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Acoustic surveys of spawning hoki off the west coast South Island and in Cook Strait during winter 1997

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1. Executive summary

The spawning hoki biomass in Cook Strait and off the west coast South Island (WCSI) was acoustically surveyed in winter 1997. The acoustic data have been analysed to produce biomass indices which add to existing relative abundance time series.

There appears to have been a moderate increase in spawning hoki biomass in Cook Strait from 1996 to 1997. The biomass appears to have returned to about the level it was in 1988, but is still well below the highest estimated levels which were recorded in 1993 and 1994.

The acoustic index of spawning hoki for the WCSI in 1997 is substantially higher than previous indices, being about 70% higher than the 1993 index. Bycatch rates in the WCSI hoki fishery have increased since 1995 and some of the increase in the hoki index can be explained by an increase in the background density of non-hoki targets in the survey area (as evidenced by the increased bycatch). When a generous allowance (of more than a three-fold increase) is made for the increase in the background density of non-hoki targets, the 1997 index is about 50% higher than the 1993 index.

2. Introduction

Acoustic surveys of spawning hoki have been conducted regularly since a 1984 pilot survey of the west coast South Island spawning grounds (Coombs & Cordue 1995). The results of acoustic surveys of spawning hoki have been an important input into hoki stock assessments for several years (Cordue 1991, 1994, Coombs & Cordue 1995). They provide a fishery independent index of spawning hoki biomass in the two major spawning grounds, WCSI and Cook Strait. The WCSI survey results also provide information on the proportion of hoki biomass which is outside a 25 nautical mile area which is closed to the main hoki fishing fleet. This is important for the interpretation and use of the CPUE data from the west coast.

During winter each year mature hoki migrate from their home grounds to spawning grounds in Cook Strait and off the WCSI. In the spawning grounds the hoki form large midwater aggregations which are readily identifiable from traces seen on echosounders. Commercial and research fishing on spawning hoki aggregations typically result in very clean catches of

hoki. The occurrence of readily identifiable single species aggregations clear of the seabed means that acoustics is an ideal method of biomass estimation for spawning hoki.

During July and August 1997 both main spawning grounds were acoustically surveyed. This report presents the results of these surveys and updates the time series of relative abundance indices for each of the spawning grounds. Because of the large increase in the WCSI indices between 1993 and 1997, some results are also presented with regard to factors which may have caused the 1997 index to be positively biased.

3. Methods

The survey design, survey operation, and data analysis methods are well established for acoustic surveys of hoki (Cordue 1990, 1991, Coombs & Cordue 1995). The survey design and analysis methods used for the 1997 surveys were a continuation of the previous successful approach. In the discussion below, unless otherwise stated, the text applies equally to each of the spawning grounds surveyed in 1997 (WCSI and Cook Strait).

Hoki have a long spawning season, typically more than 2 months. It is thought that during the spawning season there is a turnover of fish on the grounds. Therefore there is no time at which all the spawning fish are available to be surveyed. The survey design deals with this problem.

The survey design of Jolly & Hampton (1990) as adapted by Coombs & Cordue (1995) to obtain a biomass index for transient fish populations was used. This design uses sub-surveys or "snapshots" of random parallel transects within strata (Jolly & Hampton 1990) to obtain several estimates of the spawning biomass during the "main" spawning season. These estimates are then averaged to obtain an estimate of the "mean plateau height" (the average biomass during the main spawning season). Under various model assumptions, annual estimates of mean plateau height form a valid relative abundance time series (Cordue *et al.* 1992, Coombs & Cordue 1995).

Kaharoa was used for the survey in Cook Strait from late July to mid August. A 21 day booking of *Kaharoa* was made for this period and the vessel was used in 2–4 day trips from Wellington during suitable (good) weather. The same stratification has been used for several years, with the survey area including Cook Strait and Nicholson Canyons, Terawhiti Sill, and the Narrows Basin (Figure 1). A shallow-tow CREST acoustic system (Coombs 1994) was used to do the surveying. Targeted trawling on hoki marks was carried out to sample hoki length frequency distributions (the length frequencies were scaled up from measured length frequencies using the hoki catches and the acoustic biomass estimates). Additional targeted trawling was used for mark identification as needed during each snapshot.

Tangaroa was used for the survey of WCSI from mid July to mid August. A 28 day booking of *Tangaroa* was made for this period and the voyage was split into two legs. The

voyage started and finished in Wellington, with a short stopover in Nelson between legs. Two shallow-tow CREST acoustic systems (Coombs 1994) were used during the survey: a small towed-body system and a large towed-body system. The small towed-body system was used only early in the survey; most of the acoustic data were collected using the large towed-body system. Targeted trawling was used for mark identification as needed during each snapshot. The 1993 survey area and stratification were used except that a new stratum (stratum 0) north of stratum 1&2 was added (Figure 2). Stratum 0 was added to the survey area because has been commercial fishing of hoki north of the survey area during the spawning season in some years.

The acoustic data collected during the surveys were analysed (as in past years) using standard echo integration methods (Burczynski 1979) as implemented in NIWA's Echo Sounder Package (ESP) software (Cordue 1990). Acoustic backscatter (m^{-2}) was converted to hoki biomass using the ratio of mean weight to mean target strength for hoki from Coombs & Cordue (1995). Biomass estimates and their variances were obtained for each snapshot using the formulae of Jolly & Hampton (1990). The snapshots were averaged to obtain the biomass index for 1997 for each area.

The WCSI biomass estimates and the 1997 index were adjusted, as in previous years, for background species by assuming a low and constant background density of non-hoki targets in the survey area (Coombs & Cordue 1995). The adjustment was made by subtracting 0.3×10^{-6} m^{-2} from the average acoustic backscatter in each stratum (a figure derived by Coombs & Cordue (1995) using pre-spawning season data from a 1988 survey). The effect of an increase in the level of non-hoki target targets on the 1997 biomass estimates was investigated by making larger adjustments (up to a level of 3.0×10^{-6} m^{-2}).

Some data not directly associated with the acoustic surveys were analysed with regard to the WCSI acoustic results. Commercial catch and effort data for hoki and the main bycatch species for the WCSI fishery from 1988 to 1997 were partitioned into acoustic strata. The bycatch rates were used to investigate possible changes in the background density of non-hoki targets. Non-standardised CPUE (catch per kilometre) were calculated within strata to see if apparent changes in hoki biomass from the acoustics surveys had been reflected in catch rates.

4. WCSI results

4.1 Biomass estimates

Seven snapshots of the WCSI spawning grounds were completed by *Tangaroa* from mid July to mid August. The first snapshot was done with the small towed-body system and the remainder with the large towed-body system. The first snapshot was very noisy, because of a fault in the small towed-body, and has not been analysed. The last six snapshots were not noisy and have been analysed to produce biomass estimates. A new

stratum (stratum 0) was added into the survey, to the north of stratum 1&2, as in some years fishing occurred to the north of stratum 1&2 during the spawning season. To make the biomass estimates comparable to previous years, stratum 0 biomass estimates were not included in the overall biomass estimates.

Over the survey period there were indications of increasing levels of biomass in the area from late July to mid August (Table 1) associated with higher biomass estimates in Hokitika Canyon (strata 5A, 5B) and stratum 6 (Table 2). The main contributions to the overall biomass estimates came from the northern strata (strata 1&2, 4). The most northern stratum (stratum 0) had the second highest average biomass estimate (Table 2).

The time series of acoustic indices (which does not include stratum 0) shows a decline from 1988 to 1990, with a strong rise since then, with the 1997 index being more than twice that in 1988, and about 70% higher than that in 1993 (Table 3, Figure 3). The estimated average proportion of hoki biomass outside the closed area on the WCSI in 1997 was greater than previous years, being slightly more than the previous highest estimate in 1988 (Table 4).

4.2 Species identification

During the first six snapshots, 30 target identification trawls were done (Table 5). Most trawls were targeted on midwater marks in Hokitika Canyon (strata 5a, 5b) and strata south of Hokitika Canyon (strata 6, 7). A mixture of bottom trawling and midwater trawling was done in the strata north of Hokitika Canyon (strata 0, 1&2, 4).

The trawling was done for two reasons. First, to help with the analysis of the survey by identifying specific marks, so that the marks could be included or excluded from the biomass estimation depending on whether they were formed primarily by hoki or not. Second, the results add to our general target identification knowledge (whereby we associate characteristic mark types with particular species).

The types of acoustic marks seen on the WCSI in 1997 were very similar to previous years and the results of the target identification trawls held few surprises for the staff directing the trawling (Adrian Colman, Patrick Cordue pers. comm.). Trawl catches varied greatly from shot to shot, but midwater shots typically caught very little of anything (typically indicating the presence of small pelagic fishes which are not retained by the codend) or several tonnes of hoki (Table 6). The shots with the bottom trawl caught a greater range of species (as would be expected) and although hoki was normally less than 50% of the catch by weight, it was usually the most abundant single species in the catch (Table 6). The bottom trawls were mainly targeted at low density bottom referenced layers on the bottom. As is usual, there were extensive layers of this type in the northern strata throughout the survey period. The correction for background species is intended to deal with the backscatter that is recorded in these layers from non-hoki targets.

4.3 Species mix

When the 1997 biomass estimates are compared with the 1993 results, it is found that the increase in the biomass index was entirely due to the strata north of Hokitika Canyon (strata 1&2, 4). The 1997 survey has 263 000 t in Hokitika Canyon and the southern strata, with 381 000 t in the northern strata (*see* Table 2). The corresponding estimates from the 1993 survey are 265 000 t and 118 000 t (Sullivan *et al.* 1995).

Concerns were raised in the Hoki Working Group as to whether the low density layers in the northern strata were produced primarily by hoki. The correction for background species had been applied to the 1997 survey as well as in previous years, but the concern was that the biomass index in 1997 had been inflated by the inclusion of a greater proportion of backscatter from non-hoki targets (so that a larger value had to be subtracted from the average acoustic backscatter).

Hoki bycatch rates for 1988–97 using TCEPR daily processed summaries were investigated (Table 7), and it was found that the bycatch rates for a range of species had increased between 1993 and 1997 (Table 8). For the whole acoustic survey area, hoki bycatch rates for semi-demersal species were generally about 5% from 1988 to 1994, but then increased to about 15% from 1995 to 1997 (Table 8b). The ratio of the 1997 and 1988 bycatch rates can be used to adjust the amount of backscatter to subtract in the background density correction. When this is done, the biomass index is reduced from 644 000 t to 606 000 t (Table 9, Figure 3). If all species are included in the calculation of the ratio (*see* Table 8a) then the biomass index drops to 579 000 t. Larger corrections can be made, but when the backscatter to be subtracted reaches 3.0×10^{-6} m^{-2} the biomass estimate in stratum 5b in snapshot 3 is reduced to zero (Table 10d).

4.4 Size of hoki

An examination of the length frequencies of hoki in the commercial catch on the WCSI shows that the bulk of the catch came from the northern (acoustic) strata, and that there was a greater proportion of smaller fish caught in the northern strata (Figure 4). The 1997 length frequencies are quite different from those of 1993. At that time, there was very poor recruitment from the 1989 and 1990 cohorts, so that there was an absence of 50–60 cm fish in the length frequencies (*see*, for example, Sullivan *et al.* 1995). Indeed, the 1997 acoustic survey is the first survey in the time series to occur in a year in which there has been a substantial left-hand limb in the length frequencies (this has occurred in every year from 1994, *see* Ballara *et al.* 1998).

4.5 WCSI CPUE

Trends in unstandardised CPUE on the WCSI differ between acoustic strata (Figure 5). The general trend is downwards, with the CPUE index dropping from 1.37 to 0.32 from 1987 to 1997, and from 0.61 to 0.32 from 1993 to 1997. Comparing 1993 and 1997 within the acoustic strata, the CPUE is down slightly in the southern strata (from 0.37 to

0.31), and substantially down in stratum 4 (from 0.47 to 0.27) and stratum 1&2 (from 0.69 to 0.39). The only notable improvement in CPUE in recent years is in stratum 1&2 where the 1997 CPUE is greater than that in 1995 and 1996 (Figure 5).

When it is realised that CPUE is more likely to be tracking density than abundance these results are seen not to be inconsistent with the acoustic estimates in 1993 and 1997. It is notable that the biomass in the northern strata during the acoustic surveys was more aggregated in 1993 than in 1997. This is evidenced by the average within strata *c.v.*s, which in 1997 were 22% and 20% for strata 1&2, 4 respectively, and in 1993 were 28% and 30% respectively.

5. Cook Strait results

5.1 Biomass estimates

Six snapshots of the Cook Strait spawning grounds were completed by *Kaharoa* from late July to mid August in 1997 (Table 11). Similar levels of biomass were estimated during each snapshot, but biomass levels increased through the season into August, and then declined (Table 12). For most snapshots the largest estimated biomass was in Cook Strait Canyon; other strata with substantial estimated biomass on occasion were the Narrows Basin in snapshots 4 and 5, and in snapshot 4 in Stratum 5B, the deep water region outside Nicholson and Wairarapa Canyons (Table 13).

The time series of Cook Strait spawning biomass indices declines steeply from 1988 to 1992, and increases sharply in 1993 to twice the 1988 level. In the next 3 years the time series declines to about 60% of the 1988 level, approximately halving from 1995 to 1996, and there appears to have been a moderate increase in spawning hoki biomass in Cook Strait from 1996 to 1997 (Table 13, Figure 6). The biomass appears to have returned to about the level it was in 1988, but is still well below the highest estimated levels which were recorded in 1993 and 1994.

Because of the pattern of increasing biomass seen throughout the survey into August, the Hoki Working Group decided to apply a correction factor to the 1995 and 1996 biomass indices to account for the possibility that the peak biomass abundance of these seasons had not been surveyed. The ratio of the last three snapshots to the first three snapshots in 1997 was estimated at 121% and this was used to increase the 1995 and 1996 estimates (*see* Table 13). This time series of abundance was considered to be more appropriate than the uncorrected indices.

5.2 Trawl results

There were 18 successful mid-water trawl shots during the survey (Table 14). Most trawling was targeted at hoki marks for the purposes of size estimation, though some specific target identifications shots were made on jack mackerel and spiny dogfish marks

(Table 14). There appeared to be quite a lot of dogfish in Cook Strait Canyon (stratum 2) and sometimes these were caught with hoki in the targeted hoki shots (*see* shots 6, 15, and 19 in Tables 14 & 15). The dogfish marks were generally above the hoki marks and could be successfully targeted without catching much hoki (*see* shots 13 and 14, Tables 14 & 15).

5.3 Length frequencies

A total of 14 trawl shots were sampled for length with about 2500 hoki measured. A length frequency for the whole of the survey was estimated from the targeted hoki trawling during snapshots 2, 4, and 6. Length frequencies for the Narrows Basin and Cook Strait Canyon were also estimated, using all trawl shots in those strata (*see* Table 14). The length frequencies are only indicative of the size structure of the spawning population of hoki in Cook Strait. The few trawl shots, the window bursting on 8 of the 14 shots, and the imprecision of the biomass estimates (used to weight the length frequencies across strata and snapshots) means that the length frequencies should be treated cautiously.

There are more females than males in the estimated length frequency (Figure 7) but this is probably due to sampling error. Roughly equal proportions of males and females were estimated for the Narrows Basin (Figure 8) and the imbalance in the overall length frequency is due to the larger proportion of females estimated in Cook Strait Canyon (Figure 9). The 1994 cohort is quite prominent in the male length frequencies (at about 55 cm) in both strata, and a few fish from the 1996 cohort were also present, mainly in the Narrows Basin (at about 30 cm). The general belief that hoki in the Narrows Basin are smaller than hoki in Cook Strait Canyon is supported by the data. In particular, the length frequency for Cook Strait Canyon contains a much greater proportion of large females than that for the Narrows Basin.

6. CONCLUSIONS

There appears to have been a moderate increase in spawning hoki biomass in Cook Strait from 1996 to 1997. The biomass appears to have returned to about the level it was in 1988, but is still well below the highest estimated levels which were recorded in 1993 and 1994.

The acoustic index of spawning hoki for the WCSI in 1997 is substantially higher than previous indices, and about 70% higher than the 1993 index. Bycatch rates in the WCSI hoki fishery have increased since 1995 and some of the increase in the hoki index can be explained by an increase in the background density of non-hoki targets in the survey area (as evidenced by the increased bycatch). When a generous allowance (of more than a three-fold increase) is made for the increase in the background density of non-hoki targets, the 1997 index is about 50% higher than the 1993 index.

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Table 1: Acoustic snapshot estimates of the 1997 WCSI spawning hoki biomass (excluding stratum 0)

Snapshot	Date	Estimate ('000 t)	*c.v.* (%)
1	12 Jul - 16 Jul	-	-
2	16 Jul - 19 Jul	693	9
3	24 Jul - 28 Jul	473	11
4	28 Jul - 31 Jul	542	13
5	31 Jul - 3 Aug	664	14
6	3 Aug - 6 Aug	738	17
7	7 Aug - 9 Aug	756	12
Mean		644	05

Table 2: Snapshot estimates by stratum for the 1997 WCSI spawning hoki biomass ('000 t). A "-" or an italicised entry indicates that a stratum was not surveyed. The italicised entries were obtained from the previous snapshot and were used in the calculation of the biomass index and the snapshot estimates

	Stratum						
Snapshot	0	1&2	4	5A	5B	6	7
1	-	-	-	-	-	-	-
2	89	260	187	109	26	78	32
3	214	107	240	18	6	69	*32*
4	140	150	138	44	29	128	53
5	186	125	311	89	29	94	17
6	-	121	299	97	33	171	*17*
7	-	143	205	135	85	151	37
Mean	157	151	230	82	35	115	31

Table 3: Acoustic indices of hoki biomass for WCSI spawning seasons 1988–1993, and 1997. The indices have been adjusted for background species by assuming a low and constant background density of non-hoki targets in the survey area. The indices have been assigned *c.v.*s according to the procedure in Cordue *et al.* (1992) assuming a median *c.v.* of 0.25

Year	Biomass index (' 000 t)	Normalised biomass index	Number of snapshots	*c.v.*(%)
1988	274	1.00	2	33
1989	171	0.62	5	25
1990	160	0.58	7	23
1991	259	0.95	3	29
1992	218	0.80	2	33
1993	383	1.40	7	23
1997	644	2.35	6	24

Table 4: Acoustic estimates of the mean percentage of hoki biomass outside the 25 nautical mile closed area for 1988–1993, and 1997. The adjusted percentages were obtained by assuming a low and constant background density of non-hoki targets in the survey area.

Year	Mean % outside	Adjusted %
1988	74	73
1989	49	44
1990	54	49
1991	60	57
1992	66	63
1993	54	52
1997	75	75
mean	62	59

Table 5: Summary station information, and comments for WCSI 1997 acoustics survey trawl stations (MW = midwater, BT = bottom trawl)

Station	Snapshot	Stratum	Comments
1	1	5b	MW layers across Canyon, layer split, trawled on top one, caught mainly hake
2	1	6	MW layer, night, mainly hoki
3	1	6	MW layer, day, hoki
4	2	4	MW shallows (250 m over 300 m bottom), day, pearlside
5	2	4	MW on bottom, frostfish
6	2	0	BT 650 m bottom fuzz, caught mainly hoki, rats, hake, dogfish
7	2	0	BT 610–615 m bottom fuzz, hoki, rats, hake, dogfish
8	2	0	BT 650 m bottom fuzz at night, hoki, rats, etc, hoki smaller
9	3	4	MW at 450–500 m, 50 m off bottom, light marks, hoki, hake
10	3	4	BT 650 m mark under trawl 9, hoki, hake, and bits
11	3	6	near bottom, 450–500 m, mainly hoki
12	3	6	bottom fuzz at 600 m, small stuff in meshes
13	3&4	7	MW cloud, lantern fish
14	3&4	7	near bottom, 2.5 t hoki, 0.5 t JMM
15	4	5a	MW cloudy stuff at 250 m, small stuff
16	4	5	near bottom at 400 m, mostly hoki, some spiny dogfish
17	4	1&2	compact marks at 400 m, lanternfish
18	4	1&2	300 m over 600 m depth, didn't find target, mobile?
19	5	5a	280 m at head Canyon, lanternfish
20	5	5a	close bottom Canyon, dense mark, 3.5 t hoki
21	5	6	scattered MW marks, night, SWA
22	5	6	MW 360–400 m over 700–750 m, dense mark, lanternfish
23	5	6	BT at 700 m,small catch: mainly hoki, shovelnose dog, pale ghost shark, hake
24	5	6	MW at 350 m over 350–400 m, frostfish, and hoki
25	6	6	MW 275–300 m over 300 m, solid marks, 2.5 t hoki
26	6	6	MW 380–390 m over 420–440 m, scattered marks, hoki
27	6	6	MW 620–730 m over 700–750 m, bottom fuzz, stuff in meshes only
28	6	5a	MW at 400 m over 550 m, dark scattered marks, hake, scabbard fish
29	6	5a	MW at 330 m over 350 m, rubyfish, porbeagle
30	6	5a	MW at head Canyon, scattered clumps, small catch hoki

Table 6: Species summary information for the 1997 WCSI acoustics survey trawl stations

Stn.	Hoki	Hake	Frost fish	Pale ghost shark	Rattails and javelin	Silver warehou	Dogfish and sharks	Ling	JMM	Lantern fish	Total
1	25	70.0	-	-	3.0	-	1.0	3.5	-	1.0	129.5
2	110	-	5.0	-	1.0	1.0	2.0	-	-	-	136.1
3	2 720	-	1.5	-	-	-	-	-	1	-	2 726.5
4	-	-	-	-	-	-	-	-	-	-	10.0
5	3	-	30.0	-	-	-	15.0	-	-	1.0	60.0
6	90	8.0	-	25.0	41.0	-	101.0	5.0	-	-	409.0
7	75	20.0	-	10.0	31.0	2.5	21.0	30.0	-	-	298.5
8	50	12.0	-	10.0	9.0	8.0	40.0	20.0	-	-	207.0
9	20	10.0	-	-	1.0	1.5	-	-	-	0.1	41.1
10	140	35.0	-	0.5	10.5	-	0.5	2.0	-	0.5	231.1
11	250	-	-	-	-	-	-	-	-	-	255.0
12	10	0.5	-	-	-	-	-	-	-	-	20.0
13	-	-	1.0	-	-	-	-	-	-	1.0	2.0
14	2 500	-	-	-	-	-	-	-	500	5.0	3 061.0
15	-	-	5.0	-	-	-	2.0	-	5	5.0	17.0
16	2 775	-	20.0	-	-	-	200.0	-	-	-	3 005.0
17	-	-	-	-	-	-	-	-	-	1.0	6.0
18	-	-	-	-	-	-	-	-	-	1.0	1.0
19	-	-	2.0	-	-	-	0.5	-	-	1.0	3.5
20	3 510	-	-	-	-	-	200.0	-	3	-	3 743.0
21	-	-	-	-	0.2	15.0	-	-	-	0.2	20.6
22	-	-	-	-	0.5	-	-	-	-	50.0	50.0
23	120	20.0	-	15.0	10.0	-	13.0	2.0	-	-	310.4
24	20	-	25.0	-	1.0	-	2.5	-	4	-	53.6
25	2 675	-	10.0	-	-	10.0	50.0	-	-	-	2 785.0
26	375	-	10.0	-	0.2	2.0	-	-	-	1.0	388.0
27	7	1.0	-	-	0.4	2.0	-	-	-	-	26.0
28	8	20.0	3.0	-	-	-	0.2	-	-	-	53.6
29	-	-	10.0	-	-	3.0	70.0	-	-	1.0	109.5
30	70	-	1.0	-	1.0	3.0	-	-	-	-	86.0

Table 7: WCSI hoki bycatch species (in tonnes) for WCSI acoustics strata for July and August 1988–97. (source: Foreign and Specified FSU data, and TCEPR daily processed records for which full positional data were recorded. The low tonnages in 1989 are a consequence of this selection criteria)

(a) All strata

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
HOK	188 150	15 391	149 217	123 945	100 418	77 837	109 337	68 679	59 131	80 398
BAR	205	120	857	487	323	372	438	1 081	493	618
BNS	50	16	84	18	9	15	10	10	46	30
EMA	41	66	8	1 029	86	52	172	73	162	735
FRO	871	161	1 975	2 618	1 735	748	1 297	1 287	556	954
HAK	2 730	1 008	5 097	5 333	937	1 978	1 620	5 225	4 876	4 057
JAV	0	3	27	1	4	9	1	14	35	101
JMA	11	68	853	1 062	1 366	236	2 616	3 251	3 393	3 068
LDO	18	8	27	22	20	29	44	48	49	48
LIN	924	156	1 302	867	624	462	669	867	987	993
ORH	23	0	-	2	0	5	19	3	67	5
OSD	1	30	54	7	1	31	15	26	47	22
POS	0	1	2	1	-	2	4	2	7	13
RAT	-	1	26	120	2	53	10	39	152	290
RBM	27	2	8	1	3	-	12	10	8	23
RBT	0	4	-	2	1	13	66	94	143	156
RCO	6	2	59	57	238	107	73	135	96	9
RIB	5	10	16	16	13	18	18	6	18	33
SKI	291	64	282	73	68	109	99	16	4	3
SPD	47	6	153	90	317	67	538	293	705	242
SPE	3	4	3	3	2	4	21	24	40	17
SQU	73	18	27	58	97	35	126	101	83	63
SSK	2	1	27	26	32	20	60	58	118	79
STA	11	1	36	28	15	15	25	40	34	77
SWA	1 850	209	1 526	1 909	934	477	1 755	848	1 536	2 457
TAR	2	1	12	10	14	7	8	23	8	2
WAR	80	16	136	303	271	9	66	51	113	236
WWA	12	-	21	59	21	25	34	38	35	38

(b) Stratum 0:

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
HOK	114	95	324	1 174	4 395	7 609	3 407	3 348	102	1 083
FRO	1	-	-	65	25	80	9	31	-	1
HAK	1	10	3	28	16	5	8	47	4	38
JAV	0	0	0	0	0	1	0	0	0	0
JMA	0	-	1	9	-	17	85	29	5	2
LDO	1	-	-	1	2	2	2	10	-	7
LIN	3	2	1	4	48	28	21	55	3	23
RAT	0	0	0	0	-	1	-	1	0	2
SPD	-	0	3	0	21	0	1	-	1	0
SPE	-	-	0	0	0	1	1	5	1	7
SQU	-	-	0	-	14	3	1	5	-	1
SSK	0	-	-	-	7	3	3	9	-	13
SWA	17	-	4	37	55	43	19	105	9	107

(c) Stratum 1&2:

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
HOK	37 657	2 832	4 635	38 838	45 729	44 740	38 565	8 673	2 674	33 809
BAR	5	42	216	63	88	117	232	701	101	118
EMA	41	12	-	233	12	23	91	4	24	197
FRO	164	21	148	1 164	646	366	564	206	16	352
HAK	144	46	55	79	42	70	123	211	265	1 143
JAV	0	1	1	-	2	3	-	1	5	22
JMA	3	20	201	366	68	122	558	556	365	517
LDO	10	1	2	6	7	5	16	15	21	17
LIN	125	9	90	173	144	105	204	157	157	254
OSD	-	1	0	0	0	10	1	5	0	10
RAT	-	-	2	50	1	21	4	7	14	111
RBM	3	-	0	-	2	-	5	4	-	10
RBT	0	0	0	-	0	-	4	4	12	52
RCO	1	-	2	7	186	35	23	44	47	5
SKI	62	8	82	53	55	70	48	10	2	2
SPD	7	1	1	25	135	30	218	22	36	42
SPE	2	2	1	1	1	2	13	11	22	6
SQU	19	1	4	24	41	16	30	39	32	16
SSK	-	-	10	10	18	11	35	30	72	33
STA	4	-	4	5	7	4	10	14	17	8
SWA	697	30	213	1 378	426	192	980	252	259	1 551

(d) Stratum 4:

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
HOK	56 623	5 978	65 498	26 158	13 225	15 936	51 700	41 445	36 104	22 886
BAR	15	47	165	17	52	239	115	334	306	193
EMA	0	53	7	619	4	24	32	57	8	100
FRO	555	63	1 166	685	317	167	541	823	312	285
HAK	275	374	2 584	1 563	185	1 160	522	3 213	2 996	1 096
JAV	0	2	19	1	0	3	-	7	28	41
JMA	1	15	345	204	505	69	944	923	478	878
LDO	4	5	19	12	6	15	21	18	24	19
LIN	129	33	530	221	137	139	284	367	384	292
ORH	0	0	0	-	0	5	1	-	34	1
OSD	-	5	6	4	0	17	6	17	45	4
RAT	-	-	17	36	-	26	3	24	129	119
RBT	0	4	-	2	1	0	32	76	83	28
RCO	1	-	4	4	24	54	33	47	34	2
RIB	1	6	11	5	7	13	11	3	12	18
SKI	162	48	173	16	10	36	49	5	1	0
SPD	4	2	28	24	59	26	258	176	371	61
SPE	1	1	1	1	1	1	7	8	15	3
SQU	28	13	19	30	35	12	90	54	49	43
SSK	-	-	16	14	7	4	23	18	45	32
STA	1	1	9	11	4	5	12	19	13	63
SWA	968	114	795	298	133	150	674	360	1 035	475
TAR	1	-	4	5	3	1	3	8	3	1
WAR	15	5	18	47	115	1	39	40	41	60
WWA	3	-	18	22	5	17	20	33	22	13

Table 8: Hoki percent bycatch rates for all hoki bycatch species for WCSI acoustics strata, for July and August 1988–97. (source: Foreign and Specified FSU data, and TCEPR daily processed data)

(a) All species

		Stratum			
	All	0	1&2	4	5a,5b,6,7
1988	5.2	21.5	4.5	4.7	5.8
1989	13.2	15.3	7.1	14.2	15.0
1990	8.5	14.2	22.7	9.2	7.1
1991	11.5	12.7	9.5	14.8	11.4
1992	7.2	4.8	4.2	12.3	9.2
1993	6.3	2.8	2.7	13.8	13.5
1994	9.0	4.5	8.3	7.3	17.7
1995	20.0	9.2	26.7	16.1	29.1
1996	23.6	34.3	57.4	18.2	28.7
1997	18.2	19.8	13.7	17.5	26.0

(b) Semi-demersal species only

		Stratum			
	All	0	1&2	4	5a,5b,6,7
1988	5.0	21.4	4.3	4.5	5.5
1989	11.0	14.9	4.3	11.1	13.7
1990	7.3	4.6	13.4	8.3	6.1
1991	9.3	11.5	7.7	11.3	9.5
1992	5.3	4.4	3.7	7.7	6.4
1993	5.4	2.3	2.1	11.6	12.9
1994	5.9	1.9	5.9	4.9	9.9
1995	13.2	8.1	11.5	12.5	17.0
1996	16.2	19.0	37.2	15.5	14.6
1997	12.4	19.1	10.9	11.7	14.8

Table 9: WCSI acoustic biomass estimates for a range of adjustments for background species made by assuming different constant background densities of non-hoki targets in the survey area (estimates exclude stratum 0)

Backscatter subtraction (10^{-6} m^{-2})	Biomass estimate ('000 t)
0	671
0.3	644
0.6	618
0.744	606
1.05	579
1.5	540
2	496
3	409
4	321
5	235

Table 10: Snapshot estimates by stratum for the 1997 WCSI spawning hoki biomass ('000 t) using different backscatter subtractions. A "-" or an italicised entry indicates that a stratum was not surveyed. The italicised entries were obtained from the previous snapshot and were used in the calculation of the biomass index and the snapshot estimates

(a) Density subtraction of 0.6

	Stratum						
Snapshot	0	1&2	4	5a	5b	6	7
1	-	-	-	-	-	-	-
2	82	252	177	109	25	74	31
3	207	98	231	18	4	64	*31*
4	133	141	129	44	27	124	52
5	179	116	302	88	28	90	15
6	-	112	289	97	32	166	*15*
7	-	134	196	134	83	146	36
Mean	151	142	221	82	33	111	30

(b) Density subtraction of 0.744

	Stratum						
Snapshot	0	1&2	4	5a	5b	6	7
1	-	-	-	-	-	-	-
2	79	247	173	108	24	71	30
3	204	94	227	17	4	62	*30*
4	129	137	124	43	27	121	51
5	176	112	297	88	27	87	15
6	-	108	285	96	31	164	*15*
7	-	130	192	134	83	144	35
Mean	147	138	216	81	32	108	29

(c) Density subtraction of 1.05

	Stratum						
Snapshot	0	1&2	4	5a	5b	6	7
1	-	-	-	-	-	-	-
2	73	238	164	108	23	67	29
3	198	85	217	17	2	57	*29*
4	123	128	115	43	25	116	50
5	170	103	288	87	26	82	13
6	-	99	276	96	30	159	*13*
7	-	120	182	134	81	139	34
Mean	141	129	207	81	31	103	28

(d) Density subtraction of 3

	Stratum						
Snapshot	0	1&2	4	5a	5b	6	7
1	-	-	-	-	-	-	-
2	30	181	104	104	14	36	20
3	155	28	157	13	0	27	*20*
4	81	71	55	39	16	86	41
5	127	45	228	83	17	52	4
6	-	42	216	92	21	128	*4*
7	-	64	122	13	72	109	25
Mean	98	72	147	77	23	73	19

Table 11: Acoustic snapshot estimates of the 1997 Cook Strait spawning hoki biomass

Snapshot	Date	Estimate ('000 t)	*c.v.* (%)
1	24/7 - 26/7	90	26
2	28/7 - 29/7	89	20
3	1/8 – 2/8	128	18
4	7/8 – 8/8	188	21
5	9/8 – 9/8	135	16
6	11/8 – 12/8	111	20
Mean		124	9

Table 12: Snapshot estimates by stratum for the 1997 Cook Strait spawning hoki biomass ('000 t). The strata, in ascending order, are: Narrows Basin, Cook Strait Canyon, Nicholson Canyon, Wairarapa Canyon, a region connecting the previous three canyons (split into 5A and 5B in 1995), and Terawhiti Sill. A "-" or an italicised entry indicates that a stratum was not surveyed. The italicised entries were obtained from the previous snapshot and were used in the calculation of the biomass index and the snapshot estimates

	Stratum						
Snapshot	1	2	3	4	5A	5B	6
1	18	50	4	-	3	9	7
2	24	44	3	-	5	9	5
3	*24*	50	10	-	9	31	*5*
4	58	50	3	-	13	55	9
5	43	42	6	-	11	16	16
6	19	53	6	-	7	23	3
Mean	31	48	5	-	8	24	7

Table 13: Acoustic indices of hoki biomass for Cook Strait spawning seasons 1988, 1991–1997 The indices have been assigned *c.v.*s according to the procedure in Cordue *et al.* (1992) assuming a median *c.v.* of 0.25

Year	Biomass index ('000 t)		Normalised index	Number of snapshots	*c.v.* (%)
	Original	Corrected			
1988	128	128	1.00	1	40
1991	77	77	0.60	4	25
1992	54	54	0.42	2	31
1993	256	256	2.00	4	25
1994	244	244	1.90	3	27
1995	170	206	1.61	4	25
1996	80	97	0.76	5	24
1997	124	124	0.97	6	23

Table 14: Summary station information for Cook Strait acoustics survey 1997

Snapshot	Station no.	Stratum	Target species	Comments
1	1	1	HOK	
2	3	1	JMM	
2	4	1	HOK	
2	5	6	HOK	
2	6	2	HOK	window burst
2	7	2	HOK	
3	9	2	HOK	window burst
3	10	2	HOK	window burst
4	11	1	HOK	
4	12	1	HOK	window burst
4	13	2	SPD	window burst
4	14	2	SPD	
4	15	2	HOK	window burst
5	16	6	HOK	
5	18	2	HOK	
6	19	2	HOK	window burst
6	20	1	HOK	window burst

Table 15: Species summary information Cook Strait acoustics survey 1997

	Species weight (kg)						
Station	Hoki	*Caelorinchus biclinozonalis*	*Trachurus murphyi*	Spiny dogfish	Red cod	Ling	Other
1	245	10.0	35	120	8.0	10	3
3	10	8.0	1330	-	0.5	-	2.0
4	123	30.0	175	10	10.0	-	0.4
5	245	20.0	-	140	5.0	-	45.0
6	1 532	-	-	468	-	-	0.5
7	70	0.2	-	-	-	2	1.2
9	1 913	0.5	-	87	-	6	-
10	2 000	0.3	-	3	0.5	3	2.3
11	385	3.0	-	30	1.0	-	0.1
12	1 714	1.0	5	286	-	-	-
13	114	-	-	1 886	-	-	0.1
14	20	0.4	-	200	0.3	35	0.1
15	1 190	-	-	811	-	4	0.4
16	718	20.0	-	120	1.0	-	-
18	140	-	3	10	0.8	-	16.8
19	780	0.5	-	1 220	1.0	-	2.7
20	2 000	5.0	1	3	0.2	3	-

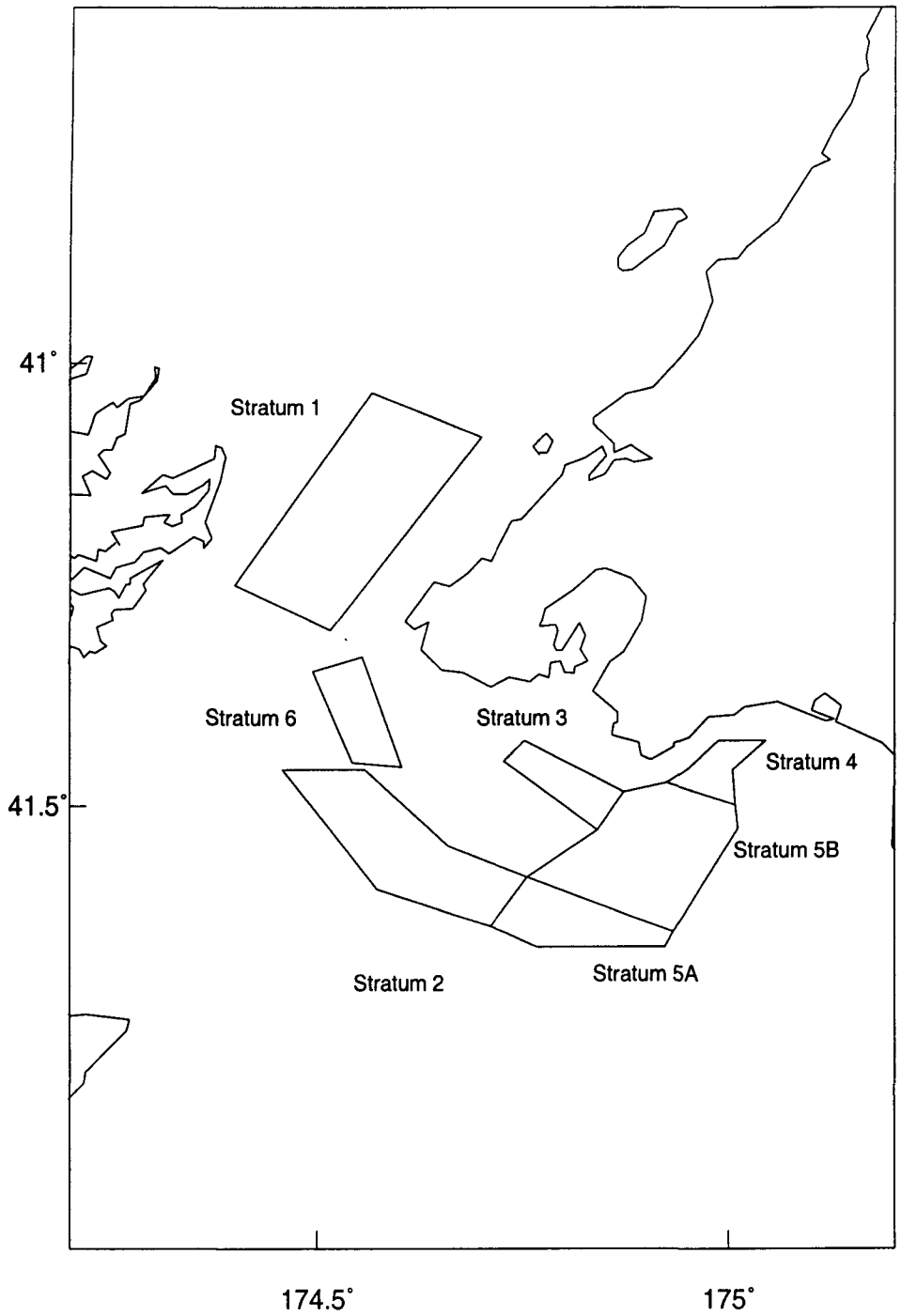

Figure 1: The strata boundaries for the 1997 acoustic survey of Cook Strait spawning hoki.

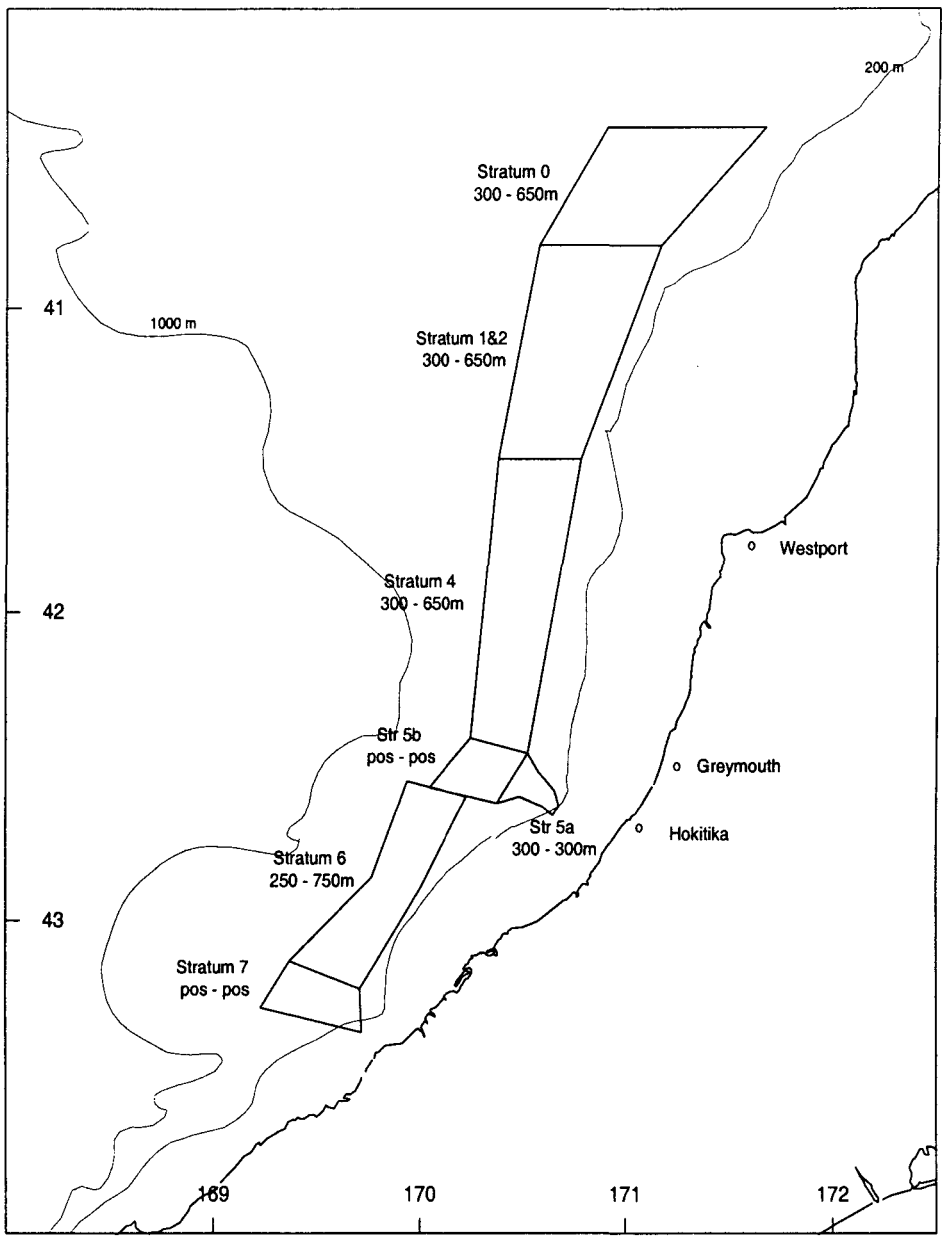

Figure 2: The strata boundaries for the 1997 acoustic survey of WCSI spawning hoki.

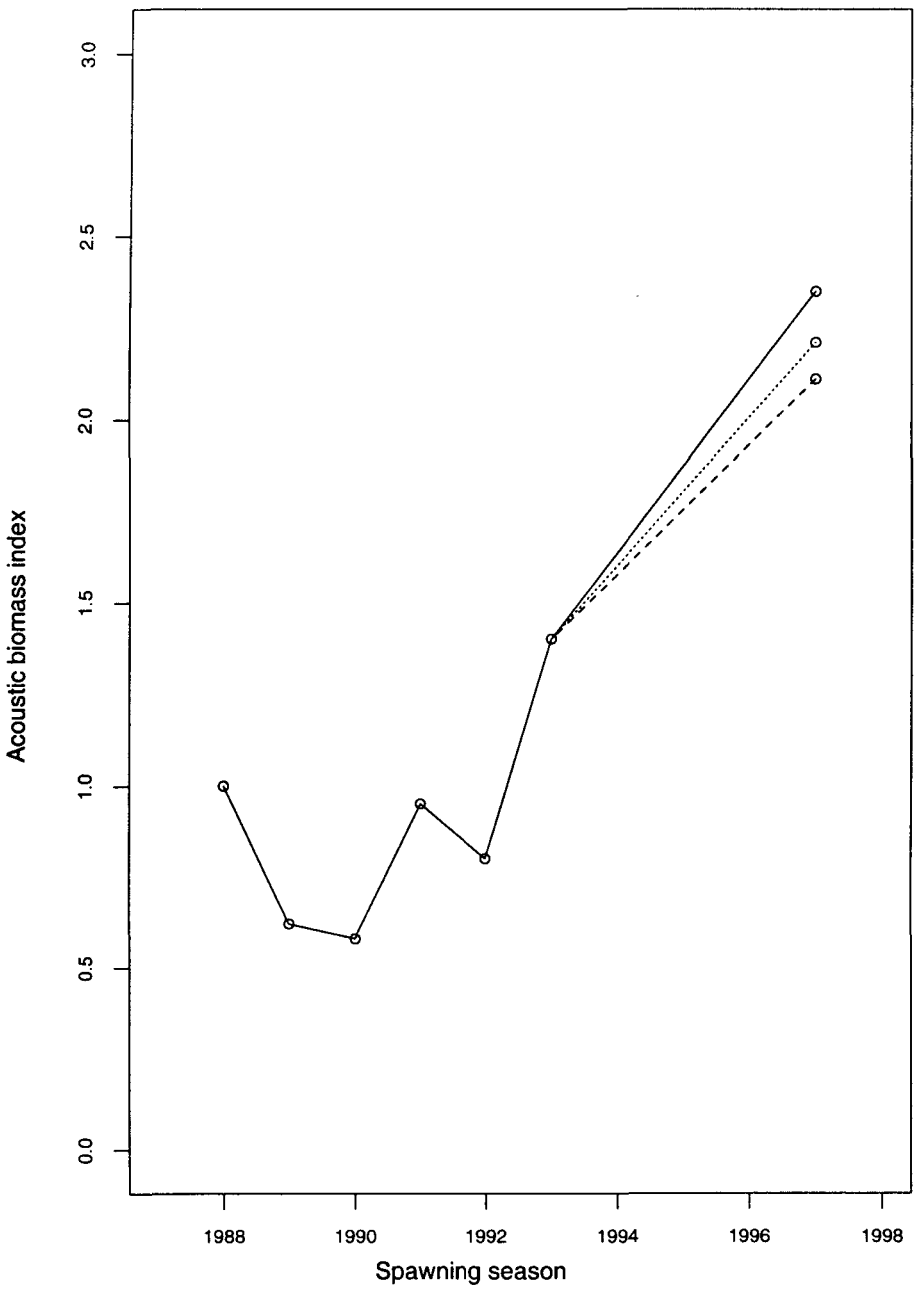

Figure 3: Acoustic indices of spawning hoki biomass on the WCSI 1988–93, and 1997 resulting from the standard backscatter subtraction (solid line) and two larger subtractions in 1997 to allow for a greater proportion of non-hoki targets (dotted and dashed lines).

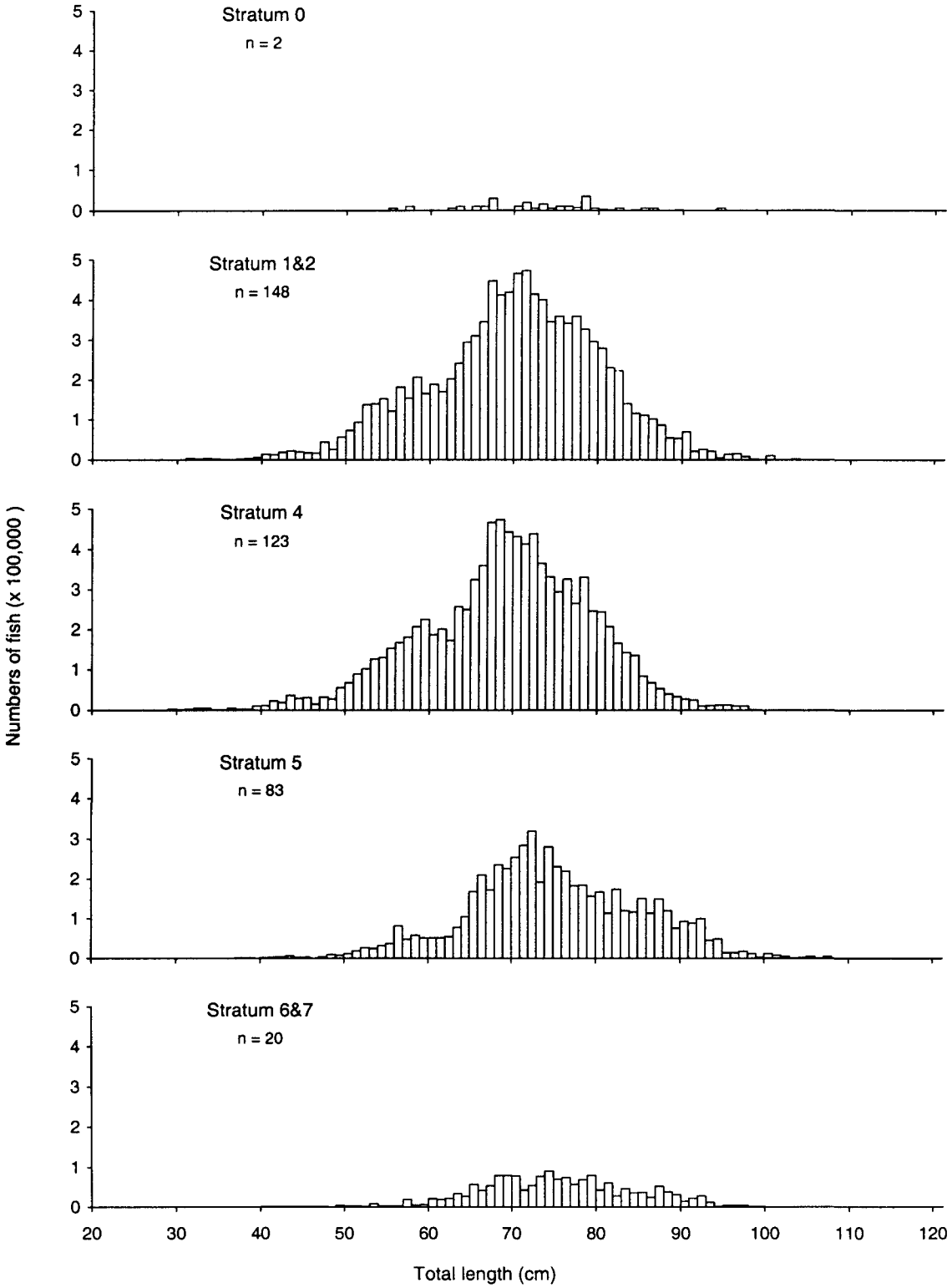

Figure 4a: Length frequency of male hoki by acoustics strata areas taken in commercial catches from west coast South Island spawning fishery in 1997 (sampled at sea by Scientific Observer Programme; n is the number of tows sampled).

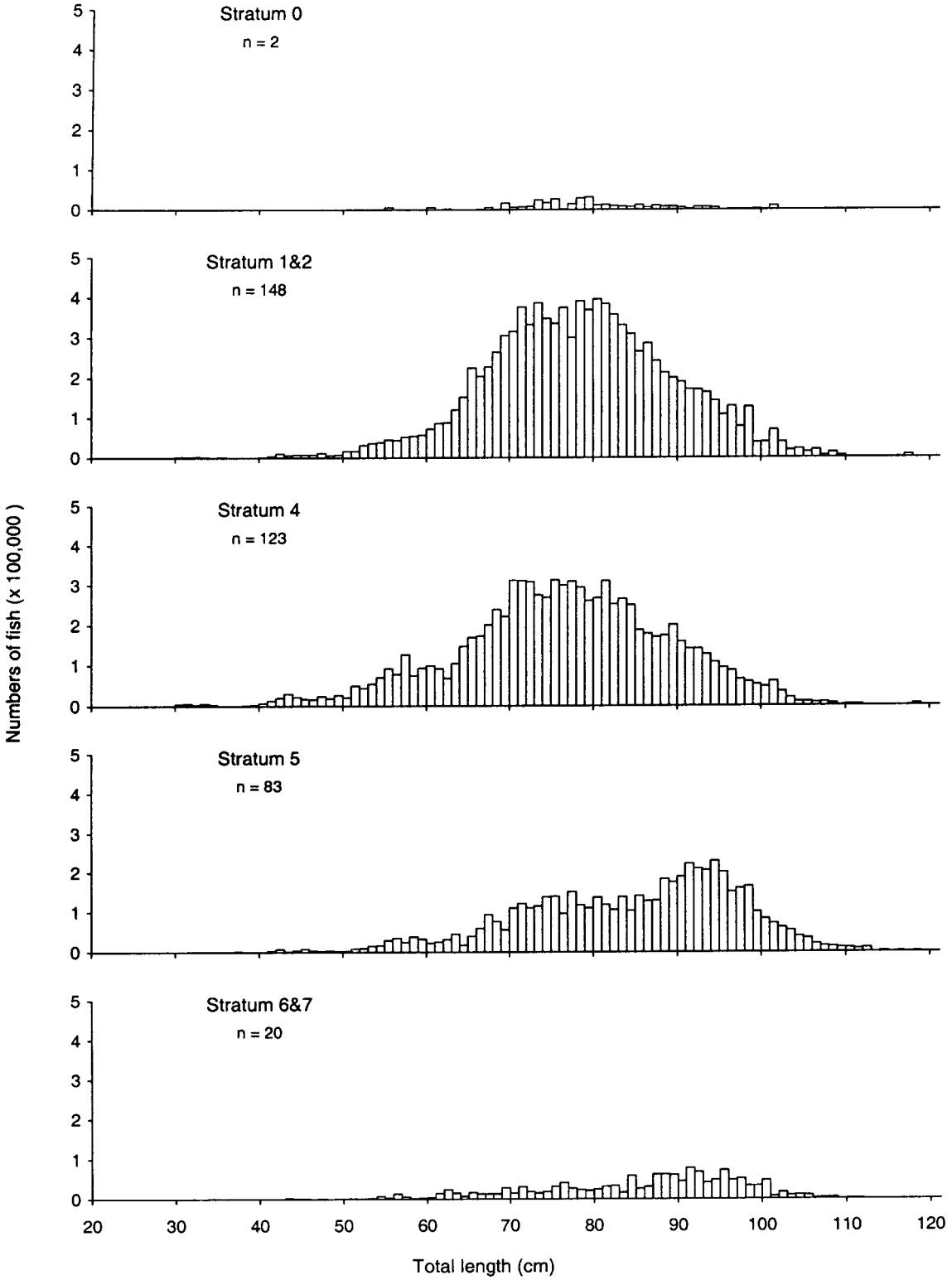

Figure 4b: Length frequency of female hoki by acoustics strata areas taken in commercial catches from west coast South Island spawning fishery in 1997 (sampled at sea by Scientific Observer Programme; n is the number of tows sampled).

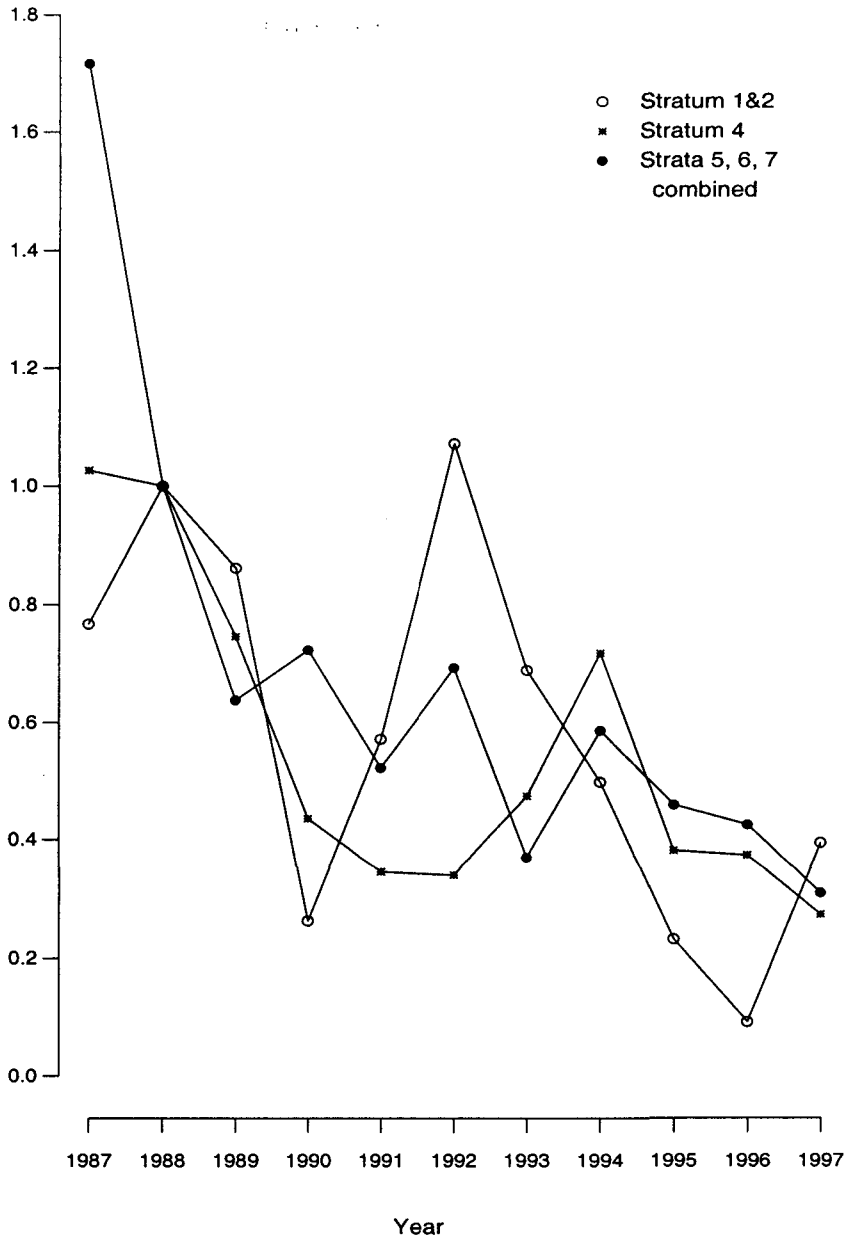

Figure 5: Comparison of CPUE unstandardised indices for acoustics strata for the WCSI fishery.

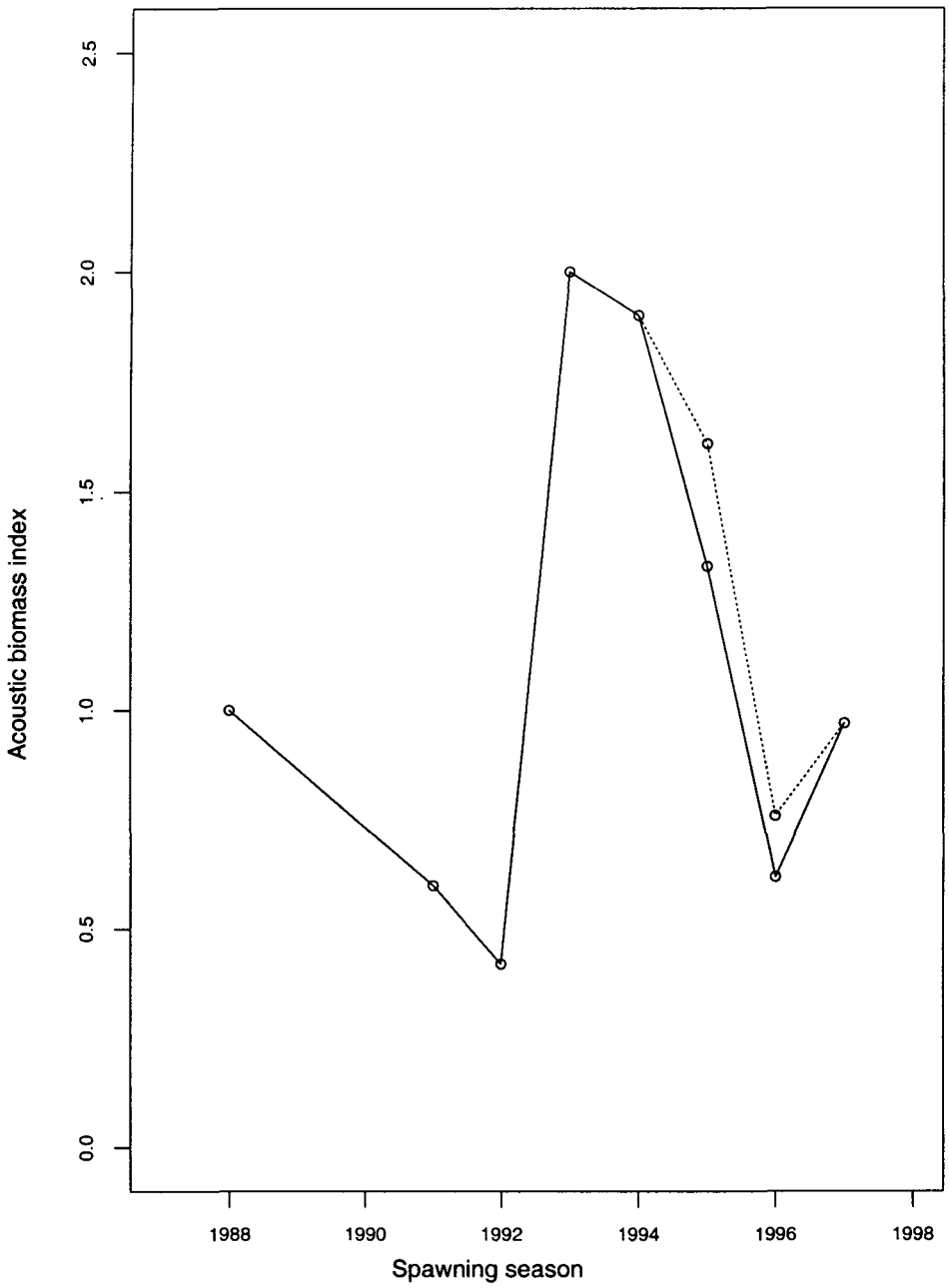

Figure 6: Acoustic biomass indices for spawning hoki in Cook Strait for 1988, and 1991–97: original indices (solid line) and adjusted indices (dotted line).

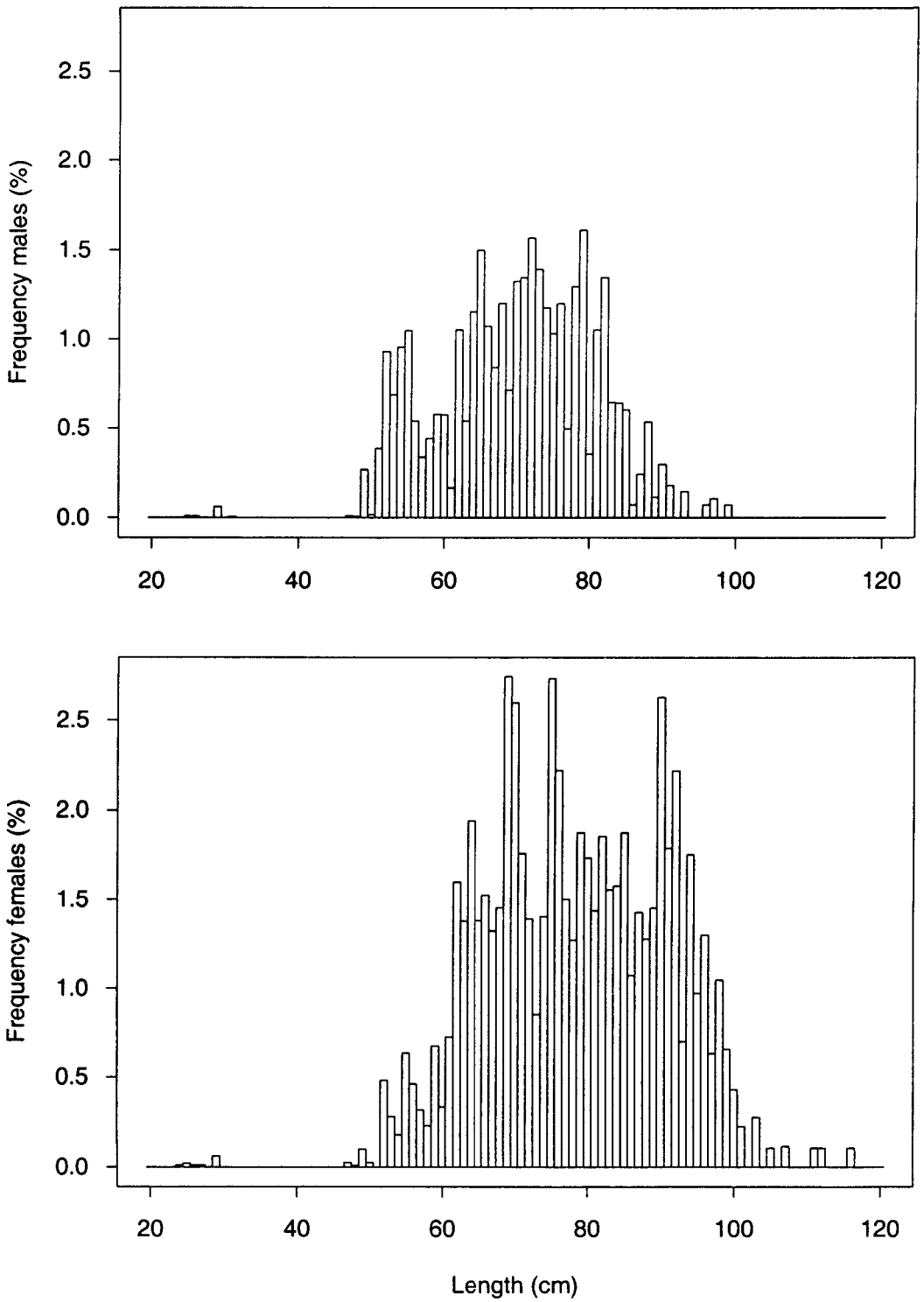

Figure 7: Length frequencies of male and female hoki for the acoustic survey of Cook Strait in winter 1997.

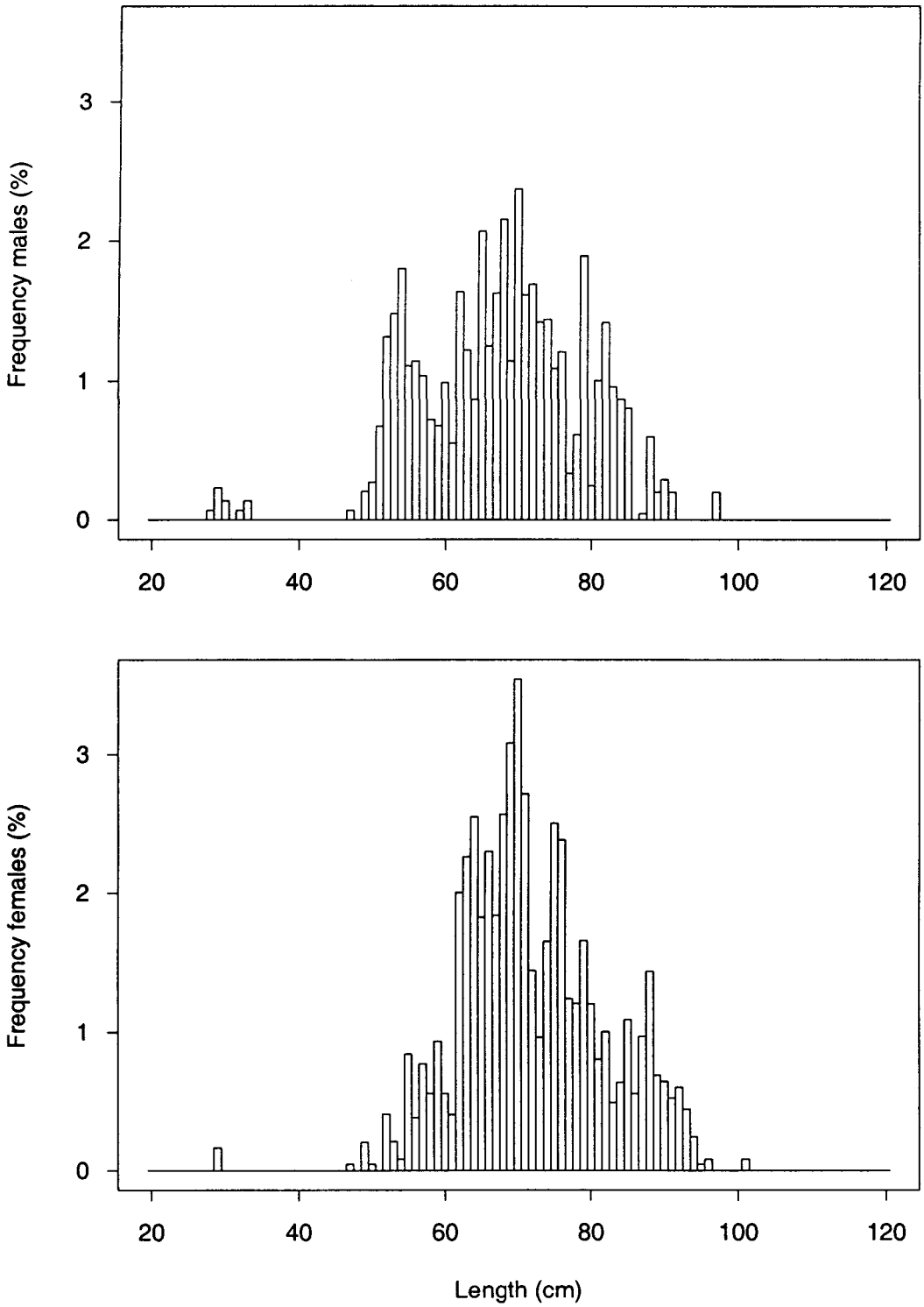

Figure 8: Length frequencies of male and female hoki in the Narrows basin for the acoustic survey of Cook Strait in winter 1997.

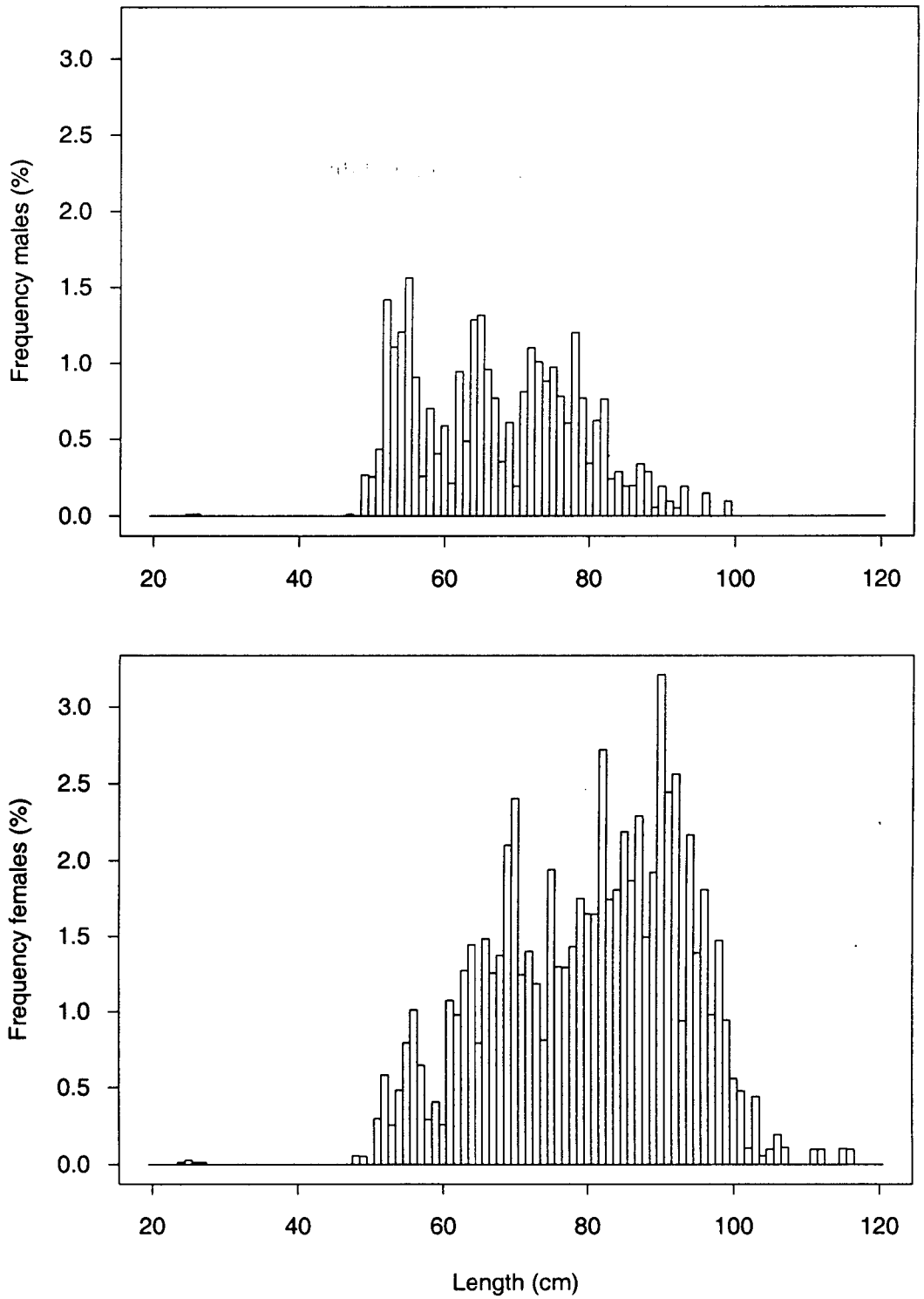

Figure 9: Length frequencies of male and female hoki in Cook Strait canyon for the acoustic survey of Cook Strait in winter 1997.