the statutory requirement was only for the combined code (OEO) for the Quota Management Reports, and consequently some loss of separate species catch information has occurred even though most vessels catching oreos are requested to record the species separately in the catch-effort logbooks. Reported landings of oreos (combined species) and TACs from 1978–79 until 2005–06 are given in Table 1.

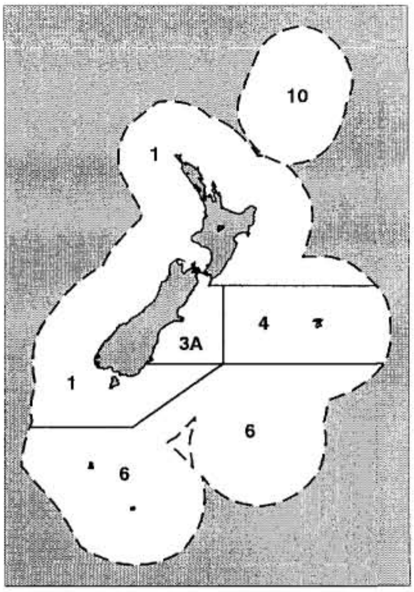

Figure 1: Oreo management areas.

Table 1: Total reported landings and TACCs (t) for all oreo species combined and total estimated catch (t) for smooth oreo (SSO) and black oreo (BOE) for OEO 4 from 1978–79 to 2005–06. – na.

Fishing	Landings		Estimated catch	
year	t	TACC	SSO	BOE
1978–79*	8 041	–	0	0
1979–80*	680	–	114	566
1980–81*	10 269	–	849	5 224
1981–82*	9 296	–	3 352	5 641
1982–83*	3 927	6 750	2 796	1 088
1983–83#	3 209	#	1 861	1 340
1983–84†	6 104	6 750	4 871	1 214
1984–85†	6 390	6 750	4 729	1 651
1985–86†	5 883	6 750	4 921	961
1986–87†	6 830	6 750	5 670	1 160
1987–88†	8 674	7 000	7 771	903
1988–89†	8 447	7 000	6 427	1 087
1989–90†	7 348	7 000	5 320	439
1990–91†	6 936	7 000	5 262	793
1991–92†	7 457	7 000	4 797	1 702
1992–93†	7 976	7 000	3 814	1 326
1993–94†	8 319	7 000	4 805	1 553
1994–95†	7 680	7 000	5 272	545
1995–96†	6 806	7 000	5 236	364
1996–97†	6 962	7 000	5 390	530
1997–98†	7 010	7 000	5 868	811
1998–99†	6 931	7 000	5 613	844
1999–00†	7 034	7 000	5 985	628
2000–01†	7 358	7 000	5 924	799
2001–02†	4 864	5 460	3 806	515
2002–03†	5 402	5 460	4 105	868
2003–04†	6 735	7 000	5 082	972
2004–05†	7 390	7 000	5 848	851
2005–06†	6 828	7 000	5 145	763

Source: FSU from 1978–79 to 1987–88; QMS/MFish from 1988–89 to 2005–06. *, 1 April to 31 March; #, 1 April to 30 September, interim TACs applied. †, 1 October to 30 September.

The OEO 4 TAC was about 7000 t from 1982–83 to 2000–01, but was reduced to 460 t in 2001–02, and then increased again to 7000 t in 2003–04. Reported estimated catches by species from data recorded in catch and effort logbooks (Deepwater, TCEPR, and CELR) are given in Table 1. Soviet catches from the New Zealand area from 1972 to 1977 were assumed to be black oreo and smooth oreo combined and to be from area OEO 3A (Doonan et al. 1995).

2. ASSESSMENT MODEL

2.1 Population dynamics

2.1.1 Partition of the population

The stock assessment model partitioned the OEO 4 smooth oreo population into two sex groups, and age groups 1–70 years, with a plus group. There were two area partitions (west and east), and two fishing partitions. East and west were treated as two stocks since results differed little when using migration or recruitment partitioned into each area.

2.1.2 Annual cycle

The nominal unit time in the model is one year during which processes (e.g., recruitment) were applied. Since these processes cannot be modelled simultaneously they were carried out in a specified sequence (Table 2). For convenience in the specifications, these were grouped into three time steps. Events were given a specified time within the year (month) through the specification of the percentage of natural mortality that was applied, assuming that it was applied uniformly throughout the year. Observations were fitted to model predictions specified by the time step and the time within the year (Table 2).

Table 2: Stock model: timing within a year for processes and when data were fitted. –, not applicable.

Model time step	Time	Process (in the order applied)	Observations fitted: Time	Observations fitted: Description
1	Oct	Recruitment	–	
	Oct	Spawning	–	
	Oct	Increment age	–	
2	Oct	Migration (if applicable)	–	
3	Oct-Sep	Fishing mortality	Oct	Acoustic abundance
			Oct	Acoustic length data
			Mar	CPUE indices
			Mar	Observer length data

2.2 Selectivities, ogives, and other assumptions

Selectivities

Separate age-based selectivity ogives were estimated for each area. Selectivities were estimated for the commercial fishery (catch) and for the acoustic survey (abundance data). When the full length frequencies were fitted, the ogives were logistic curves with parameters for the age of 50% selection and for the ages from 50 to 95% selection. When just the left hand side (LHS) of the length frequencies was fitted, the ogives were effectively knife-edge and were modelled as logistic but with the ages from 50 to 95% selection set to a range between 0 and 1. Young fish (less than about 7 years old) are probably in mid-water and so were not counted by the acoustic survey. At 6–7 years these fish settle on the bottom and are then available to the acoustic survey technique. The young fish are almost fully selected by the trawl gear when they do settle on the bottom, and therefore the estimated selectivity should represent the biological and not the fishing process.

The last observation is particularly relevant to the selectivities for the acoustic abundance data that were estimated from the associated length data collected during the 2001 and 2005 surveys. The length data were collected by trawling, which has a selectivity that could bias the acoustic selectivity. However, the acoustic selectivity is due to the fish settling on the bottom and once settled are fully selected by the trawl gear so the trawl selectivity is irrelevant.

Migration

No migration factors were used.

Maturity

The maturity ogive developed during the 2002 stock assessment was used (see appendix A in Doonan et al. 2003a).

2.3 Modelling methods, parameters, assumptions about parameters

The stock assessment analyses were conducted using CASAL (Bull et al. 2002). This was implemented as an age-structured population model that took account of the sex and maturity status of the fish and allowed inclusion of length frequency data. The Bayesian estimator was employed. The model incorporated deterministic recruitment, life history parameters, and catch history (Table 3). Data fitted in the analysis were the 1998, 2001, and 2005 acoustic abundance estimates (see Table 6), standardised combined CPUE indices (Tables 4a, 4c, & 4d), observer length data (Tables 7 & 8), and the 2001 and 2005 acoustic survey length data (see Figures 9 & 10). The model was used to estimate biomass. These procedures were conducted with the following steps.

1. Model parameters were estimated using maximum likelihood and the prior probabilities.
2. Samples from the joint posterior distribution of parameters were generated with the Markov Chain Monte Carlo procedure (MCMC) using the Metropolis algorithm.
3. A marginal posterior distribution was found for each quantity of interest by integrating the product of the likelihood and the priors over all model parameters; the posterior distribution was described by its median, 5, and 95 percentiles for parameters of interest.

The following assumptions were made in the analyses carried out to estimate biomass.

(a) The acoustic abundance estimates were unbiased absolute values.
(b) The CPUE analyses provided a relative index of abundance for smooth oreo in the whole of OEO 4.
(c) The ranges used for the biological values covered their true values.
(d) One assumed value (0.9) of the maximum fishing mortality (F_{max}) was used in all the analyses of smooth oreo below.
(e) Recruitment was deterministic and followed a Beverton & Holt relationship with steepness of 0.75.
(f) Catch overruns were 0% during the period of reported catch.
(g) The population of smooth oreo in OEO 4 was a discrete stock or production unit.
(h) The catch history was accurate.

3. OBSERVATIONS AND MODEL INPUTS

3.1 East and west fisheries

Initial analysis of OEO 4 oreo catch data showed marked changes in fishing patterns over time. This involved a progression of high catches starting in the west and moving east and appeared to represent successive exploitation of new areas (Figure 2). Areas in the west previously exploited did not later return to sustained high catches. The target species and the type of fishing changed over time with smooth oreo the target species in the west on flat, dropoff, and hills from the late 1970s, with a gradual change to target fishing for orange roughy on hills in the east in the late 1980s (Figure 3). To capture this exploitation pattern, two areas were used and so the CPUE, catch, length, and abundance data were split at 178° 20' W.

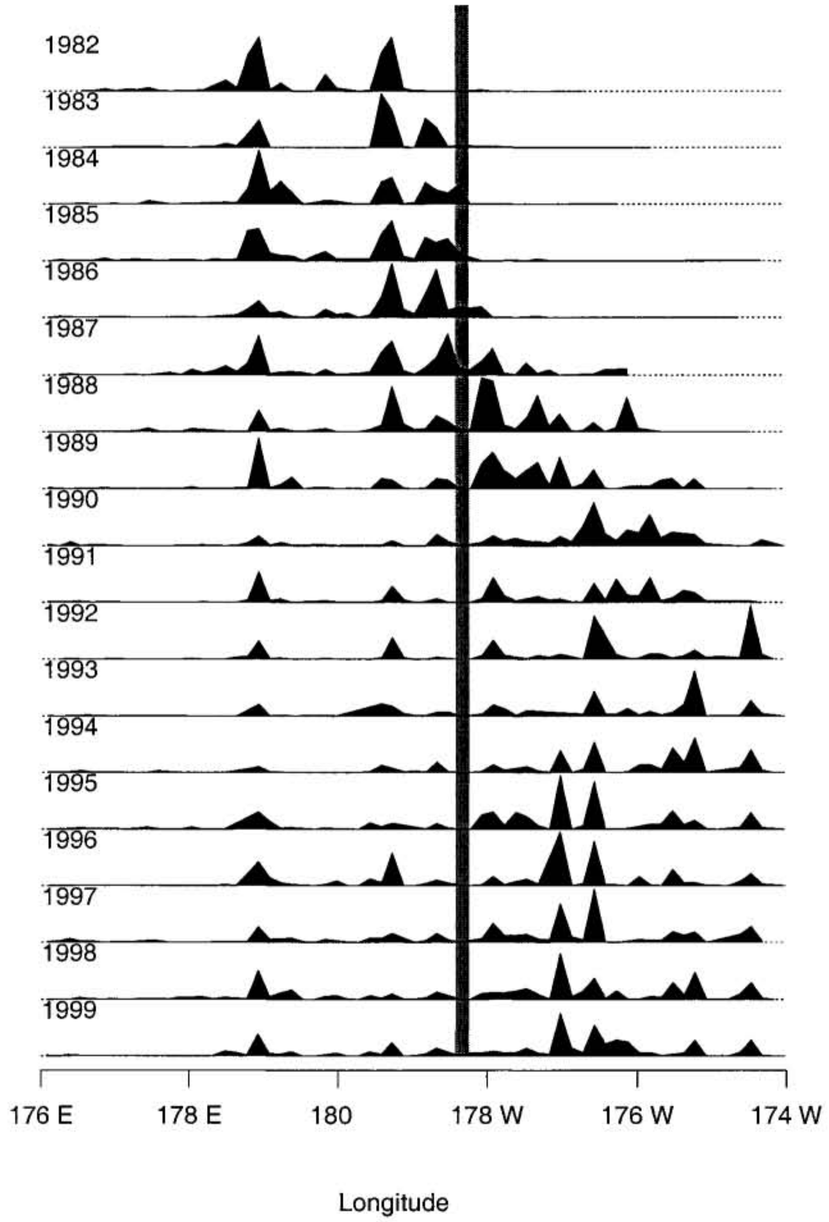

Figure 2: All estimated reported catches of smooth oreo (black shading, t) by longitude over time from OEO 4 on the south Chatham Rise between 176° E and 174° W, south of 44° S. Years are fishing years, e.g., 1982 is 1981–82. There were low reported catches of smooth oreo before 1981–82 so 1982 included that year plus prior catches. Vertical scale is 1000 t between years (horizontal lines). The vertical line at 178° 20' W marks the split between west and east parts of OEO 4.

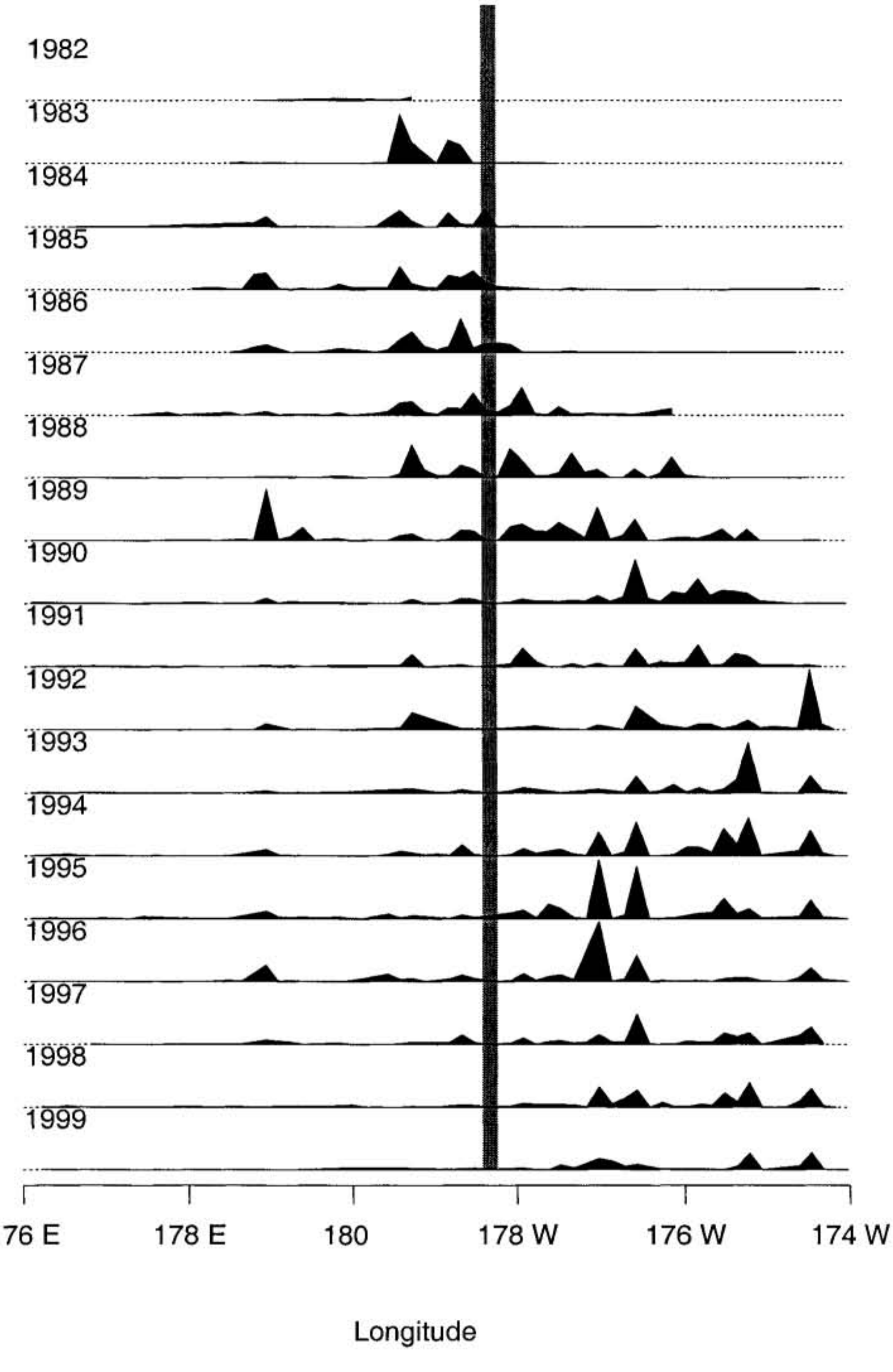

Figure 3: **Estimated reported catches of smooth oreo (black shading, t) where target species was orange roughy, by longitude over time from OEO 4 on the south Chatham Rise between 176° E and 174° W, south of 44° S. Years are fishing years, e.g., 1982 is 1981–82. There were low reported catches of smooth oreo before 1981–82 so 1982 included that year plus prior catches. Vertical scale is 1000 t between years (horizontal lines). The vertical line at 178° 20' W marks the split between west and east parts of OEO 4.**

3.2 Catch history

Catch history is presented in Table 3 and includes the yearly total catch for OEO 4 and catches from west and east (split at 178° 20' W). Catches from 1978–79 to 1982–83 (1 April to 31 March) were assumed to be for fishing years (1 October to 30 September).

1 The 1978–79 landings of unspecified oreo (8041 t, see Table 1) were assumed to be the same proportion of smooth oreo to black oreo estimated catch reported in 1979–80 (114/(114+566) = 0.168). The estimate of the 1978–79 smooth oreo catch was 8041 t x 0.168 = 1351 t.
2 The 6 month landings of smooth oreo reported as 1983–83 (1861 t, Table 1) were split and half each (930.5 t) added to the preceding and subsequent years (1982–83 and 1983–84). There was only an 8 t difference between estimated and reported landings in 1983–83 (see Table 1), so no adjustment to the reported smooth oreo catch was made.
3 From 1979–80 to 2005–06 the landings were calculated by multiplying the value by the proportion of smooth oreo to black oreo estimated catch in Table 1.

Table 3: Reconstructed catch history (t) of smooth oreo from OEO 4. "OEO 4" is the catch from the whole area. "West" is the proportion of the total taken west and "East" is the catch taken to the east of 178° 20′ W.

Year	OEO 4	West	East
1978–79	1 351	1 351	0
1979–80	114	114	0
1980–81	1 436	1 436	0
1981–82	3 465	3 430	35
1982–83	3 757	3 757	0
1983–84	5 817	5 759	58
1984–85	4 736	4 547	189
1985–86	4 922	4 380	541
1986–87	5 670	4 196	1 474
1987–88	7 771	2 642	5 129
1988–89	7 225	2 457	4 769
1989–90	6 788	1 154	5 634
1990–91	6 028	1 808	4 220
1991–92	5 504	1 211	4 293
1992–93	5 918	1 420	4 498
1993–94	6 287	1 069	5 218
1994–95	6 961	1 392	5 568
1995–96	6 364	2 227	4 137
1996–97	6 339	1 712	4 627
1997–98	6 159	1 848	4 311
1998–99	6 025	1 749	4 283
1999–2000	6 366	1 670	4 696
2000–01	6 484	1 720	4 764
2001–02	4 284	1 436	2 848
2002–03	4 459	1 332	3 127
2003–04	5 653	1 519	4 134
2004–05	6 451	1 818	4 633
2005–06	5 946	1 302	4 644

3.3 Relative abundance estimates from CPUE analyses

The analyses were updated from those described by Doonan et al. (2003a) by including data from 2000–01 to 2005–06.

Data

The catch and effort data were restricted to that area within OEO 4 (the "study area") where the main smooth oreo fishery occurred from 1978–79 to 1998–99 (Figure 4). Data from OEO 4 were divided into target smooth oreo and bycatch smooth oreo and into pre- and post-global positioning system (GPS) with a further subdivision into a west series from 1979–80 to 1988–89 and an east series from 1992–93 to 2005–06). The intermediate years (1989–90 to 1991–92) represented a period of rapid improvement of fishing ability due largely to the introduction of GPS and therefore those data were omitted from the analysis.

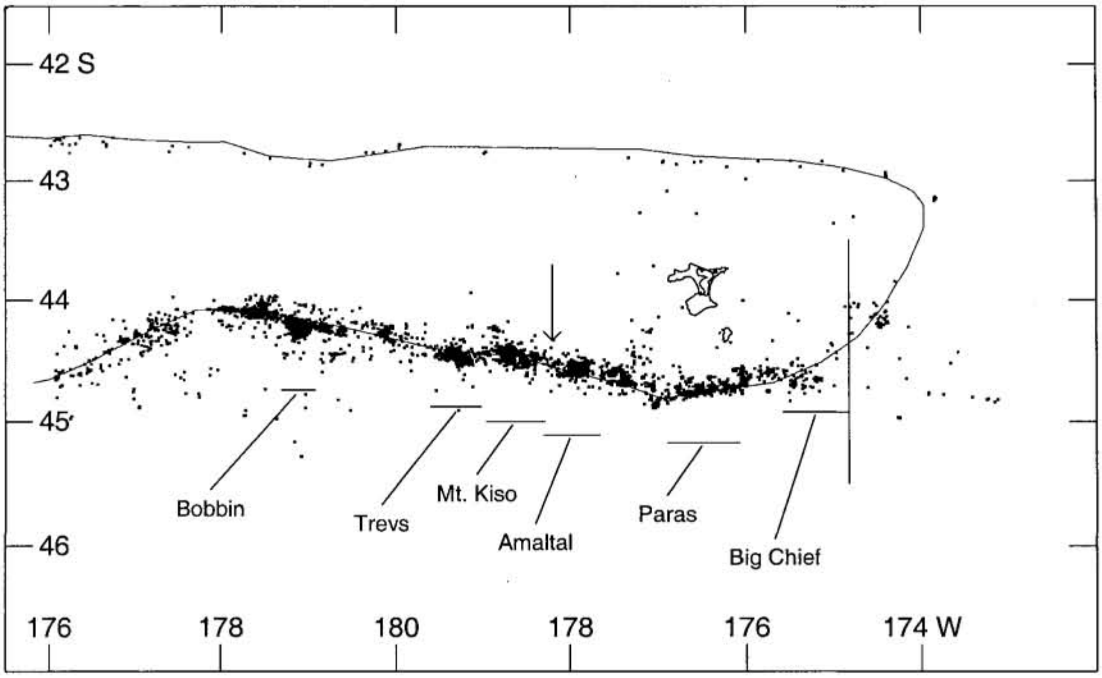

Figure 4: Start position (dots) of all trawls targeting smooth oreo in OEO 4 from 1978–79 to 1998–99. The western end of the study area is the boundary of OEO 4 at 176° E. The eastern boundary of 174° 50' W is shown with a vertical line. An arrow shows the position of the west/east split at 178° 12.6' W. Some main fishing patches are also indicated with horizontal bars. The axis-line (curved line) onto which positions were projected is also shown.

Method of CPUE analysis

The CPUE analysis method was described by Doonan et al. (1995, 1996, 1997a) and involved regression-based methods where the zero catch tow and the positive catch tow data were analysed separately to produce positive catch and zero catch indices. For target fishing, a combined index was calculated (see Coburn et al. 2001). The predictor variables considered in the analysis included axis-position (position along a line drawn west to east through the fished band along the continental slope of the south Chatham Rise), depth, season, time, hill (indicated if a tow started within 5 km of a known hill), and vessel. The reference year was arbitrarily assigned to a year near the middle of the time series. A revised method was introduced in the 2003 stock assessment to convert the index values to a canonical form by dividing each value by the geometric mean of the index series following the suggestion of Francis (1999) and resulted in the index value for the reference year being a value other than 1. Annual c.v.s for the combined indices were estimated using a jackknife technique (Doonan et al. 1995), but the method was revised by using the canonical index values to calculate the jacknife c.v. values and resulted in the reference year c.v. having a value other than 0.

For the smooth oreo (SSO) and unspecified oreo (OEO) target fisheries, combined indices were used in the assessment model, but for bycatch fisheries (orange roughy target fishing) only the positive catch indices were used.

Results of CPUE analysis

Originally, six analyses were carried out: target smooth oreo or unspecified oreo pre-GPS, target smooth oreo or unspecified oreo post-GPS, bycatch smooth oreo (target orange roughy) pre-GPS, bycatch smooth oreo (target orange roughy) post-GPS, target smooth oreo or unspecified oreo post-GPS west, target smooth oreo or unspecified oreo post-GPS east (Coburn et al. 2001). However, only four (A–D below) were chosen for use in the 2003 assessment model analyses since three satisfied the criteria of preferring the target smooth oreo or unspecified oreo analyses to bycatch analyses, but the bycatch post-GPS series (7 years) was used instead of the target smooth oreo or unspecified oreo post-GPS east series because the latter had only 4 years in the series including one where the jacknife c.v. was 236%. In the 2003 stock assessment (Doonan et al. 2003a), only the indices for A, C, and D below were used in the base case and these three were also used in the assessment described below. Only C and D were updated because the A series was unchanged (Table 4, Figure 5).

A Target SSO, pre-GPS series. Data used were from 1981–82 to 1988–89 and were mainly from the west. The final model for positive catch used vessel, season, and axis-position and that for zero catch used vessel, axis-position, and season. The combined index from the final year was approximately half that of the first year (Table 4a).

B Target SSO or OEO, post-GPS series. Data used were from 1992–93 and 1994–95 to 2000–01 and were from east and west. The final model for positive catch used season, depth, vessel, and axis-position and that for zero catch used vessel, axis-position, year, depth, and season. The combined index changed little over time (Table 4b).

C Target SSO or OEO, post-GPS west series. Data used were from 1992–93 and 1995–96 to 2000–01. The final model for positive catch used depth, season, axis-position, vessel, and year and that for zero catch used axis-position, vessel, year, time, depth, and season. The final combined index was approximately twice that of the first year index (Table 4c).

D Bycatch post-GPS series. Data used were from 1992–93 to 2000–01 and were mainly from the east. The final model for positive catch used axis-position, vessel, season, and depth. The positive catch index in the last year was about half that of the first year (Table 4d).

3.4 Relative abundance estimates from trawl surveys

Trawl surveys of oreos on the south Chatham Rise were carried out in seven years between 1986 and 1995 (Table 5). The abundance estimates from the surveys before 1991 were not considered to be comparable with the *Tangaroa* series because different vessels were used. Other data from those early surveys were used, e.g., gonad staging to determine length at maturity. The 1991–93 and 1995 "standard" (flat, undulating, and drop-off ground) surveys are comparable but were considered to be problematic because catchability estimates were inconsistent (Doonan et al. 1997a). The estimates were not included in the base case for the 2001 stock assessment (Doonan et al. 2001) and are not included in this assessment.

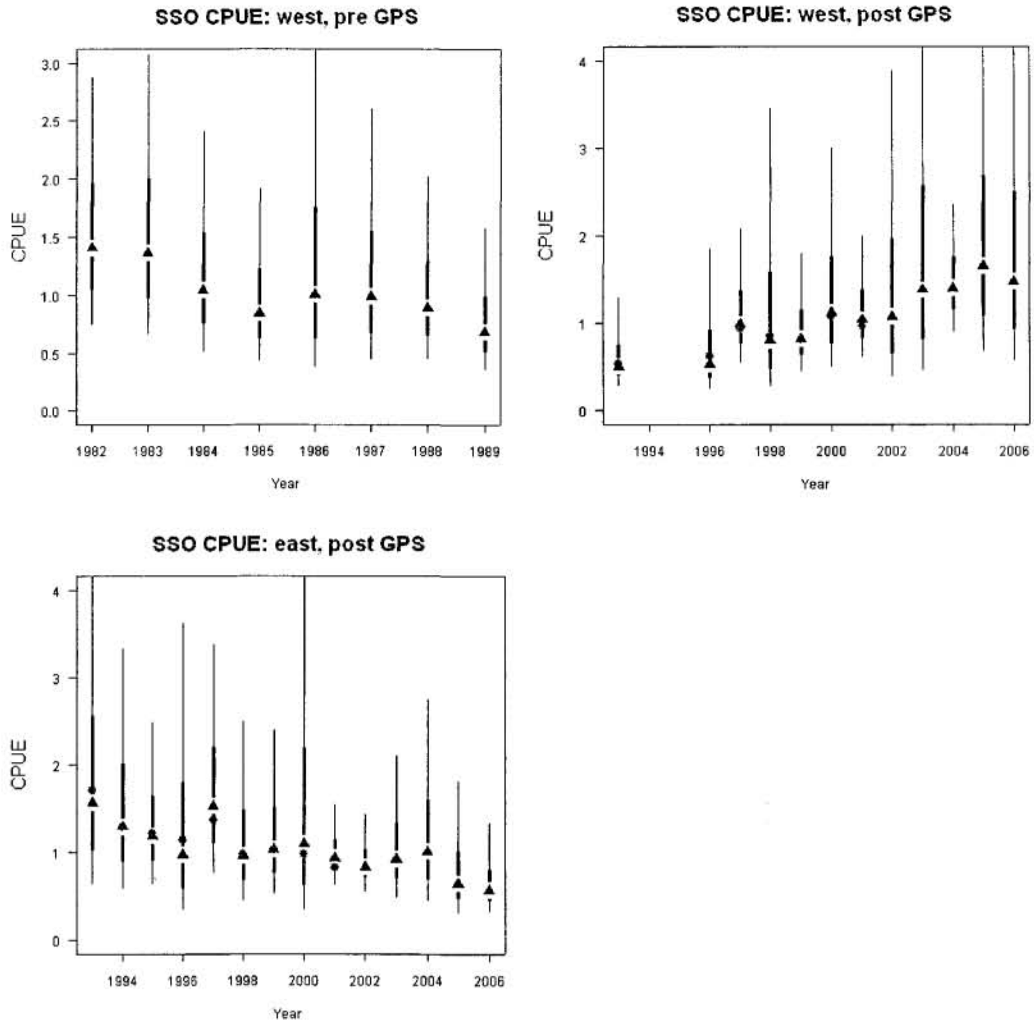

Figure 5: **Standardised CPUE indices (triangles) for target SSO, pre-GPS series (upper left), target SSO or OEO, post-GPS west series (upper right), bycatch post-GPS series (lower). The thinner vertical lines are ±2 s.d, the thicker vertical lines are ±1 s.d, The dots are the indices used in the last stock assessment (Doonan et al. 2003a).**

Table 4: **Smooth oreo time series of abundance indices from standardised CPUE analyses. West series are from target SSO data, east series used bycatch data from ORH fishing. –, no data.**

(a)	West pre-GPS	
Year	Index	c.v.
1981–82	1.40	15
1982–83	1.36	19
1983–84	1.04	21
1984–85	0.84	20
1985–86	1.00	44
1986–87	0.99	28
1987–88	0.89	20
1988–89	0.68	22

(c)	West post-GPS	
Year	Index	c.v.
1992–93	0.50	29
1993–94	–	–
1994–95	–	–
1995–96	0.53	53
1996–97	0.99	17
1997–98	0.80	74
1998–99	0.82	19
1999–2000	1.12	30
2000–01	1.04	13
1992–93	1.07	54
1993–94	1.38	54
2004–95	1.40	8
2005–96	1.65	31
2006–97	1.47	38

(d)	East post-GPS	
Year	Index	c.v.
1992–93	1.56	33
1993–94	1.29	27
1994–95	1.18	16
1995–96	0.96	57
1996–97	1.52	18
1997–98	0.96	28
1998–99	1.03	22
1999–2000	1.10	71
2000–01	0.93	8
1992–93	0.83	10
1993–94	0.92	21
2004–95	1.00	31
2005–96	0.64	34
2006–97	0.57	24

Table 5: **Random stratified trawl surveys (standard, i.e., flat tows only) for oreos on the south Chatham Rise (OEO 3A & OEO 4).**

Year	Area (km^2)	Vessel	Survey area	No. of stations	Reference
1986	47 137	*Arrow*	South	186	Fincham et al. (1987)
1987	47 496	*Amaltal Explorer*	South	191	Fenaughty et al. (1988)
1990	56 841	*Cordella*	South, southeast	189	McMillan & Hart (1994a)
1991	56 841	*Tangaroa*	South, southeast	154	McMillan & Hart (1994b)
1992	60 503	*Tangaroa*	South, southeast	146	McMillan & Hart (1994c)
1993	60 503	*Tangaroa*	South, southeast	148	McMillan & Hart (1995)
1995	60 503	*Tangaroa*	South, southeast	172	Hart & McMillan (1998)

3.5 Absolute abundance estimates from acoustic surveys

The 1998 and 2001 absolute abundance estimates were revised in Doonan et al. (Unpublished results).

1998 survey

Absolute estimates of abundance were available from the acoustic survey on oreos that was carried out from 26 September to 30 October 1998 on *Tangaroa* (voyage TAN9812) (Doonan et al. 2000). The survey covered 59 transects over 6 strata on the flat and 29 transects on 8 hills (Figure 6). A total of 95 tows were carried out for target identification and to estimate target strength and species composition. The 1998 survey abundance was re-estimated for total smooth oreo, instead of just recruited fish as reported by Doonan et al. (2000, 2001). The scale-up factor to take the flat survey abundance to the trawl survey area was also re-estimated for total (versus recruited) smooth oreo. The latter value became 1.75 (2.0 for recruited fish) for the abundance as a single area and also for the east area, and 2.21 for the west area. The scale-up factor to take the trawl survey area abundance to the whole of OEO 4 was also revised upwards from 1.07 to 1.11. The same values were used when the abundance was split into Layer (unfished) and School (fished) mark-types. The estimate was further revised to use the square-root weighting for the trawl data and to align the net catchability with that used in 2005 survey (Doonan et al. unpublished results). The revised abundance estimates are in Table 6.

2001 survey

Absolute estimates of abundance were available from the acoustic survey on oreos carried out between 16 October and 14 November 2001 using *Tangaroa* for acoustic work and *Amaltal Explorer* for trawling (Doonan et al. 2003b). The flat survey included 138 transects and 84 trawls over 10 flat area strata whilst the hill survey included 46 transects and 36 trawls over 14 hills (Figure 7). The estimate was revised to align the net catchability with that used in 2005 survey (Doonan et al. unpublished results). The revised abundance estimates are in Table 6.

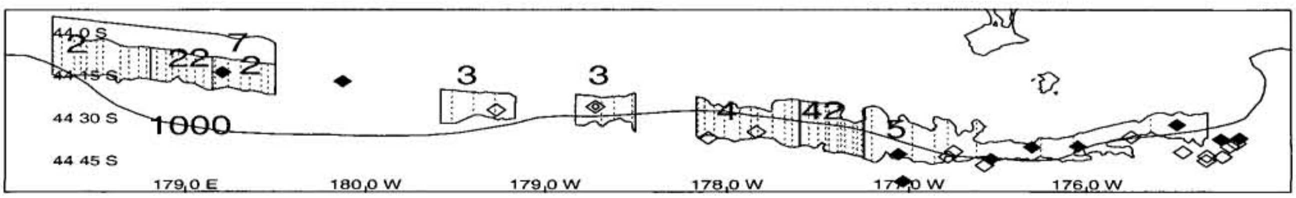

Figure 6: **1998 OEO 4 acoustic survey area showing smooth oreo (2–5, 22 & 42) and black oreo (7) flat strata (dark lines) and transects (dashed lines). Hills selected for sampling (♦) plus hills listed but not selected for sampling(◊).**

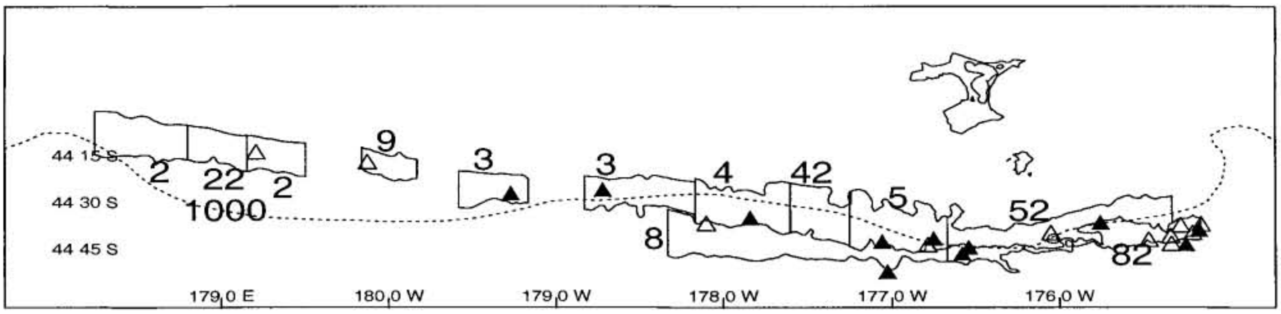

Figure 7: **Flat strata and hills surveyed (filled triangles) in the 2001 acoustic survey. Hills not surveyed are the empty triangles. The dotted line is the 1000 m depth contour.**

2005 survey

Absolute estimates of abundance were available from the acoustic survey on oreos carried out between 3 and 22 November 2005 using *Tangaroa* for acoustic work and *San Waitaki* for trawling (Doonan et al. unpublished results). The flat survey included 116 transects and 67 trawls over 10 flat area strata whilst the hill survey included 49 transects and 29 trawls over 15 hills (Figure 8). Abundance estimates are in Table 6.

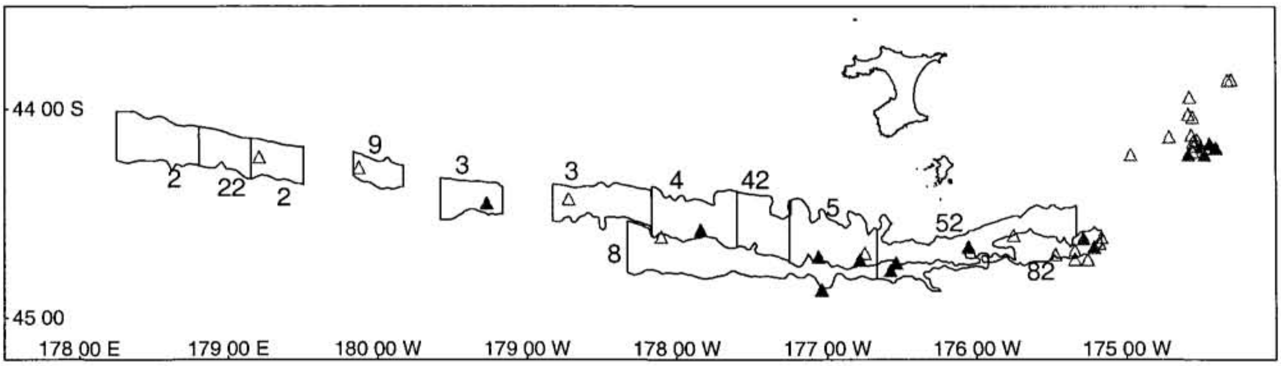

Figure 8: **Flat strata and hills surveyed (filled triangles) in the 2005 acoustic survey. Hills not surveyed are the empty triangles.**

Table 6: **Estimated absolute abundance (t) and c.v.s from acoustic surveys in 1998, 2001, and 2005 by east, west, and for the combined area.**

Survey	Area	Abundance (t)	c.v. (%)
1998	West	22 600	52
	East	127 000	37
	All	146 000	34
2001	West	43 000	35
	East	183 200	22
	All	218 200	22
2005	West	32 200	31
	East	91 800	30
	All	115 500	28

3.6 Length data analyses

Observer length frequencies

Observer length data were extracted from the observer database. These data represent proportional catch at length and sex. Starr (Deepwater Working Group unpublished document #02/51, 6 June 2002) found that the observer data needed stratifying on the basis of a west-east split at 178° 12.6' W and also on a 6 month seasonal split. The working group settled on October-March and April-September periods resulting in a total of four strata for OEO 4 with two in each of the west and east parts. The length frequencies were combined over strata by the proportion of catch in each stratum. Using seasonal strata meant that many years did not have data for each stratum (Table 7). The rules used to form length frequencies were:

- there must be data in each stratum, except when the proportion of catch in a stratum was lower than 5% (all areas) or 10% (east or west area separately);
- a total of at least 5 tows for the year;
- tows were excluded where there was not more than 30 fish measured or if there were no data on either females or males.

This resulted in 15 years data for the east, and 7 years data for the west (Table 7). The new length frequencies for this analysis are shown in Figure 9

Table 7: Observer length frequencies for the west and east areas: number of tows by stratum (season and area) for the length data, and whether a length frequency was used in the stock assessment ("Y"). Boxes for the west data indicate years that data was combined and the "Y" gives the year it was assigned to. †, years with new data.

	West			East		
Year	Oct-Mar	Apr-Sep	Used	Oct-Mar	Apr-Sep	Used
1987	2	1		0	0	
1989	10	5	Y	1	0	
1990	4	0		0	0	
1991	16	0		26	4	Y
1992	6	0		45	8	Y
1993	0	0		22	16	Y
1994	1	0		64	33	Y
1995	1	0		42	30	Y
1996	9	10	Y	6	6	Y
1997	11	0		28	3	Y
1998	2	9	Y	20	9	Y
1999	0	7		30	21	Y
2000	3	15	Y	14	0	
2001	8	14	Y	44	5	Y
2002†	0	3		24	16	Y
2003†	3	4	Y	28	6	Y
2004†	1	6		27	3	Y
2005†	3	3		18	46	Y
2006†	3	14	Y	3	14	Y

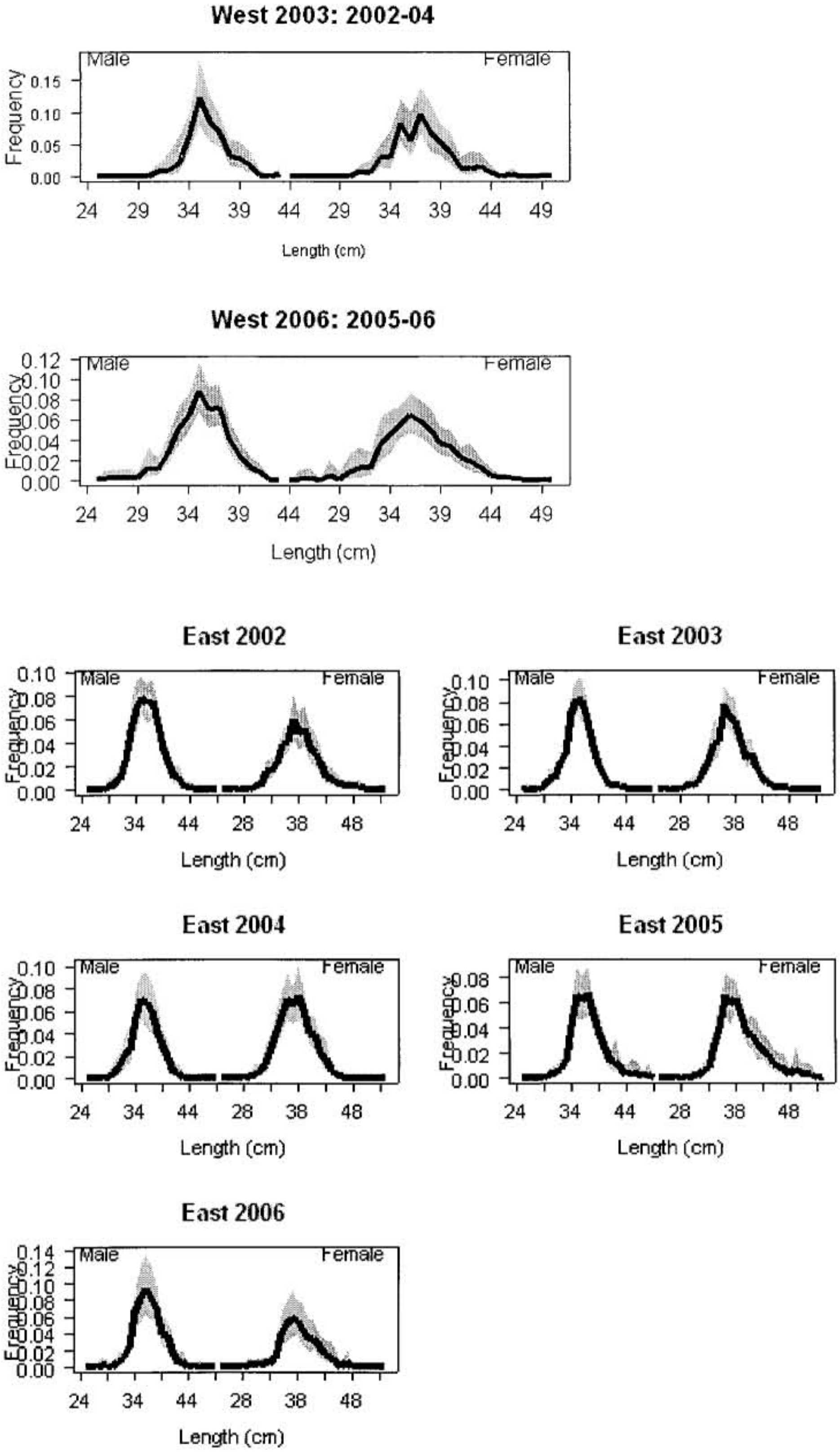

Figure 9: New observer length frequencies since the last stock assessment (2003) for west and east areas. Grey areas are the ±2 s.e. regions on the individual length bins.

In the 2003 stock assessment, the distribution employed for the length frequency was lognormal (Bull et al. 2002). In 2007 the Deepwater Stock Assessment Working Group selected the robustified multinomial distribution (Bull et al. 2002) after reviewing results from several model runs. Results are in Table 8. This required a process error parameter, N, that controlled the variance for a length class. The selected N made the the standard devisation of the normalised residuals (SDNR) equal to one for each of the west and east blocks of data (Table 8). The N assigned to each length frequency was proportional to the number of tows in the frequency, but normalised so that the mean equalled N.

Table 8: Assigned N for the observer length frequencies. "–", no data.

Year	N East	N West
1989	–	417
1991	150	–
1992	300	–
1993	600	–
1994	1238	–
1995	1125	–
1996	225	750
1997	112	–
1998	338	167
1999	788	–
2000	–	250
2001	188	667
2002	600	–
2003	225	250
2004	112	–
2005	675	–
2006	112	250

Length frequency data from the 2001 and 2005 acoustic surveys

Population length frequencies were generated for the whole area, the east, and the west areas. These frequencies were in the CASAL form that included an implicit sex ratio, i.e., the normalisation was over both male and female frequencies so that the sum of the frequencies over both summed to 1, not 2 as in the more usual way. Each frequency was estimated using the length data from trawls in each mark-type substratum weighted by the catch rates and the proportion of abundance in the sub-stratum. For the flat strata, the method was:

$$f_{l,s} = \sum_{i,j} \frac{N_{i,j}}{\sum_{i2,j2} N_{i2,j2}} \sum_{k} \frac{cr_{i,j,k,s}}{\sum_{k2}\left(cr_{i,j,k2,male} + cr_{i,j,k2,female}\right)} f_{i,j,k,s,l}$$

where f is the length frequency, l is the length class, s is sex, i is stratum, j is mark-type, k is tows within mark j and stratum i, cr is catch rate, and N is abundance by numbers. N was estimated as the abundance by weight divided by the mean weight, where the mean weight was a mean weighted bycatch rate. The denominator for the catch rate part was over both males and females to account for the sex ratio. For hills, the same form was used, but some changes were needed to account for subsampling of hills within each of the three groups of hills. Example length frequencies are shown for the 2001 survey in Figures 10 and 11.

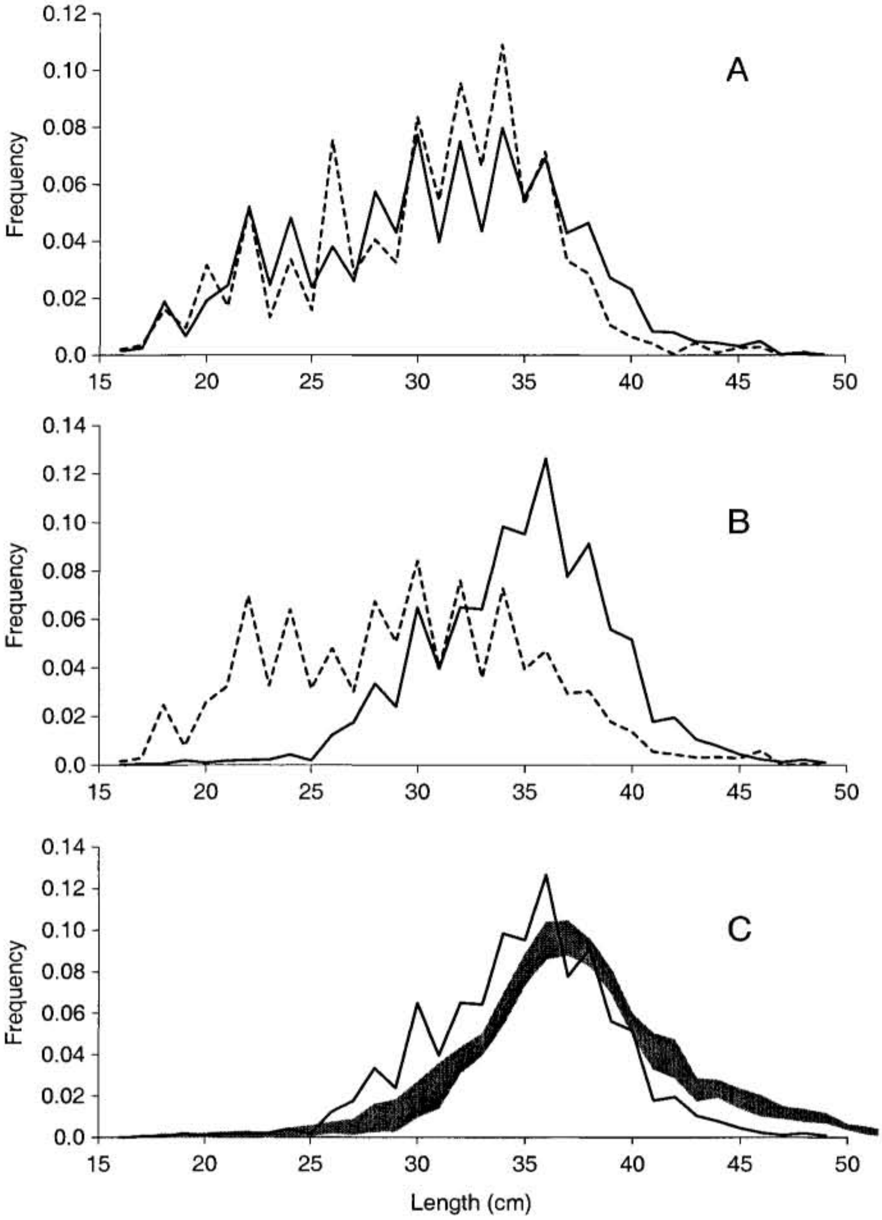

Figure 10: Acoustic survey 2001 length frequencies. A) female (solid line) and male (dashed line) frequencies for the trawl survey area. B) east female length frequency for the School mark-types (solid line) and Layer mark-types (dashed line). C) east female frequency for the School mark-types (solid line) and an approximate inter-quartile region (shaded area) for the annual observer length frequencies in the east area for the years 1991 to 2001. Annual observer length frequencies were obtained by weighting the tow data by catch only, i.e., seasonal adjustments were not used.

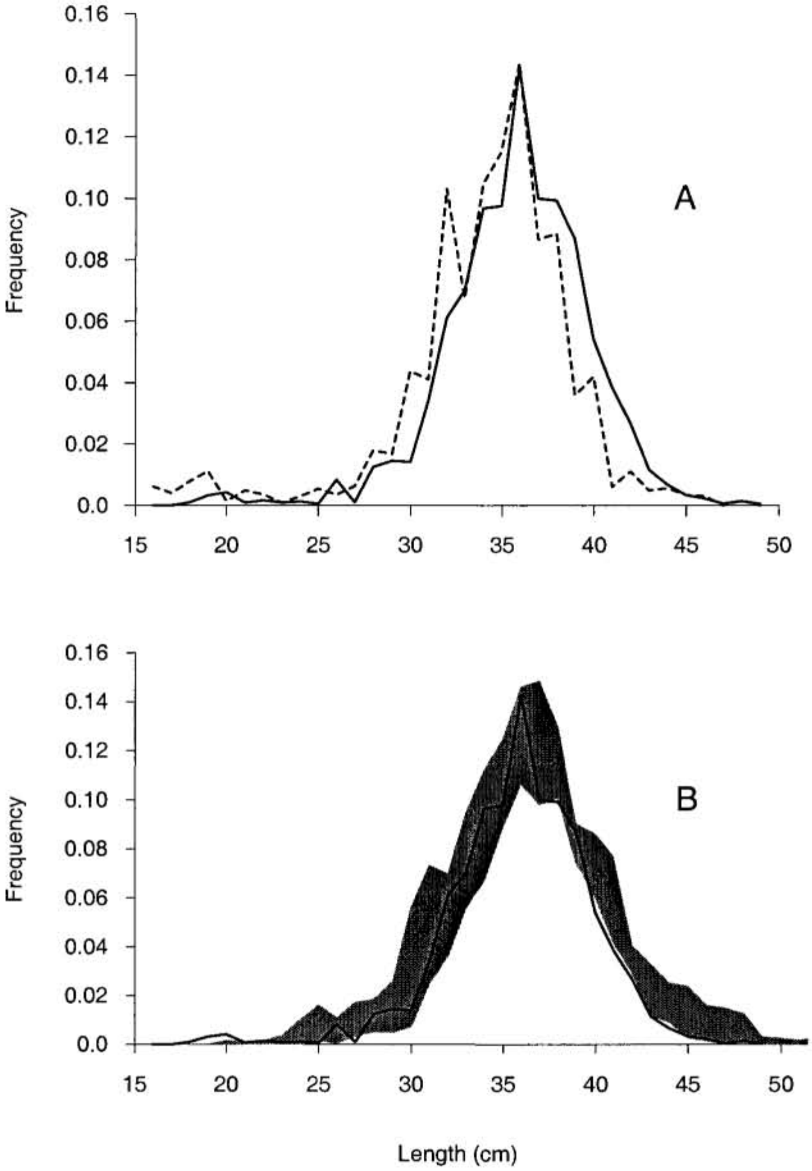

Figure 11: Acoustic survey 2001 length frequencies. A) west female length frequency for the School mark-types (solid line) and Layer mark-types (dashed line). B) west female frequency for the School mark-types (solid line) and an approximate inter-quartile region (shaded area) for the annual observer length frequencies in the west area for the years 1991 to 2001. Annual observer length frequencies were obtained by weighting the tow data by catch only, i.e., seasonal adjustments were not used.

A lognormal distribution was used for the error structure of the length frequencies and the c.v.s estimated from a log(cv) versus 1/log(p) relationship, where p was the frequency. The relationship was estimated from bootstrapped c.v.s that had two parts. First, the tow data were re-sampled within each sub-stratum (mark-type in an area stratum) and, secondly, the $N_{i,j}$ were bootstrapped from the estimated abundance (i.e., they included bootstrapping from catches, acoustic backscatter and target strengths). The trawl catches induced a correlation between the bootstrapped $N_{i,j}$ and the re-sampled tow data for the length frequencies because these data were used in both parts of the analysis and to be consistent they should be re-sampled once and used in both parts. However, this correlation was ignored here since the development of software to continue this analysis was beyond the scope of the study and so the tow data in each part were treated independently. The estimated relationships based on 200 bootstrap values are given in Table 9.

Table 9: Coefficient of variation estimates for the 2001 and 2005 survey acoustic length frequencies: estimated coefficients for the regression, log(cv) = A + B /log(proportion).

	A		B	
Area	Value	S.E.	Value	S.E.
2001				
West	0.74	0.1	7.74	0.49
East	0.39	0.1	7.73	0.47
2005				
West	0.55	0.13	6.59	0.59
East	0.55	0.16	6.72	0.7

Figure 10C shows the close correspondence between the observer length data and the School mark-types. The observer data relate well to the School mark-types length frequency, but not to the Layer mark-type frequency, although there appears to be some selectivity within the School mark-types since the observer data is shifted to larger values by about 1.5 cm in the case shown (female, east area). Similar patterns occur for the length frequencies of males in the east and length frequencies from the west area.

Observations of fishing during the survey and anecdotal evidence from fishers corroborate this correspondence. Further, catch rates in the Layer mark-types were too low to be economic. Also, remarks from the skipper of the catcher vessel indicated that some marks in the School mark-types would not be fished as they were too small and shallow, so some selectivity is practised and this may be the cause of the shifts in length frequencies from the School mark-types and the observer data.

3.7 Biological data

The fixed values for the life history parameters used in the assessment are from Doonan et al. (1997b) (Table 10). Growth was von Bertalanffy and recruitment was Beverton & Holt. In some cases growth or natural mortality (M) were estimated.

Table 10: Fixed life history parameters for smooth oreo.

Parameter	Symbol (unit)	Female	Male
Natural mortality	M (yr^{-1})	0.063	0.063
von Bertalanffy parameters	L_∞ (cm, TL)	50.8	43.6
	k (yr^{-1})	0.047	0.067
	t_0 (yr)	-2.9	-1.6
Length-weight parameters	a	0.029	0.032
	b	2.90	2.87
Recruitment variability		0.65	0.65
Recruitment steepness		0.75	0.75

3.8 Development of base case

A base case was used to develop the Markov Chain Monte Carlo (MCMC) analysis. Early model runs showed that the likelihood values were dominated by the fits to the observer length frequency data and that there were poor model fits for the right-hand limb of the length frequency distributions.

Exploration of the effect of the right hand side (RHS) of the length frequencies was tried on the west fishery on its own using the 2003 assessment base case model structure with the addition of two fisheries selectivities, early and late (cut-off was 1991) and also using the new data up to 2005–06. The estimate of west B_0 was 41 000 t. B_0 was 93 000 t using just the CPUE and acoustic abundances and allowing selectivites to be estimated. If only the LHS of length frequencies was fitted (for selectivities), then B_0 was 69 000 t. Just using the length frequency data gave an estimated B_0 of 32 000 t. Thus fitting the abundance data needs higher B_0 values, whilst the RHS of the length frequencies needed a low B_0 value and the balance reached when all data are included is in favour of the RHS of the length frequencies by 3:1.

There were other runs that could give better fits to the abundance data (B_0 in the range 57–123 000 t) such as estimating M (0.3), a migration of larger fish out of the survey area and fishery, or just scattering the commercial length frequencies evenly over the whole analysis time frame. An explanation for this last is that there is a poor data balance with most of the commercial length data from 1996 onwards, whereas the fishery started in early 1980s and it had a substantial decline in CPUE by the late 1980s. The effect of the length data is partly related to the large number of components in the likelihood so other data can be out-weighted when a conflict of evidence exists. Thus, the observer length data has about 12 length classes on the RHS, times 2 sexes times 7 years data to give about 168 components, while the two CPUE series have 8 + 12 = 20 components and the acoustic abundance series has 3.

In the 2003 assessment, in order to fit the length frequency data, either growth or M needed to be estimated in the model (Doonan et al. 2003a). Here, two alternative approaches were tried: changing the observer length frequency distribution to the robustifed multinomial and just fitting to the LHS (up to the peak) of the length frequencies. The latter was prompted by the miss-fits to the RHS of these length frequencies which then outweighed the abundance data to push down the virgin biomass estimate to get better fits. The main purpose of the length data is to define the selectivities and this is largely carried out by the LHS of the length distribution. The RHS of the length distribution is determined by factors including recruitment, year-class-strength, and correct growth form, none of which are known well at the time of this study. Using both the robustifed multinomial and fitting to the LHS of the length frequencies gave the best fit to the abundance data and the Working Group choose this to be the base case. The model was also simplified by making it a two stock model, rather than use migration or a partition of the recruitment into each area (east and west). This does not change the results very much, but it allows process error on the west acoustic length frequency, which was tied down to a c.v. of 1% in the 2003 assessment so that the east data did not create a mis-fit in the west data.

In summary the base case used an east/west split for all data inputs, a fixed M (0.063), and had two stocks, one in the west and another in the east, with no migration from the east to the west area. Growth was not estimated in the model and selectivities were made effectively knife-edged. Acoustic length data were fitted to the model using a log-normal likelihood with process errors. The observer length data were fitted using the robustified multinomial.

Estimated model parameters and priors are presented in Table 11 and parameter names and codes are listed in Table 12.

Table 11: Estimated parameters and priors of the NIWA CASAL assessment model. U, uniform distribution estimated for both sexes combined.

Parameter	Number	Prior
Virgin biomass (West and East)	2	ln B_0 ~U[0, ln (500 000)]
West catchability coefficient [pre-GPS CPUE]	1	U[0, 1]
East catchability coefficient [post-GPS CPUE]	1	U[0, 1]
West catchability coefficient [post-GPS CPUE]	1	U[0, 1]
Age-based selectivity - commercial fishery		
Age at 50% selected (east & west)	2	U[1, 50]
Extra years to 95% selected (east & west)	2	U[0,1]
Age-based selectivity - acoustic survey		
Age at 50% selected (east & west)	2	U[1, 50]
Extra years to 95% selected (east & west)	2	U[0,1]
Process errors		
Observer length data	2	U[0,1.5]
Acoustic length data	2	U[0,1.5]

Table 12: Parameters for which correlations and posterior distributions are given: parameter codes and descriptions.

Code	**Description**
Bo_W	West mature virgin biomass
Bo_E	East mature virgin biomass
WF_A50	West fishery selectivity, age at 50% selection
WF_50to95	West fishery selectivity, ages from 50% to 95% selection
EF_A50	East fishery selectivity, age at 50% selection
EF_50to95	East fishery selectivity, ages from 50% to 95% selection
WAco_A50	West acoustic selectivity, age at 50% selection
WAco_50to95	West acoustic selectivity, ages from 50% to 95% selection
EAco_A50	East acoustic selectivity, age at 50% selection
EAco_50to95	East acoustic selectivity, ages from 50% to 95% selection
B_cur_W	West current mid-year abundance
B_cur_W(%Bo)	West current mid-year abundance as a percentage of west virgin biomass
B_cur_E	East current mid-year abundance
B_cur_E(%Bo)	East current mid-year abundance as a percentage of east virgin biomass
Bo_total	Total mature virgin biomass
B_cur	Total current mid-year abundance
B_cur(%Bo)	Total current mid-year abundance as a percentage of total virgin biomass

3.9 Projections

No projections were performed because the immediate sustainability of the stock was not considered to be an issue.

3.10 Biomass estimates

Biomass was estimated as the median of the posterior distributions. Yields were not estimated since there was not a sustainability issue.

4. RESULTS

4.1 MPD results

The MPD parameter estimates and run details are listed in Tables 13 and 14.

Table 13: Run summary: MPD fits. Run 2, the base case in the 2003 assessment, with the data updated to the 2007 model year (2005–06), and the current base case (bold). –, not applicable.

	Run 2, 2003	Run 2, 2007	**Base case, 2007**
(a) Estimated parameters			
Virgin biomass (t)	165 000	141 000	**198 000**
L_{∞}_female (cm)	47.26	47.3	-
L_{∞}_male (cm)	41.08	41.0	-
c.v. L_{∞} female	0.1	0.10	-
c.v. L_{∞} male	0.1	0.09	-
Selectivity (years):			
West fishery, age at 50% selection	26.04	26.7	**25.9**
West fishery, ages 50–95% selection	0.1	0.44	**0.5**
East fishery, age at 50% selection	24.72	26.7	**23.7**
East fishery, ages 50–95% selection	5.67	6.1	**0.4**
East acoustic, age at 50% selection	8.45	10.2	**8.2**
East acoustic, ages 50–95% selection	0.17	2.1	**0.5**
West acoustic, age at 50% selection	22.68	23.5	**21.1**
West acoustic, ages 50–95% selection	0.1	0.1	**0.5**
Proportion recruited to west	0.26	0.31	-
C.v. of process error for length frequencies:			
East acoustic survey	0.9	0.75	**0.50**
West acoustic survey	0.02	0.01	**0.35**
East fishery (observer)	0.49	0.55	-
West fishery (observer)	0.58	0.47	-
(b) Log-likelihoods for data sets	Run 2, 2003	Run 2, 2007	**Base case, 2007**
East acoustic abundance	2.2	2.5	**-2.2**
West acoustic abundance	11.8	15.0	**-2.4**
East (bycatch) post-GPS CPUE	-10	-14.2	**-13.1**
West (target) post-GPS CPUE	-3.1	-0.3	**-5.4**
West (target) pre-GPS CPUE	-4.5	-4.7	**-8.9**
East acoustic survey length frequency	27.2	48.6	**5.6**
West acoustic survey length frequency	96.5	151.9	**-11.7**
East fishery (observer) length frequency	66.8	234.1	**-524**
West fishery (observer) length frequency	104.4	146.1	**-214.8**
West fishery catch penalty	0	0	**0**
East fishery catch penalty	0	0	**0**
Prior on B_0	12	11.9	**22.8**
Total	303.2		

Table 14: Run summary: MPD fits. Run 2, the base case in the 2003 assessment, with the data updated to the 2007 model year (2005–06), and the 2007 base case (bold). –, not applicable.

Biomass estimates

	Run 2, 2003	Run 2, 2007	**Base case, 2007**
Mid-year, mature			
B_0	159 000	136 000	**191 000**
B_{2002}	83 400	58 300	**113 000**
B_{2002}/B_0	53%	43%	**59%**
B_{2006}	–	52 200	**107 000**
B_{2006}/B_0	–	38%	**56%**
Mid-year, mature_W			
B_0	41 000	41 800	**61 000**
B_{2002}	12 200	12 700	**32 000**
B_{2002}/B_0	30%	30%	**52%**
B_{2006}	–	12 400	**31 800**
B_{2006}/B_0	–	30%	**52%**
Mid-year, mature_E			
B_0	118 000	94 100	**130 000**
B_{2002}	71 200	45 600	**81 300**
B_{2002}/B_0	60%	48%	**63%**
B_{2006}	–	39 900	**75 600**
B_{2006}/B_0	–	42%	**58%**

Adding the new data into the 2003 assessment base case makes the assessment more pessimistic, but non-abundance parameter values do not change much with the largest changes for the 50% selectivity values. This effect seems related to adding more length frequencies and so weighting the abundances more towards their inclinations, as noted above. Consequently, the base case for 2007 is more optimistic than both of the Run 2 results since the effect of the RHS of the length frequencies was deliberately removed. A comparison of the log-likelihoods for the abundance data (see Table 13b) between the two 2007 runs show that these data fit better in the current base case, apart from the east CPUE series.

The east abundance data fitted the model so that most data were within 2 s.e. of the predicted trajectories (Figure 12). Similarly for the west abundance data, except that the increasing trend in the post-GPS CPUE is matched by a flat predicted trajectory (Figure 12). The acoustic survey and observer length frequency data fits had no systematic mis-fits (Figures 13 & 14). The Q-Q normal plots of the residuals (Figures 15–16) are approximately standard normal (as they are assumed to be in the model) for only the acoustic length frequencies and the west post-GPS CPUE; the other two CPUE series fitting with less error than assumed (process error is fixed for the CPUE), but with a normal error structure. The observer length frequency Q-Q normal plots were mostly standard normal, except for a few percent that have far more negative residuals than they should (the LHS dips down from the 1:1 line in Figure 16). Fits and Q-Q normal plots to annual observer length frequencies are given in Appendix A.

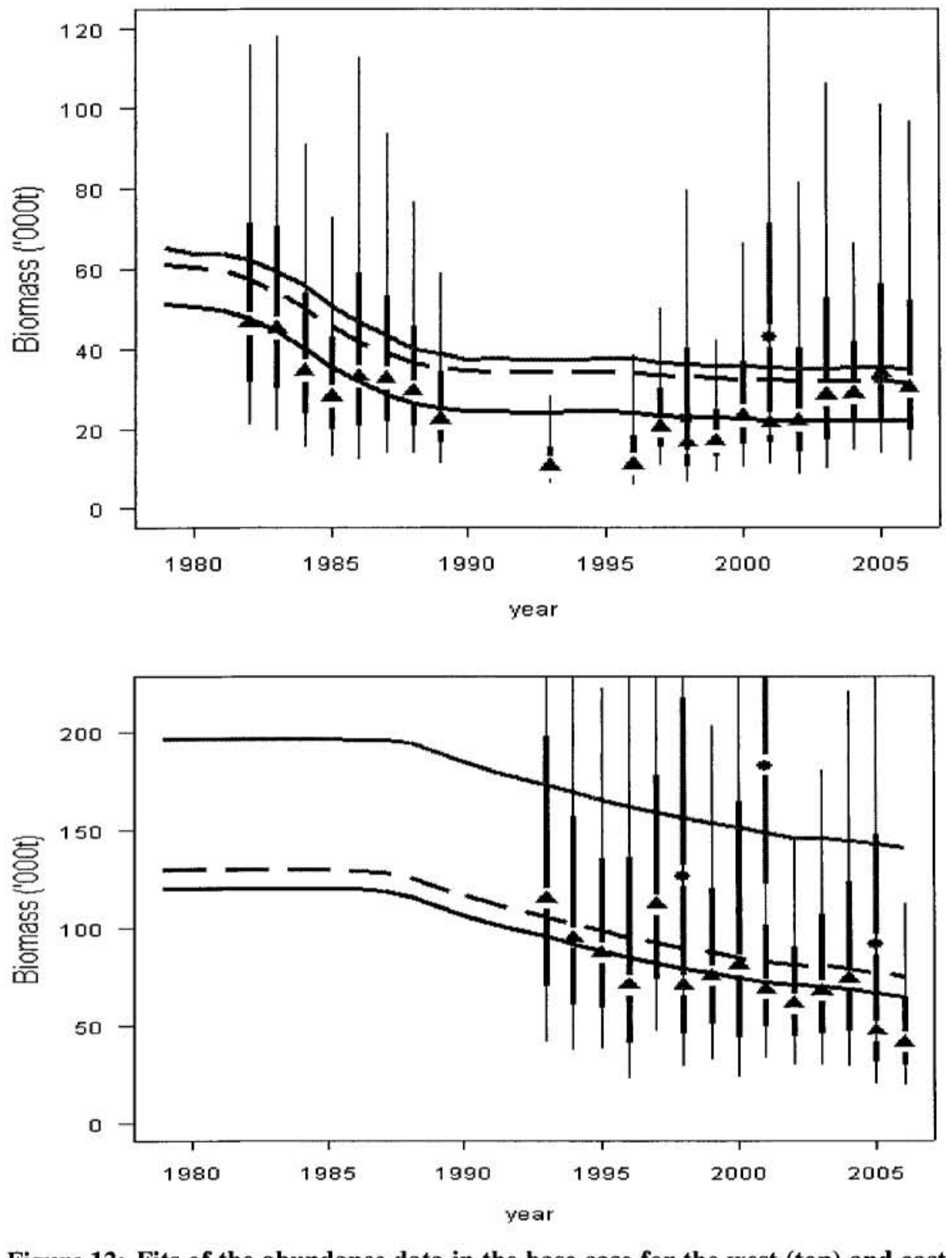

Figure 12: Fits of the abundance data in the base case for the west (top) and east (bottom) areas. Ovals are the acoustic (absolute) estimates. Triangles are the CPUE indices scaled by catchabilities to abundance. Curved lines are the model estimates of biomass (t), solid top line is the abundance that the acoustics measures, dashed line is the mature abundance, and the bottom solid line is the vulnerable (to fishing) abundance. Vertical thinner error bars for acoustic and CPUE estimates are ± 2 S.D., the thicker bars are ± 1 S.D.

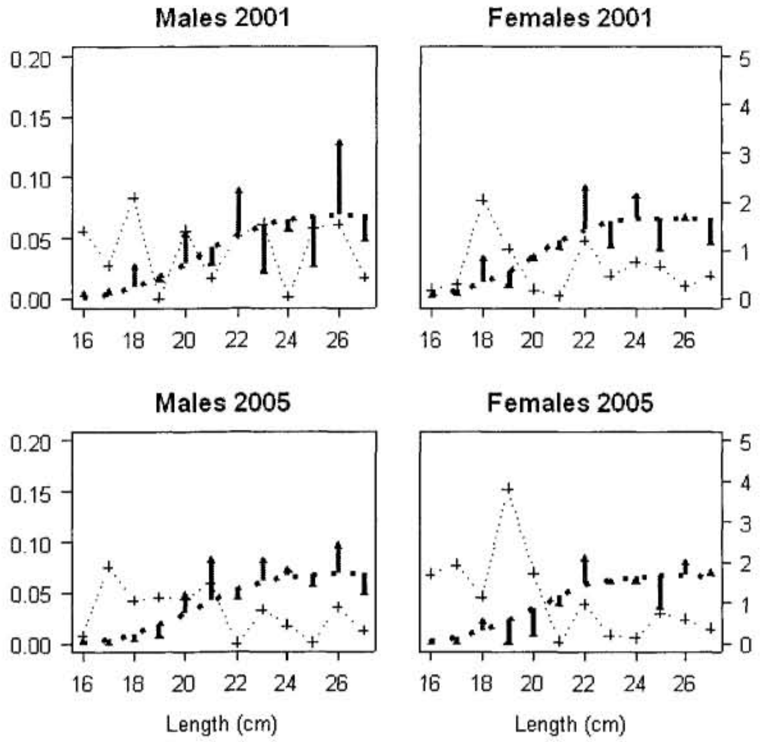

Figure 13: Model fits (line of squares) of the 2001 and 2005 acoustic length frequency data (triangles) in the base case, males on the left and females on the right. The right-hand axis shows a plot of normalised residuals (crosses) averaged as absolute values across years.

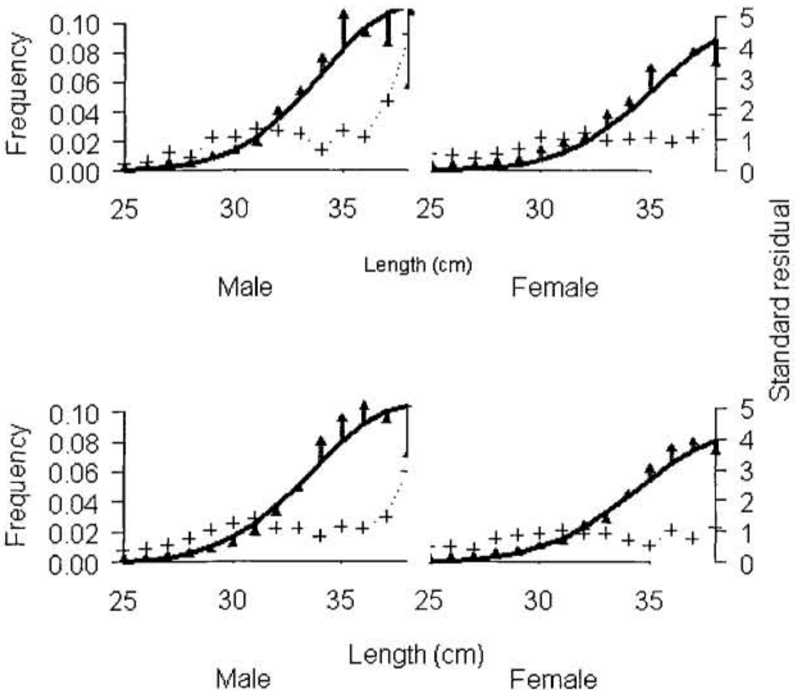

Figure 14: Fits of the composite observer length frequency data (triangles) in the base case for the west (top) and east (bottom), males on the left and females on the right. The composite length frequency distribution (solid line) was generated by averaging the model length frequency data across years. The right hand axis shows a plot of normalised residuals (crosses) averaged as absolute values across years.

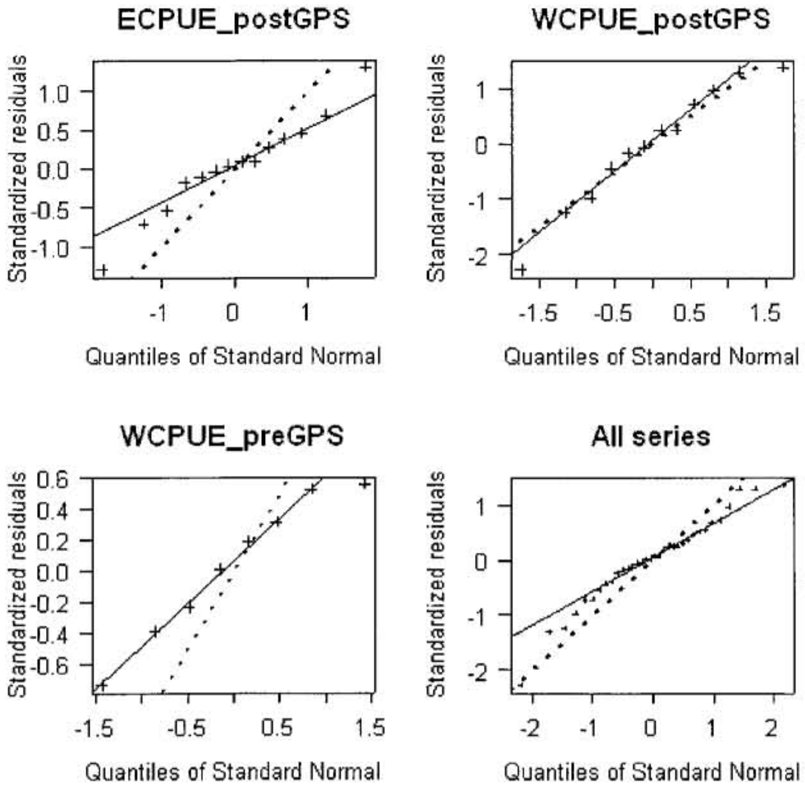

Figure 15: Q-Q normal plots for all the normalised residuals (crosses) from the three CPUE indices. The dashed line is the 1:1 line and the solid line is the regression line estimated from the residual points between -1 and 1 on the x-axis.

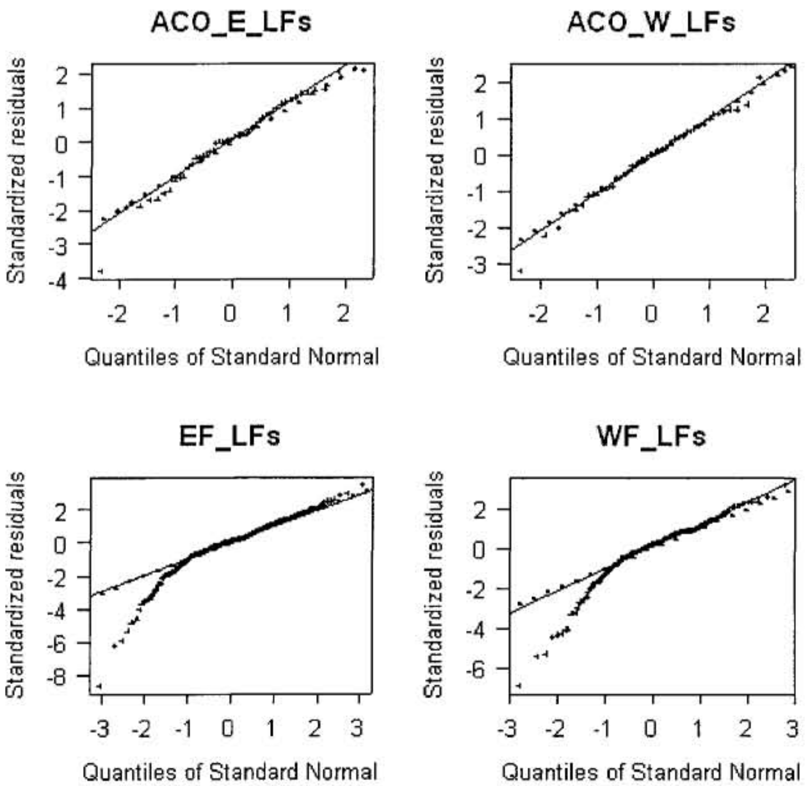

Figure 16: Q-Q normal plots for all the observer (EF and WF) and acoustic (Aco_E, Aco_W) length frequency normalised residuals (crosses). The dashed line is the 1:1 line and the solid line is the regression line estimated from the residual points between -1 and 1 on the x-axis.

4.2 Bayesian estimates

MCMC were run for 2 million values and systematically sub-sampled at every 1000th sample. Convergence appears to have been achieved (Figure 17) and re-running the MCMC independently from the first series gave cumulative densities that were almost the same (Figure 18).

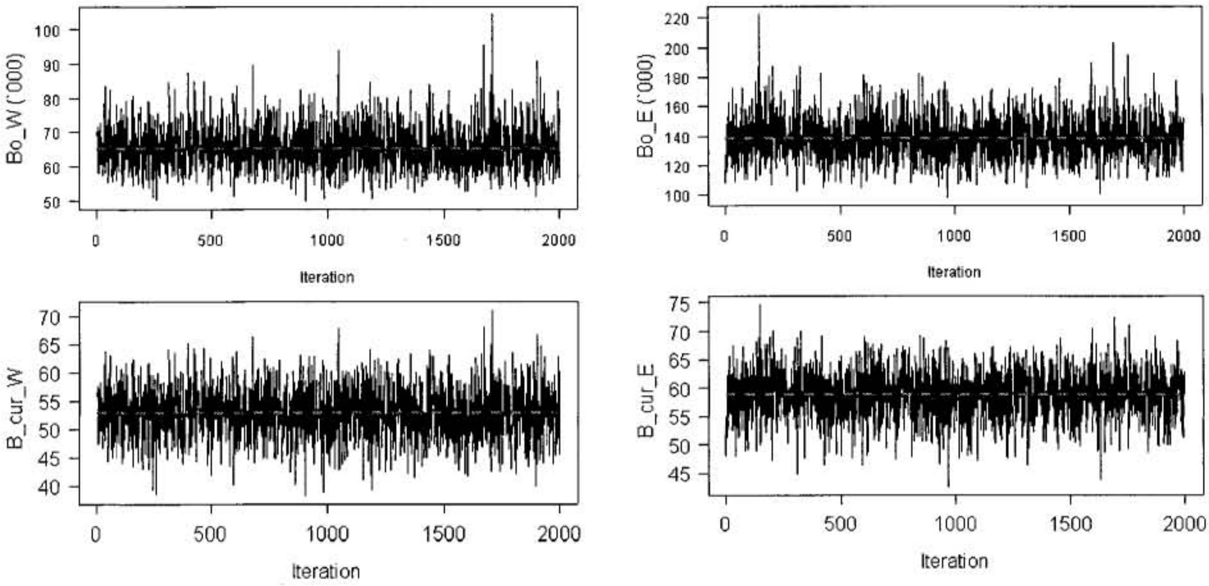

Figure 17 Time series of MCMC estimates for the west (left) and east (right) B0 and Bcurrent for the base case. The continuous line is a running average of estimates using a window of 100. The dashed line is the mean over the series.

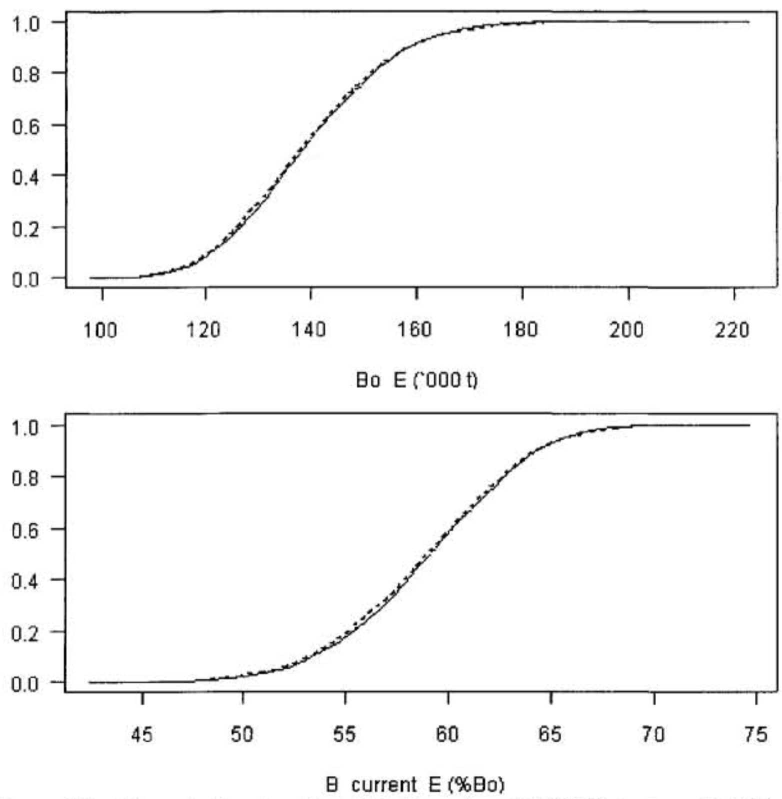

Figure 18: Cumulative density plots from two MCMC chains of 2000 and 1838 values.

For the Bayesian estimates the first 10% were excluded. Convergence final length was 1800 values. Bayesian estimates were therefore based on the median of 1800 values. The MCMC runs did not estimate the process error of the length data so these were fixed at the MPD estimates. Table 15 shows that the summarised posterior distributions and real parameters had low c.v.s, i.e., 11% or less. The parameters of the type X-50to95 had high c.v.s, but they were constrained to be between 0 and 1. Derived parameters, e.g., $B_{current}$, had modest c.v.s, which were low when expresses as a percentage of virgin biomass (Table 15).

Table 15: Bayesian estimates: summary statistics of the posterior distributions for the base case. See Table 12 for parameter codes and description. –, not applicable.

Parameter	Median	c.v. (%)	C.I.05%	C.I.95%	MPD
Bo_W	64 400	10	55 700	76 200	63 600
Bo_E	137 000	11	116 000	163 000	134 000
WF_A50	25.8	2	25	26.8	25.9
WF_50to95	0.6	44	0.2	1	0.5
EF_A50	23.6	1	23.2	24.2	23.7
EF_50to95	0.5	51	0.1	0.9	0.4
WAco_A50	21.1	3	20.3	22	21.1
WAco_50to95	0.6	46	0.1	1	0.5
EAco_A50	8.2	2	8	8.6	8.2
EAco_50to95	0.6	41	0.2	1	0.4
B_cur_W	33 900	19	25 000	45 900	–
B_cur_W(%Bo)	52.7	9	45	60.2	52.1
B_cur_E	80 500	18	59 600	106 000	–
B_cur_E(%Bo)	58.8	7	51.5	65.4	58.2
Bo_total	202 000	8	178 000	231 000	–
B_cur	115 000	14	91 600	144 000	–
B_cur(%Bo)	57	6	51.3	62.4	–

The only strong correlations were between the west and east virgin biomasses and the age at 50% selectivity for their fishery (Appendix B, Table B1). Plots of posterior distributions for the base case model results using 1800 samples of the MCMC chain are shown in Appendix B, Figures B2–B5. The posterior distributions all had relatively low variation.

The distributions for the current mature biomass and the current vulnerable biomass as a percentage of virgin biomass are approximately symmetrical (Figure 19).

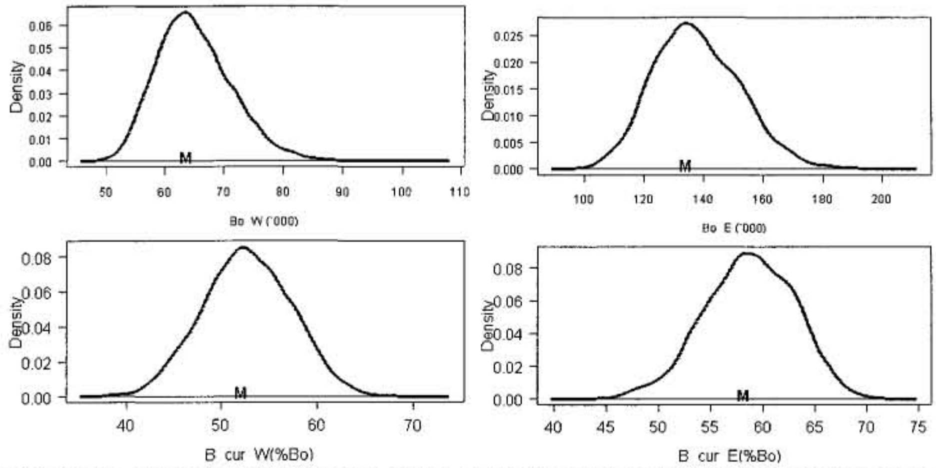

Figure 19: Posterior distribution of the derived parameters: current mature biomass as a percentage of the virgin biomass (A) and current vulnerable biomass as a percentage of the virgin biomass (B).

4.3 Parameter uncertainty

As in the 2003 assessment, sampling error and the quantity of data are not a problem in this analysis, but there are large potential biases in the data that could shift the assessment substantially. These include: using deterministic recruitment, the large proportion of the total acoustic abundance found in the Layer marks, using a linear relationship between standardised CPUE and abundance, and treating the acoustic abundance estimates as absolute values. Further, the post-GPS CPUE series go in opposite directions, increasing in the west, while decreasing in the east. Only the latter was fitted in the assessment. The error in the estimate of M was not incorporated into the model although it potentially could be since the M estimate had a c.v. of 25% (Doonan et al. 1997b).

4.4 Biomass estimates

The biomass estimates are given in Table 15.

5. DISCUSSION AND CONCLUSIONS

The 2007 analysis partly solves a long-standing problem with fitting the full length frequencies in the assessment model. In the 2003 assessment, this was "solved" by extreme measures such as estimating M, or the recruitment year class strength. In 2003 this approach was adopted because there were no data for these processes (age frequencies) and this resulted in a compromised solution. The approach adopted in 2007, of just fitting to the left-hand limb of the length frequencies, allowed selectivites to be estimated (although only as knife-edge) and so avoided the complications of fitting to the trailing edges. Consequently, this assessment is more optimistic since fitting the full length data required using a low virgin abundance.

In the 2003 assessment, the smooth oreo biomass estimates had a median mature 2001–02 mid-year biomass of 90 400 t, 55% of B_0 and yield estimates ($MCY_{long\text{-}term}$ of 4200 t) that suggested that an annual catch of 4284 t (mean catch in OEO 4 from 2001–02) was sustainable (Doonan et al. 2003a). In 2007 the median 2006–07 mid-year biomass was 115 000 t, or 57% of B_0, so this assessment is more optimistic than the 2003 analysis. The annual catch (2005–06) is 5145 t so there should not be a sustainability issue.

In 2007 the acoustic biomass series was still treated as an absolute abundance estimate, but this is not a problem for the MPD estimates since excluding the acoustic data does not change the estimates that much, i.e., the CPUE data alone and the acoustic data alone MPD runs give similar results so they seem to be consistent. However, the absolute nature of the acoustic estimates means that the MCMC variation is low as can be seen in the MCMC acoustic data alone run compared to that for the CPUE data alone run (Appendix C). The latter has very wide limits.

Model biomass estimate results have extra uncertainty from a number of other factors that are outside the model and the analyses, including the sensitivity to the target strength of smooth oreo and the use of deterministic recruitment and the assume a linear relationship between standardised CPUE and abundance.

6. ACKNOWLEDGMENTS

This work was carried out for the Ministry of Fisheries under project OEO2006/02. .

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APPENDIX A: **Fits and Q-Q normal plots for each observer length frequency in the MPD base case.**

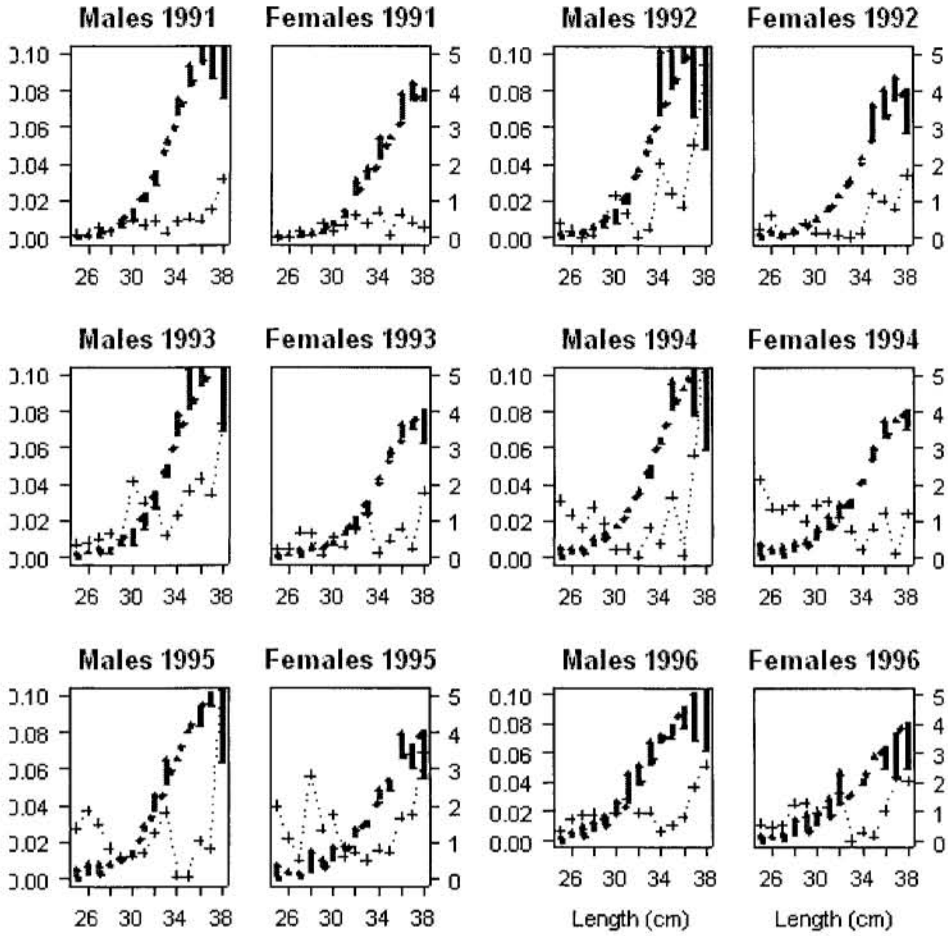

Figure A1: Annual east observer length frequency distributions (triangles) fitted to the model base case (dashed line). The right hand axis shows a plot of absolute normalised residuals (crosses).

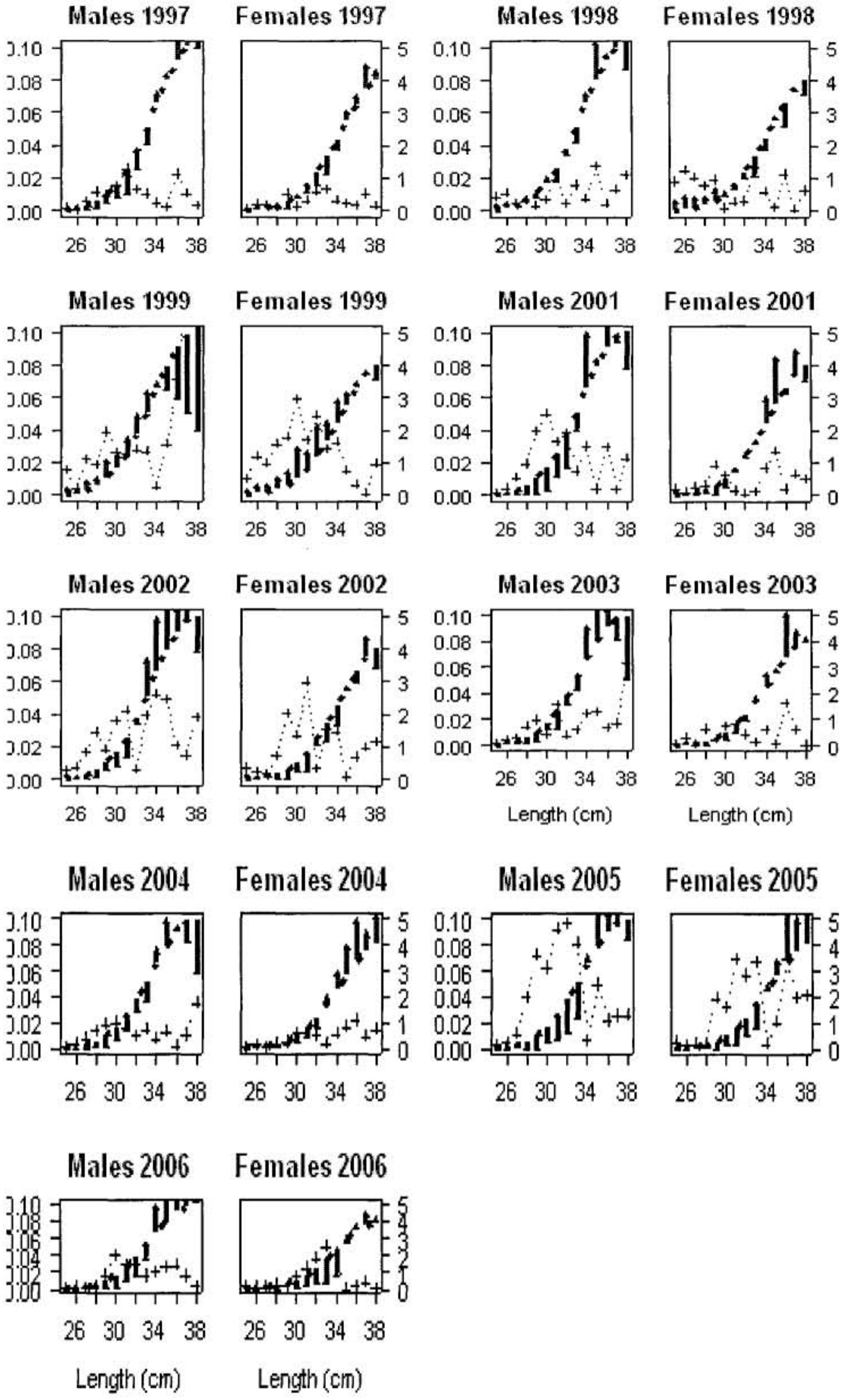

Figure A1 ctd: Annual east observer length frequency distributions fitted to the model base case.

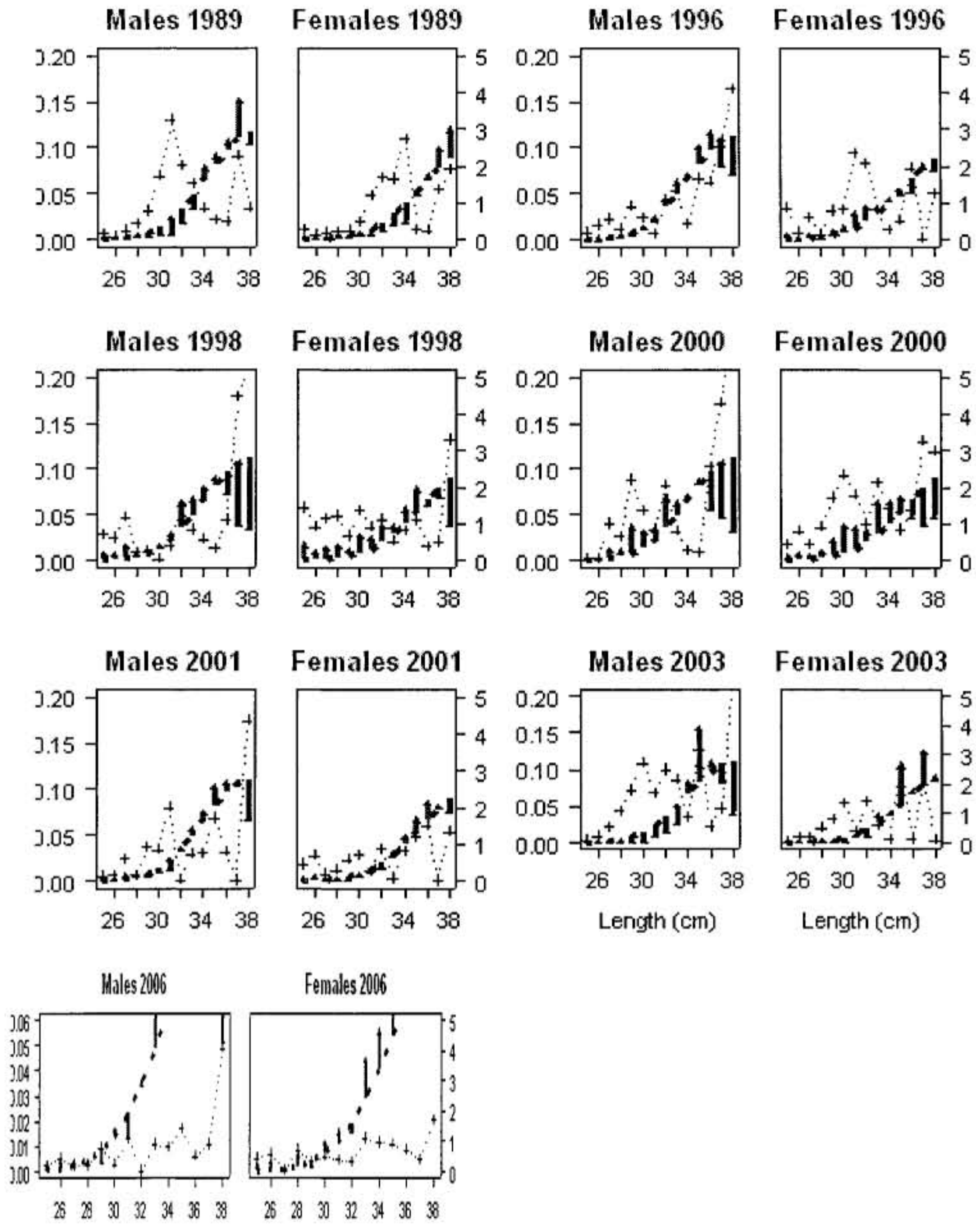

Figure A2: Annual west observer length frequency distributions (triangles) fitted to the model base case (dashed line). The right hand axis shows a plot of absolute normalised residuals (crosses).

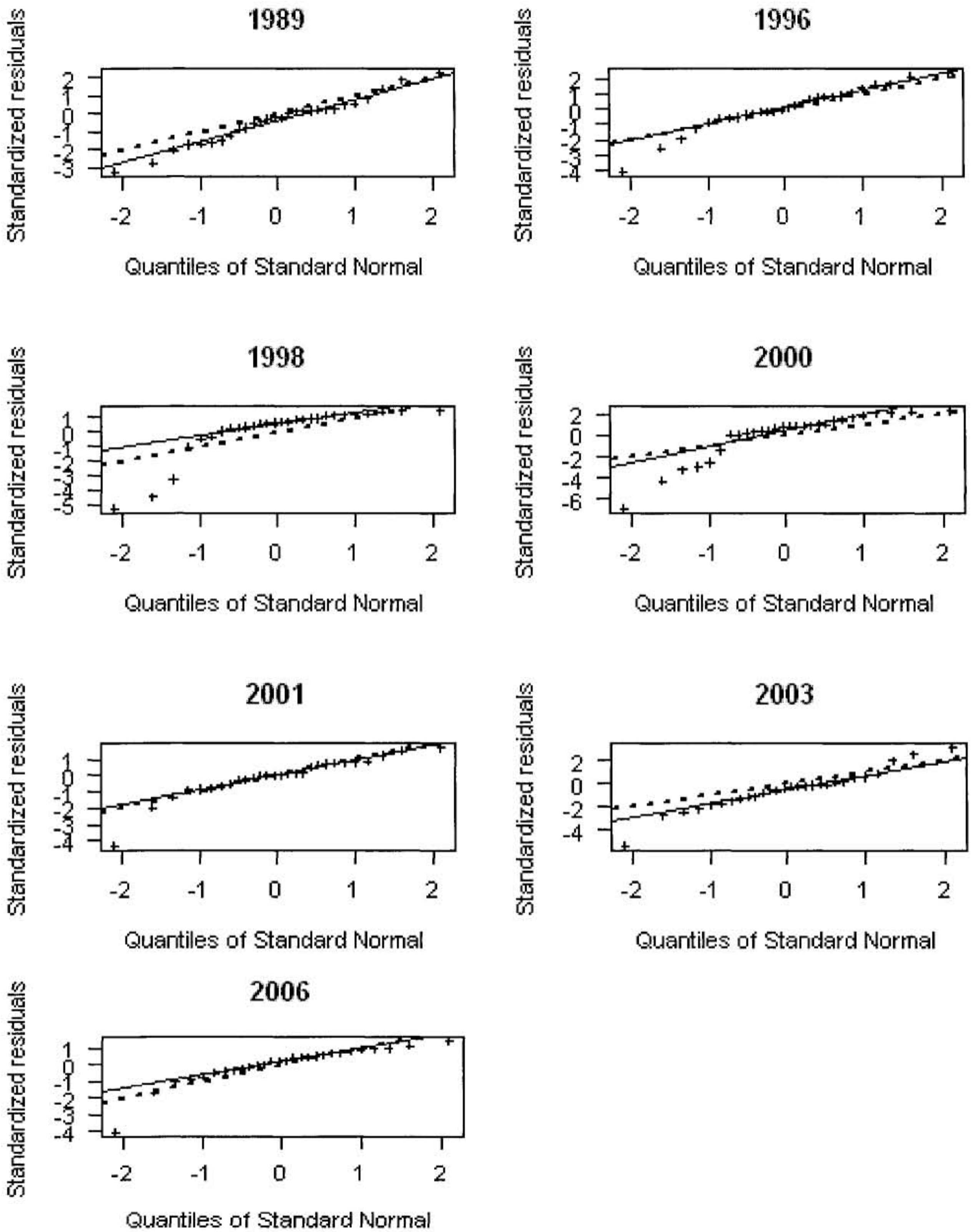

Figure A3: Q-Q normal plots of the normalised residuals (crosses and dots) for each west observer length frequency distribution. The dashed line is the 1:1 line and the solid line is the regression line estimated from the residual points between -1 and 1 on the x-axis.

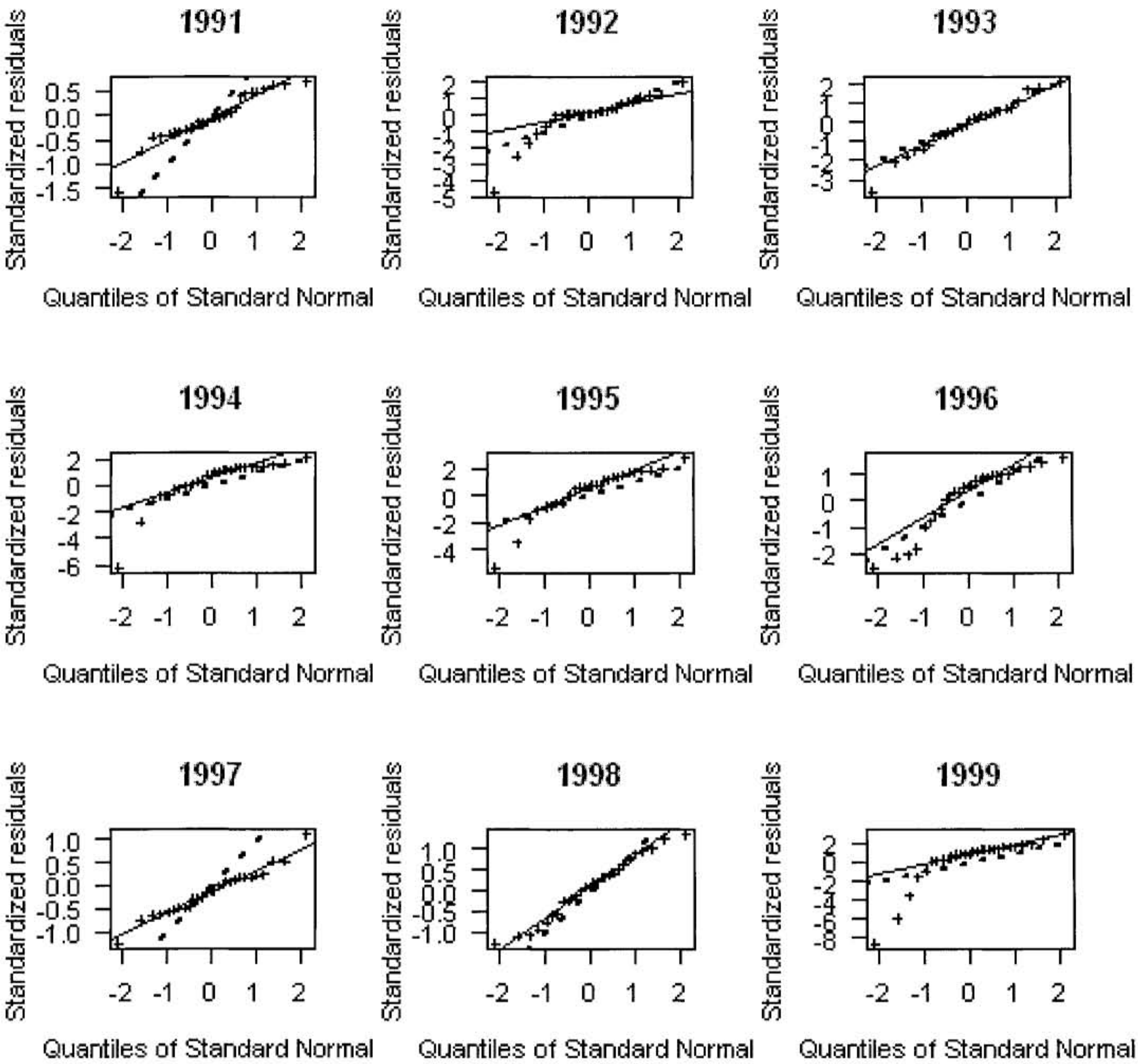

Figure A4: Q-Q normal plots of the normalised residuals (crosses and dots) for each east observer length frequency distribution. The dashed line is the 1:1 line and the solid line is the regression line estimated from the residual points between -1 and 1 on the x-axis.

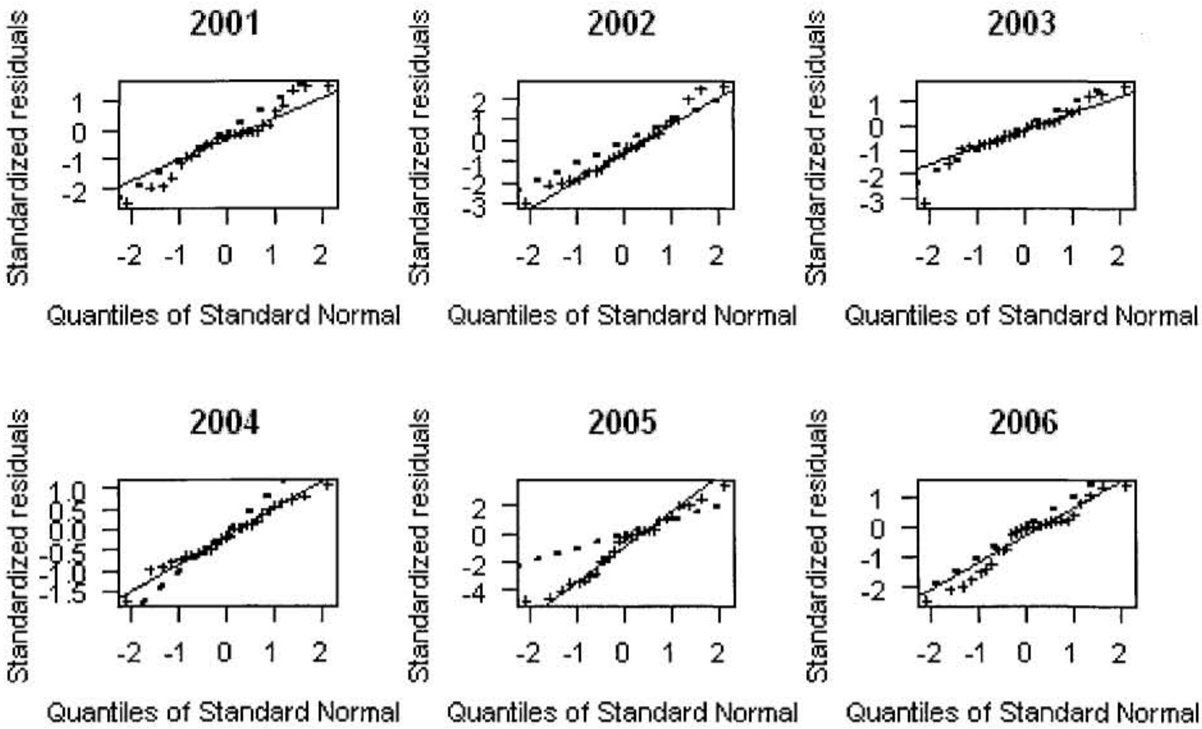

Figure A4: continued.

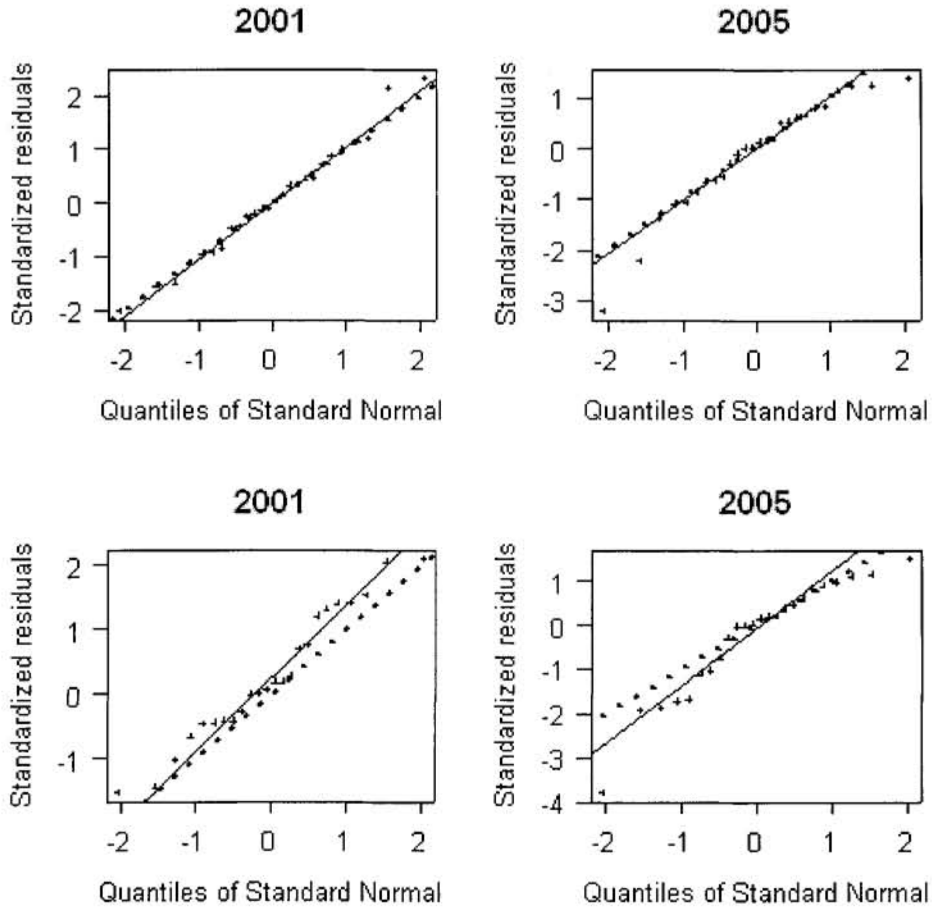

Figure A5: Q-Q normal plots of the normalised residuals (crosses and dots) for each acoustic length frequency distribution. The dashed line is the 1:1 line and the solid line is the regression line estimated from the residual points between -1 and 1 on the x-axis.

APPENDIX B: **Bayesian estimate plots.**

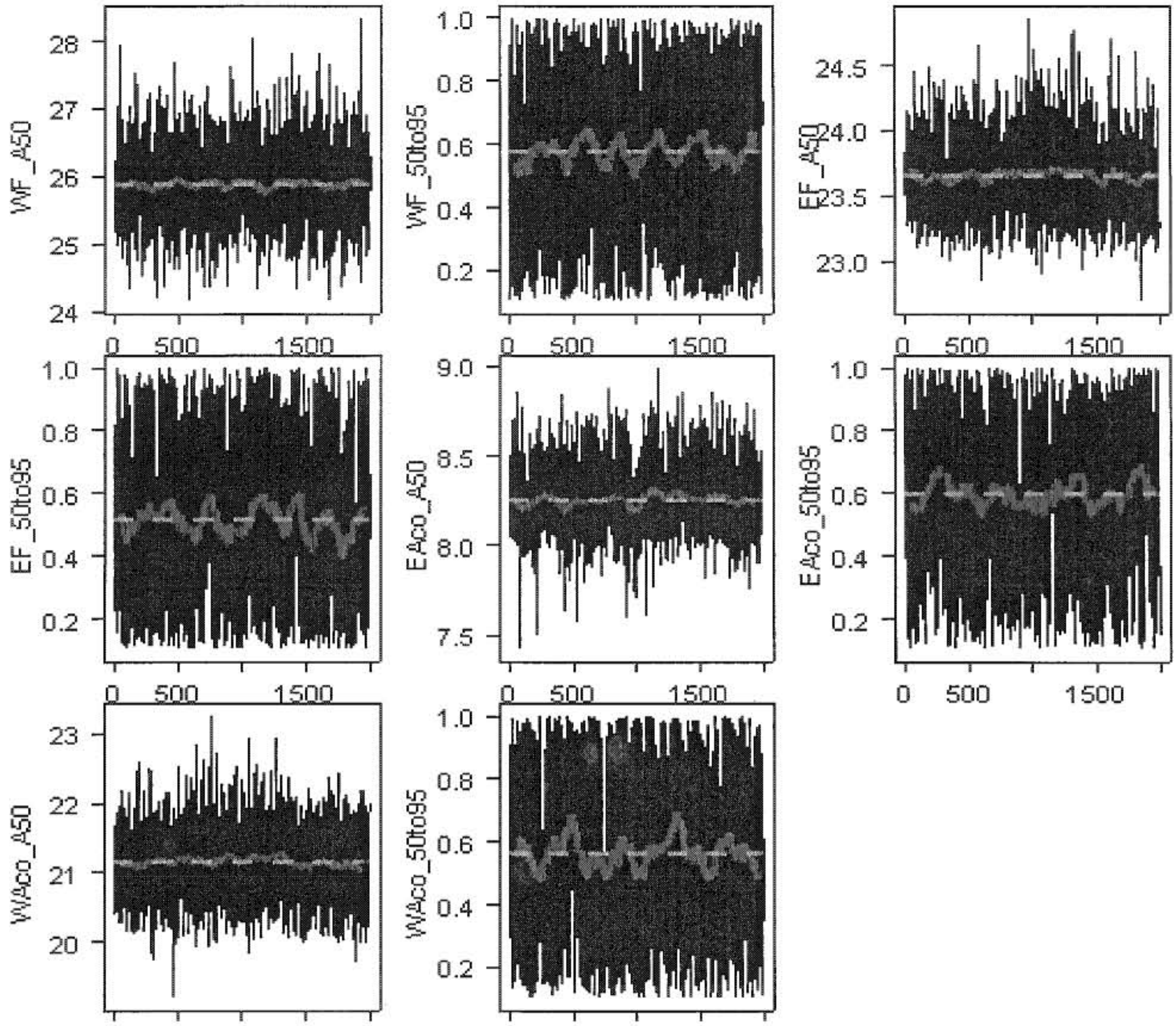

Figure B1: Time series of parameter estimates from MCMC for non-abundance parameters in the base case.

Table B1: Correlation (%) between MCMC parameter estimates.

	Bo_W	Bo_E	WF_A50	WF_50to95	EF_A50	EF_50to95	WAco_A50	WAco_50to95	EAco_A50	EAco_50to95
Bo_W	100	1	-35	-3	4	1	-5	3	1	1
Bo_E	1	100	-4	1	-27	-2	1	1	6	2
WF_A50	-35	-4	100	4	-2	2	-2	-1	-2	-2
WF_50to95	-3	1	4	100	0	0	-3	1	-1	2
EF_A50	4	-27	-2	0	100	18	-1	1	-1	-2
EF_50to95	1	-2	2	0	18	100	-1	-2	1	-5
WAco_A50	-5	1	-2	-3	-1	-1	100	5	1	1
WAco_50to95	3	1	-1	1	1	-2	5	100	3	0
EAco_A50	1	6	-2	-1	-1	1	1	3	100	28
EAco_50to95	1	2	-2	2	-2	-5	1	0	28	100

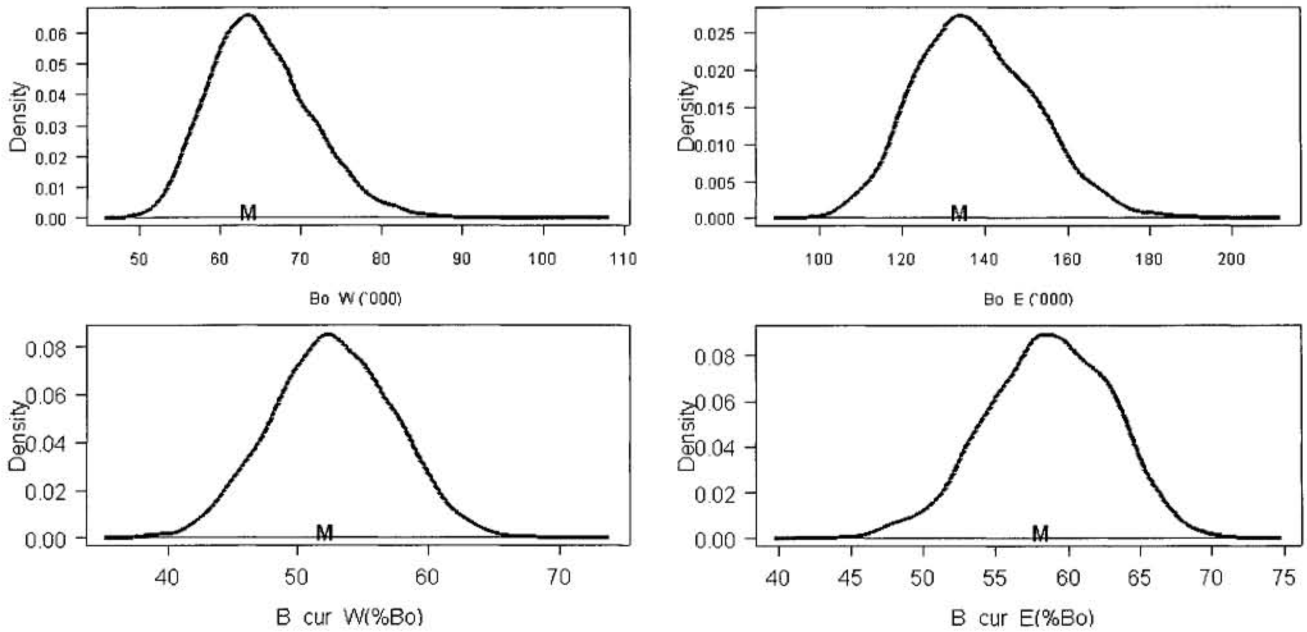

Figure B2: Posterior distribution plots for mature virgin biomass and current biomass for west (left) and east (right). See parameter definition and abbreviations in Table 12.

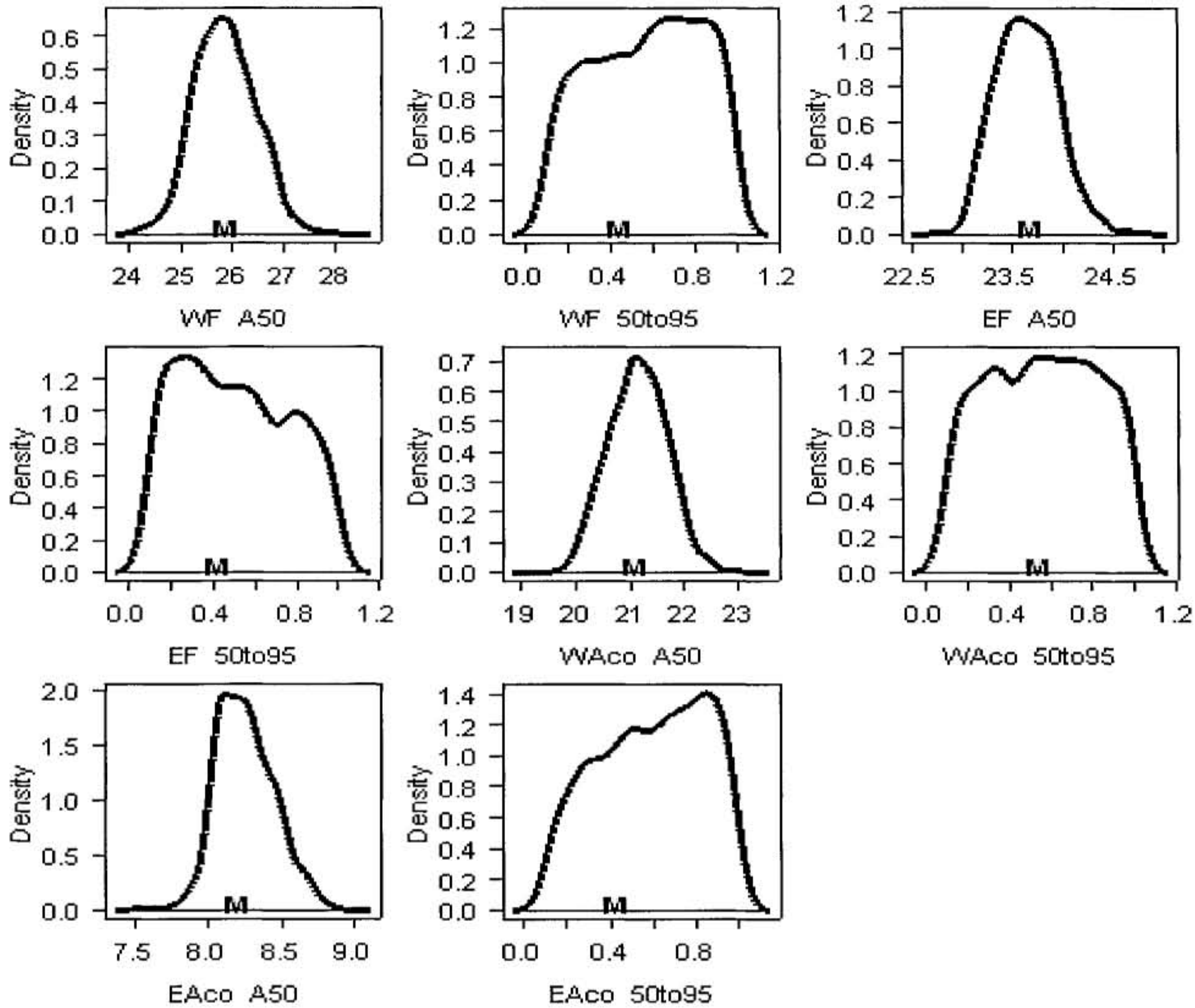

Figure B3: Posterior distribution plots for the west fishery selectivity, age at 50% selection (top left); west fishery selectivity, for ages from 50% to 95% selection (top middle); east fishery selectivity, age at 50% selection (top, right); east fishery selectivity, for ages from 50% to 95% selection mid-row, left), the west acoustic selectivity, age at 50% selection (mid-row, middle); west acoustic selectivity, for ages from 50% to 95% selection (mid-row, right); east acoustic selectivity, age at 50% selection (bottom left); east acoustic selectivity, for ages from 50% to 95% selection (bottom middle). See parameter definition and abbreviations in Table 12.

APPENDIX C: MCMC parameter estimates using each data source alone.

MCMC estimates from two analyses where just one data source was present: CPUE series and the acoustic data.

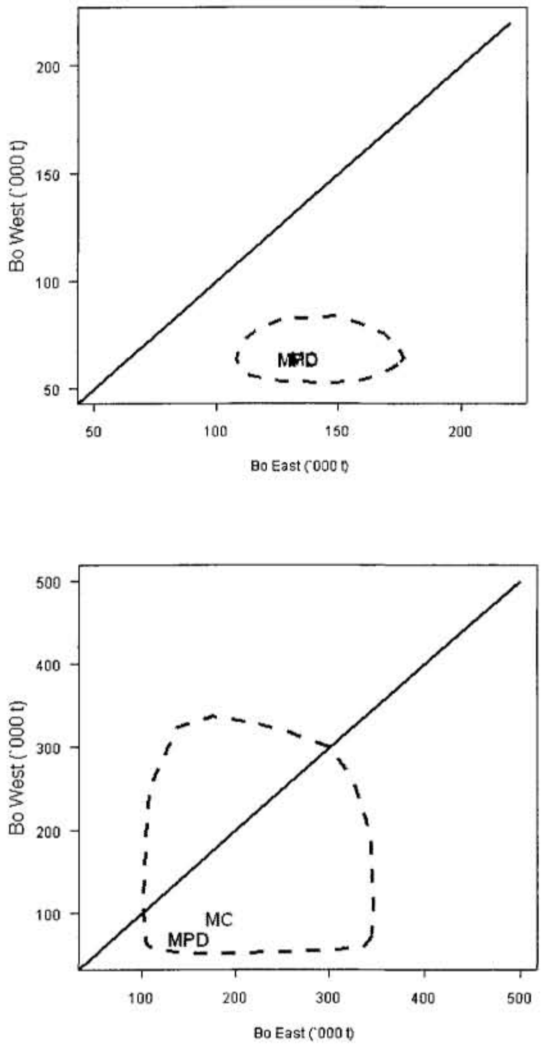

Figure C1: Simultaneous 95% confidence limits for the west and east mature virgin biomass estimates. Top left, base case; top right, acoustic data only; bottom left, CPUE data only.

Table C1: MCMC parameter estimates for acoustic data only. –, n.a.

Name	Median	C.v. (%)	C.I.05	C.I.95	MPD
Bo_W	61 600	11	52 600	74 300	60 300
Bo_E	142 000	11	120 000	171 000	140 000
WF_A50	26	2	25	27	26
WF_50to95	0.6	46	0.1	0.9	0.48
EF_A50	24	1	23	24	24
EF_50to95	0.5	50	0.1	0.9	0.44
WAco_A50	21	2	20	22	21
WAco_50to95	0.6	47	0.1	1	0.54
EAco_A50	8	2	8	9	8
EAco_50to95	0.6	41	0.2	1	0.54
B_cur_W	31 100	21	21 800	43 900	-
B_cur_W(%B_0)	50	10	42	59	49
B_cur_E	85 600	18	63 400	115 000	–
B_cur_E(%B_0)	60	7	53	67	60
Bo_total	204 000	8	180 000	235 000	–
B_cur	118 000	15	92 900	148 000	–
B_cur(%B_0)	58	6	52	63	–

Table C2: MCMC parameter estimates for CPUE data only. –, n.a.

	Median	C. v. (%)	C.I.05	C.I.95	MPD
Bo_W	94 200	56	57 100	275 000	69 100
Bo_E	184 000	32	114 000	321 000	150 000
WF_A50	25	3	24	27	26
WF_50to95	0.5	49	0.1	1	0.5
EF_A50	24	1	23	24	24
EF_50to95	0.5	50	0.1	1	0.49
B_cur_W	64 000	75	26 500	245 000	–
B_cur_W(%B_0)	68	19	46	89	56
B_cur_E	128 000	45	58 200	264 000	–
B_cur_E(%B_0)	69	14	51	82	62
Bo_total	300 000	29	194 000	491 000	–
B_cur	214 000	40	107 000	405 000	–
B_cur(%B_0)	71	12	55	82	–