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Annual changes in the abundance of hoki year classes on the Chatham Rise (January 1992–95) and the Southern Plateau (December 1991–93)

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This series documents the scientific basis for stock assessments and fisheries management advice in New Zealand. It addresses the issues of the day in the current legislative context and in the time frames required. The documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

ANNUAL CHANGES IN THE ABUNDANCE OF HOKI YEAR CLASSES ON THE CHATHAM RISE (JANUARY 1992–95) AND THE SOUTHERN PLATEAU (DECEMBER 1991–93)

M. E. Livingston and K. A. Schofield

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1. EXECUTIVE SUMMARY

Four trawl surveys to assess the recruitment of hoki and the size of the eastern stock have been completed since the annual series using the *Tangaroa* began on the Chatham Rise in January 1992. The results of these surveys were used in the 1995 stock assessment of hoki.

The results show that the Chatham Rise is predominantly a nursery ground for young hoki and that fluctuations in biomass reflect variations in both the year class strength and the age at which hoki move off the Rise to recruit elsewhere. The surveys show that 1988, 1991, and 1992 were years of relatively strong hoki recruitment and that the age at which most fish of a particular year class move off the Rise can vary from 3 to 6 years. Further, the movement may be significant over several years, not just one. Within a year class, males tend to move a year ahead of females.

The changes in numbers of hoki in an individual year class do not follow a set pattern. Between the first two surveys on the Chatham Rise, most year classes increased in abundance, in particular the 4 year olds (spawned 1988). In subsequent years, this and most of the other year classes declined in number. These data support the hypothesis that small hoki become increasingly vulnerable to the trawl, but that older year classes decline markedly. The decline is too great to be explained by fishing or the assumed natural mortality of M = 0.25, and it is likely that the hoki are recruiting elsewhere, such as to the Southern Plateau. Three trawl surveys conducted in November-December 1991–93 on the Southern Plateau provide limited support for this hypothesis with increases in numbers of particular year classes that match some of the decreases of the same year classes from the Chatham Rise, but there are some major discrepancies. The trawl surveys on the Southern Plateau were discontinued after 1993, so it is unknown whether fish expected to recruit to the south did so or not.

Relative year class strengths during the *Tangaroa* survey series and data from earlier *Wesermünde*, *Shinkai Maru*, and *Amaltal Explorer* surveys back to 1979 were compared. Results indicated that relatively strong recruitment may have occurred in 1978, 1979, 1982, and 1983.

Comparisons of gear parameters among surveys show that *Tangaroa* is providing a consistent sampling tool.

2. INTRODUCTION

The current view is that hoki spawned on the west coast of the South Island (including Puysegur) and in Cook Strait (including the east coast of the South Island) mostly move to the Chatham Rise nursery grounds by the time they are 2 years old (Livingston & Schofield 1995). As they reach maturity, they may recruit to adult grounds elsewhere or remain on the Rise, depending on which stock they are part of. The adult fish may have true fidelity (i.e., fish return to spawn in the area in which they themselves were spawned) or they may be of mixed origin, spawning on the nearest spawning ground, irrespective of their own origin. The present assessment assumes the former (Sullivan *et al.* 1995).

Although managed as a single stock, hoki are assessed annually as two stocks (Sullivan & Cordue 1992, Sullivan *et al* 1995). There is no genetic evidence for a split, but since morphometric and growth rate differences have been found between the two spawning grounds (Horn & Sullivan 1996, Livingston & Schofield 1996) a cautious approach in determining yield has been taken. Of the two stocks, the western stock, which resides primarily on the Southern Plateau and spawns off the west coast of the South Island, is substantially larger than the eastern stock, which resides primarily on the Chatham Rise and spawns in Cook Strait. Juvenile hoki (2–5 years old) of both stocks appear to reside and mix together on the Chatham Rise in relatively shallow water. As the fish reach maturity, they recruit to their respective stocks.

The Chatham Rise forms the only known major nursery ground for hoki and four trawl surveys in hoki depths on the Chatham Rise (January 1992 to January 1995) have been completed since an annual time series to monitor hoki recruitment and eastern adult stock abundance began using *Tangaroa*. A series of three trawl surveys was also carried out in the Southland and Sub-Antarctic areas (hereafter referred to as the Southern Plateau) from December 1991 to December 1993 to monitor western stock abundance (Chatterton *et al.* 1993, Chatterton & Hanchet 1994).

In this report we explore the data for patterns in changes of biomass, changes in year class numbers, and the distribution of hoki between the Chatham Rise and the Southern Plateau. The year class numbers of 1–3 year old hoki on the Chatham Rise have been used to estimate relative year class strength of hoki (Cordue 1995). Catch-at-age data from the west coast South Island fishery provides a historical record of western stock year class strength, from which the model results suggested that hoki recruitment between 1980 and 1986 was weaker than average (Cordue 1995). We analyse independent data from a range of research surveys carried out between 1979 and 1990 to test this interpretation.

3. METHODS

3.1 *Tangaroa* trawl surveys 1991-95

Stratified random trawl surveys were used to sample the hoki population from 200 to 800 m depths on the Chatham Rise, and 300-800 m depths on the Southern Plateau (Figures 1, 2). R.V. *Tangaroa* was used for each survey, and deployed an 8-seam winged bottom trawl net with a 60 mm mesh codend. The gear and its deployment procedure were standardised for each survey (Hurst *et al.* 1992). Both survey areas were subdivided into strata based on depth intervals and area, and tow positions were determined using a random generation program. Stratum details and number of tows in each survey are given in Tables 1 and 2. In January 1993, 1994, and 1995, station allocation was optimised for 2 year old hoki to improve sampling efficiency while maintaining low *c.v.*s.

The catch from each tow was sorted and weighed by species, and subsampled to obtain data on size distribution, sex ratios, reproductive condition, and feeding, according to the procedures outlined by Hurst *et al.* (1992).

Doorspread estimates of biomass and total population numbers of hoki were estimated using the area-swept method of Francis (1984, 1989). Calculations were done with the Trawlsurvey Analysis Program described by Vignaux (1994), assuming a value of 1.0 for vertical and areal availability, and vulnerability. To obtain estimates of year class abundance in each year, we used a length-based program, MIX (MacDonald & Green 1988), which derives proportions of the population in each year class (for a given data set), by dissecting the length frequency distribution into mixtures of normal distributions for each age class. For consistency, we have used the estimates used by Sullivan *et al.* (1995). The first five year classes of male hoki are relatively easy to identify. We therefore used MIX to estimate proportions of individual year classes up to age 5, and 6 year olds and over were combined into a single group (males). Female hoki grow faster than males, so the proportions of females up to age 6 were estimated individually; 7 year olds and over were combined into a single group.

In tracking the year class abundance estimates between years we have compared observed losses and gains with expected losses and gains, assuming a natural mortality of 0.25 for each year class (Sullivan *et al.* 1995). Fishing mortality has not been included. For reference, the age of hoki and their year of birth with respect to each survey are given in Appendix 1.

Factors which could alter catchability and availability, such as station distribution, sea temperatures, tow parameters and wind conditions, were compared between surveys.

3.2 Earlier trawl surveys, 1979-90

Data on hoki size distribution and numbers of fish were compared from trawl surveys in hoki depths, conducted from 1979 to 1990. The most reliable surveys are those listed in Table 3. With the exception of the *Wesermünde* survey in 1979, all followed a stratified random design and had over 80 stations. The main problem with comparison of these data is the difference in fishing power between vessels. Further, surveys were conducted in various seasons, not necessarily consistent with the current series (Table 3). Here we present scaled length frequencies from each survey listed, and relative numbers of hoki in each size class. The data were then used to estimate catchability (q) values for each year class. Values of q that fell outside the feasible range were taken to indicate that there was a discrepancy between the west coast catch-at-age data and the trawl survey data (Cordue 1995).

To compare year class numbers, modal length ranges corresponding to observed length modes were selected by eye and used to estimate numbers of fish-at-age using the Trawl Survey Analysis Program.

4. RESULTS

4.1 *Tangaroa* surveys 1991-95

(a) Survey comparability

Catch distribution, biomass, and length frequency distributions of the main species caught in the surveys are summarised in individual survey reports (Chatterton & Hanchet 1994, Horn 1994a, 1994b; Schofield & Horn 1994, Schofield & Livingston 1995, Ingerson & Hanchet 1995, Ingerson *et al.* 1995). All surveys were completed and all strata were sampled.

Station numbers on the Chatham Rise were reduced from 184 in 1992 to 122 in 1995, largely because of improved optimisation techniques. The reductions occurred mostly in the west and central strata of the Chatham Rise. Temperature ranges were similar each year, although in January 1994, the Subtropical Convergence Zone was a little further north, resulting in slightly cooler temperatures over most of the Rise (Table 4). Wind conditions were predominantly from the south in all surveys (Appendix 2). Tow and gear parameters were similar in all the Chatham Rise surveys (Table 5).

On the Southern Plateau, the distribution of stations was similar across strata for all three surveys (*see* Table 2). Temperatures were highest in December 1992 (Table 6). Tow and gear parameters were slightly more variable than on the Chatham Rise, but not statistically different (Table 7). The relative station distribution with depth changed little between surveys and southerly conditions prevailed in all surveys (Appendix 3).

(b) Biomass estimates

Total hoki biomass on the Chatham Rise increased substantially between 1992 and 1993, and dropped back to its former level in 1994 and 1995 (Table 8). Although females contributed more to the biomass than males, the pattern of change was the same for both sexes (Table 8). Subdivision of the data into juveniles (less than 59 cm TL) and adults (greater than 60 cm TL), shows that the biomass of juveniles has been relatively high each year since 1993, and that the drop in total biomass reflects a decline in the number of adult hoki (*see* Table 8).

On the Southern Plateau, total hoki biomass increased from December 1991 to 1993 (Table 9): juveniles contributed less than 5% to the total hoki biomass on the Southern Plateau, and the increase appears to reflect growth rather than increasing numbers of fish.

(c) Size structure

The length frequency distribution of hoki on the Chatham Rise changes from year to year, depending on the numbers of newly recruiting fish (Figures 3, 4). The 1987 and 1988 year classes were clearly evident in January 1992 and 1993, as were the younger 1991 and 1992 year classes in January 1994 and 1995. The intervening 1989 and 1990 year classes do not appear to be well represented in any survey, probably because they are both relatively weak (Figures 3, 4).

On the Southern Plateau, the length frequency distribution includes mostly fully recruited year classes (Figures 5, 6). In 1991, the adult distribution was bimodal, but the mode at 70 cm had merged with the larger mode by 1993. There is little indication of strong recruitment from any of the younger fish seen in abundance on the Chatham Rise.

4.2. *Tangaroa* surveys 1991-95, MIX analysis

Further exploration of the length frequency data using MIX to compare numbers of hoki-at-age between Chatham Rise surveys confirm that relatively large numbers of hoki were spawned in 1987, 1988, 1991, and 1992 compared with 1989 and 1990 (Table 10). Both the 1987 and 1988 year classes declined heavily between surveys in 1993, 1994, and 1995 (Table 10). The first Southern Plateau survey in December 1991 shows that the 1987 year class was already present there when the survey series began. Female numbers of this year class declined slightly by December 1992, while males declined by almost 50% (Table 11).

The gains and losses of each year class (assuming a natural mortality of 0.25 for each year class) suggest relatively large losses from the Chatham Rise, and small gains on the Southern Plateau. For example, there appears to have been a net loss of 13.9 million females from the 1987 year class on the Chatham Rise between 1993 and 1994, with a further loss of 4.8 million by 1995. The gain of females from the 1987 year class on the Southern Plateau is only 1.7 million (Table 12). Among hoki spawned in 1988, the loss of 16.8 million females from the Chatham Rise is not met by the relatively small gain of 2.1 million females on the Southern Plateau. The commercial catch on the Southern Plateau in 1992 and 1993 was negligible, therefore, fishing mortality does not explain the magnitude of the losses (P. Cordue, NIWA, pers. comm.).

4.3 Earlier surveys, 1979-90

The length frequencies from surveys listed in Table 3 are presented in Figures 7 to 11. The first Chatham Rise survey in 1979 indicates modal peaking of the 1+ and 2+ fish, spawned in 1978 and 1977 (Figure 7). The next survey, completed in March 1983, used fully randomised sampling (Figures 8, 9): three year classes, 1981, 1980, and 1979 are clearly represented here. The survey in December 1983 covered the Chatham Rise east of 176 °E only and picked up large numbers of hoki spawned in 1982 (Figures 8, 9). A winter survey of the whole Chatham Rise in 1986 found extremely large numbers of 3 year old fish, spawned in 1983, and again a peak corresponding to 1982 hoki (Figures 8, 9). By November

1989 there was little evidence of these year classes as adults, which suggests that they had recruited to other areas. The length frequency in 1989 was dominated by the 1987 and 1988 year classes (Figures 8, 9), which continued to show as strongly in the *Tangaroa* time series up to 1994.

Length modes on the Southern Plateau are more difficult to follow as they merge into the adult plus group which contains up to 20 year classes. The earliest survey in October-November 1979 shows no dominant modes (Figure 7). From Figures 10 and 11 the survey in March 1982 shows a mode of fish almost 2 years old (spawned 1980) at about 38 cm TL . The peak of the adult plus group, however, is at 65 cm, with a reasonable number of fish present between 55 and 65 cm TL, compared with October 1983 and November 1989 where there are very few fish of those lengths. The next survey to show numbers of fish of 55–65 cm TL is in December 1990 (Figures 10, 11) and in December 1991 as the 1987 and 1988 year classes appear in the Southern Plateau surveys (Figures 5, 6). The presence of the 1978 year class of hoki on the Southern Plateau in 1982 followed by lack of recruitment of the 1979 year class from the Chatham Rise in 1983 is very similar to the situation observed for the 1987 year class, which began to recruit south in 1990, whereas the 1988 year class delayed until 1992. The length distribution on the Southern Plateau in March 1982 also suggests that 1978 was a year of relatively strong recruitment.

The numbers of hoki at age (males and females combined) are given in Table 13. No adjustment for fishing power has been attempted. Year classes which stand out as having high numbers on the Chatham Rise are 1979, 1980, 1982, and 1983 (all over 100 million). If the fishing power of the *Shinkai Maru* was twice that of the *Amaltal Explorer* (*see* discussion of relative fishing power, Hurst & Schofield (1990) then the 1987 and 1988 year classes would also be over 100 million. On the Southern Plateau, 1978 and 1977 stand out as relatively strong, whereas, even doubled, the numbers surveyed by the *Amaltal Explorer* in 1989 and 1990 do not approach these values.

The figures in Table 13 appear to contradict the modelling results of Cordue (1995) which suggest that year classes spawned before 1986 were average or less strong than those spawned after 1986. Cordue used abundance indices and catch-at-age data from the west coast South Island to estimate year class strength for each year from 1983 to 1990. Estimation of q's for each year class gives unusually high values for 1979, 1982, 1983, and 1986, suggesting that these year class strengths may be underestimated by the model (Cordue 1995).

5.0 DISCUSSION AND CONCLUSIONS

The four Chatham Rise surveys between 1992 and 1995 show that both year class strength among 1–3 year old hoki and the proportion of hoki in the older year classes remaining on the Chatham Rise cause year to year fluctuations in biomass and size distribution. Total biomass rose from 120 000 to 186 000 t in 1993 and dropped back again to 120 000 t in 1995. The adult proportion of that biomass was less, and the juvenile biomass was greater, in 1995 compared with 1992. The large increase in total biomass between 1992 and 1993 is explained by a large influx of new recruits (1991 year class) as well as growth of the 1988 year class which unexpectedly remained on the Rise. Although there was significant recruitment again in 1994 (1992 year class), more than half of the strong 1988 year class had left, leading to a decline in biomass. By 1995, a further 70% of the 1988 year class had departed, leading to a further decline in biomass.

The ongoing decline of year class numbers over several years suggests that movement of an age class off the Rise occurs over an extended period. Hydrological conditions, population density, and food availability may all influence the timing and extent of movement. It seems, therefore, that some year classes may depart from the Chatham Rise (presumably to recruit mainly to the Southern Plateau) at 2 years old, while others, such as the 1988 year class, wait until they are over 5 years old. Movement of hoki from the Chatham Rise to the Southern Plateau is only weakly supported by the data. However, because the Southern Plateau time series only covered 3 years, the hypothesis has not been satisfactorily tested. One year class of interest (1987) had already moved, while the other (1988) delayed departure from the Chatham Rise.

The trawl surveys demonstrate the value of maintaining constant vessel, gear, and towing procedures from year to year. We are able to conclude that any changes in relative abundance of hoki (or other species) are either real, or reflect changes in catchability, or a combination of the two.

Year class strength of hoki is highly variable. There is some suggestion that year class strength is greater in colder years. The preliminary analyses presented suggest that relatively strong year classes were spawned in 1979, 1980, 1982, 1983, 1987, 1988, 1991, and 1992. Plots of the Southern Oscillation Index (Appendix 5) identify all these years except 1988 as relatively cold and having a negative oscillation index. Blagoderov (1978) found that cold spawning seasons more often resulted in strong hoki year classes than warm spawning seasons.

In conclusion, the trawl survey series of hoki, in particular on the Chatham Rise, is beginning to provide a useful, comparable set of data. It is only through its continuation long term that our understanding of hoki year class strength, recruitment patterns to other areas, and stock structure can improve.

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Table 1: Survey dates, station numbers, and area of surveys, Chatham Rise, January 1992–95

	1992	1993	1994	1995
Voyage code	TAN9106	TAN9212	TAN9401	TAN9501
Area (km^2)	135 843	139 879	139 938	139 584
Dates	28/12/91–1/2/92	30/12/92–6/2/93	2–31/1/94	4–27/1/95
Total no. of stations	184	194	165	122
No. of stns in stratum				
1	3	3	3	3
2	6	6	3	3
3	6	4	4	6
4	4	3	4	3
5	9	7	4	4
6	7	7	6	3
7	9	7	11	12
8	7	5	5	3
9	7	9	7	4
10	10	7	5	6
11	9	5	5	9
12	9	6	4	7
13	7	6	4	6
14	8	6	5	6
15	12	12	12	3
16	12	10	10	3
17	13	14	11	4
18	9	17	23	3
19	16	25	10	3
20	8	12	7	8
21	3	6	6	3
22	3	4	4	10
23	4	3	4	3
24	3	3	3	3
25	0	7	5	4

Table 2: Survey dates, station numbers, and area of surveys, Southern Plateau, December 1991–93

	1991	1992	1993
Voyage code	TAN9105	TAN9211	TAN9310
Area (km^2)	275 130	275 132	275 356
Dates	17/11/91–21/12/91	16/11/92–20/12/92	15/11/93–20/12/93
Total no. of stations	154	160	138
No. of stations in stratum			
1	7	3	3
2	3	3	4
3	4	6	4
4	8	6	8
5	9	13	10
6	4	6	6
7	8	9	6
8	5	7	5
9	15	15	12
10	14	15	11
11	11	8	9
12	9	9	7
13	21	20	13
14	12	11	13
15	15	16	18
16	9	8	6
17	0	5	4

Table 3: Survey dates, vessel, area, and number of stations in pre-*Tangaroa* surveys on the Chatham Rise and Southern Plateau, 1979–90

Date	Vessel	Area surveyed	No. of Stns	Reference
Nov 1979	*Wesermünde*	Chatham Rise	22	Kerstan & Sahrhage 1980
Mar-May 1982	*Shinkai Maru*	Southern Plateau	218	van den Broek *et al.* 1984
Mar 1983	*Shinkai Maru*	Chatham Rise	117	Fenaughty & Uozumi 1989
Oct-Nov 1983	*Shinkai Maru*	Southern Plateau	184	Hatanaka *et al.* 1989(a)
Nov-Dec 1983	*Shinkai Maru*	Chatham Rise (east)	85	Hatanaka *et al.* 1989(b)
Jul 1986	*Shinkai Maru*	Chatham Rise	93	Livingston *et al.* 1991
Oct-Nov 1989	*Amaltal Explorer*	Southern Plateau	125	Livingston & Schofield 1993
Nov-Dec 1989	*Amaltal Explorer*	Chatham Rise	107	Livingston & Schofield 1995
Nov-Dec 1990	*Amaltal Explorer*	Southern Plateau	177	Hurst & Schofield 1995

Table 4: Station numbers and temperature data for Chatham Rise surveys, January 1992–95 (STCZ, Subtropical Convergence Zone, *c.v.*, coefficient of variation)

	1992	1993	1994	1995
No. of stations				
Phase 1	146	149	149	112
Phase 2	38	46	16	10
Hoki *c.v.*s				
Biomass	7.7	10.3	9.8	7.6
Population no.	8.0	19	18	8
Station density (per km^2)	1 : 738	1 : 721	1 : 848	1 : 1144
Bottom temp. range (°C)	6.6–11.5*	5.8–10.9	5.2–10.8*	5.8–10.5*
No. of CTD drops	0	29	0	0
Surface temp range (°C)	13.0–17.8*	12.5–16.1	11.7–16.0*	12.1–16.5*

* CTD and Scanmar data in 1993 indicated that Scanmar was reading 0.4 °C low. 1992 data may be 7.0–11.9 °C, and 13.4–18.2 °C; 1994 data may be 5.6–11.2 °C and 11.1–16.4. °C; 1995 data may be 6.2–10.9 °C and 12.5–16.9°C

Table 5: Tow and gear parameters by depth range for Chatham Rise surveys January 1992–95 (x = mean, s.d. = standard deviation, *n* = number of measurements)

	1992		1993		1994		1995	
	$\bar{x}$	s.d.	$\bar{x}$	s.d.	$\bar{x}$	s.d.	$\bar{x}$	s.d.
Tow parameters								
Tow length (n. ml)	3.0	–	3.0	–	2.96	0.20	2.98	0.19
Tow speed (knots)	3.50	0.05	3.52	0.12	3.6	0.12	3.5	0.04
Gear parameters (m)								
200–400 m								
Headline height	6.6	0.4	6.4	0.5	6.5	0.5	6.9	0.5
Doorspread	116.6	6.7	121.4	7.7	114.0	5.8	114.3	5.6
n	46	–	71	–	57	–	33	–
400–600 m								
Headline height	6.6	0.4	6.5	0.33	6.5	0.4	6.8	0.5
Doorspread	121.8	5.9	122.5	7.9	118.5	4.1	117.5	5.3
n	103	–	94	–	84	–	66	–
600–800 m								
Headline height	6.7	0.4	6.7	0.39	6.5	0.3	7.0	0.4
Doorspread	120.7	6.4	121.7	9.6	120.5	4.9	119.3	6.1
n	35	–	30	–	24	–	23	–

Wingspread = 27.3 m. Ratio of doorspread to wingspread = 4.3 : 1

Table 6: Station numbers and temperature data for Southern Plateau surveys, December 1991–93

	1991	1992	1993
No. of stations			
Phase 1	143	140	123
Phase 2	11	20	15
Hoki *c.v.*s			
Biomass	6.8	6.1	9.2
Population no.	10	7	13
Station density (per km^2)	1 : 1787	1 : 1720	1 : 1994
Bottom temp range (°C)	4.8–9.3	–	4.6–9.6
Surface temp range (°C)	7.7–12.7	7.9–13.5*	6.7–12.2*

* CTD used.

Table 7: Tow and gear parameters by depth range for Southern Plateau surveys, December 1991–93 (x = mean, s.d. = standard deviation, *n* = number of measurements)

	1991		1992		1993	
	$\bar{x}$	s.d.	$\bar{x}$	s.d.	$\bar{x}$	s.d.
Tow parameters						
Tow length (n. ml)	2.98	0.15	2.99	0.15	2.98	0.13
Tow speed (knots)	3.49	0.06	3.52	0.12	3.52	0.06
Gear parameters (m)						
300–600 m						
Headline height	6.63	0.33	7.38	0.45	7.17	0.34
Doorspread	126.1	5.90	119.4	4.45	118.0	6.18
n	85	–	85	–	75	–
600–800 m						
Headline height	6.67	0.29	7.34	0.30	7.07	0.25
Doorspread	126.9	8.47	124.0	6.87	123.8	5.37
n	65	–	69	–	59	–

Wingspread = 27.3 m. Ratio of doorspread to wingspread = 4.3 : 1

Table 8: Biomass (t x 10^3) of hoki, Chatham Rise, January 1992–95 (coefficient of variation in parentheses)

	1992	1993	1994	1995
Females				
Juveniles (≤ 59 cm TL)	11.2	20.9	29.8	26.2
Adults (≥ 60 cm TL)	57.2	84.0	53.7	41.5
Total	68.4 (7.4)	104.9 (9.6)	83.5 (9.4)	67.7 (7.8)
Males				
Juveniles (≤ 59 cm TL)	14.5	20.7	29.6	25.3
Adults (≥ 60 cm)	36.3	59.8	32.5	27.5
Total	50.8 (8.5)	80.5(11.6)	62.1(11.0)	52.8 (8.0)
Male and female Total	119.2 (7.7)	185.4(10.3)	116.0 (9.8)	120.5 (7.6)

Table 9: Biomass (t x 10^3) of hoki, Southern Plateau, Nov-Dec 1991–1993 (coefficient of variation in parentheses)

	1991	1992	1993
Females			
Juveniles (≤ 59 cm TL)	0.8	0.3	2.5
Adults (≥ 60 cm TL)	49.3	54.4	58.4
Total	50.1 (6.2)	54.7 (5.7)	60.9 (8.9)
Males			
Juveniles (≤ 59 cm TL)	1.2	0.2	2.6
Adults (≥ 60 cm)	28.9	32.5	36.0
Total	30.1 (8.4)	32.7 (7.5)	38.6(10.7)
Male and female Total	80.2 (6.2)	87.4 (6.1)	99.5 (9.2)

Table 10. Results of MIX analysis, Chatham Rise hoki surveys, January 1992-95. (p = proportion of population, *n* = number of hoki x10⁶)

Age	1992 p	1992 *n*	1993 p	1993 *n*	1994 p	1994 *n*	1995 p	1995 *n*
Females								
1	0.074	6.5	0.494	86.5	0.297	42.8	0.158	18.1
2	0.000	0.0	0.056	9.8	0.372	53.6	0.475	54.4
3	0.478	42.0	0.000	0.0	0.049	7.1	0.203	23.3
4	0.286	25.2	0.274	48.0	0.000	0.0	0.082	9.4
5	0.076	6.7	0.134	23.6	0.229	33.0	0.000	0.0
6	0.057	5.0	0.003	0.5	0.031	4.5	0.072	8.3
7+	0.040	3.5	0.040	7.0	0.023	3.3	0.011	1.3
Total *n*		88.9		175.4		144.3		114.8
Males								
1	0.073	5.6	0.542	87.3	0.341	45.3	0.163	16.9
2	0.000	0.0	0.49	7.9	0.400	53.1	0.507	52.5
3	0.576	43.9	0.000	0.0	0.035	4.6	0.182	18.9
4	0.301	22.9	0.332	53.5	0.000	0.0	0.056	5.8
5	0.042	3.2	0.067	10.8	0.188	25.0	0.000	0.0
6+	0.007	0.5	0.010	1.6	0.036	4.8	0.052	5.4
Total *n*		76.1		161.1		132.8		99.8

Table 11. Results of MIX analysis, Southern Plateau hoki surveys, November-December 1991-93. (p = proportion of population, *n* = number of hoki x10⁶)

Age	1991 p	1991 *n*	1992 p	1992 *n*	1993 p	1993 *n*
Females						
1	0.043	1.6	0.020	0.7	0.011	0.4
2	0.000	0.0	0.016	0.5	0.063	2.4
3	0.059	2.2	0.000	0.0	0.018	0.7
4	0.344	12.7	0.065	2.2	0.000	0.0
5	0.000	0.0	0.315	10.6	0.106	4.0
6	0.000	0.0	0.000	0.0	0.263	10.0
7+	0.551	20.4	0.580	19.5	0.540	20.6
Total *n*		36.9		33.5		38.1
Males						
1	0.063	1.7	0.024	0.6	0.014	0.4
2	0.000	0.0	0.013	0.3	0.086	2.5
3	0.078	2.2	0.000	0.0	0.006	0.2
4	0.419	11.7	0.053	1.3	0.000	0.0
5	0.000	0.0	0.261	6.3	0.106	3.1
6+	0.438	12.2	0.648	15.6	0.789	23.4
Total *n*		27.8		24.1		29.6

+ Indicates plus group of, for example 6 years and older fish.

Table 12. Gains and losses of hoki (numbers of fish x 10^6) on the Chatham Rise and Southern Plateau, 1991-95. Gains and losses were estimated as the difference between observed and expected numbers of fish from year to year, assuming M = 0.25 for each year class.

Chatham Rise	Jan 1992-93	Jan 1993-94	Jan 1994-95
Females			
2	+ 4.7	- 13.7	+ 21.1
3	0	- 0.5	- 18.4
4	+ 15.3	0	+ 3.9
5	+ 4.0	- 4.3	0
6	- 4.7	- 13.9	- 16.8
7+	+ 0.4	- 2.5	- 4.8
Males			
2	+ 3.5	- 14.9	- 17.2
3	0	- 1.6	-22.5
4	+ 19.3	0	+ 2.2
5	- 7.0	-16.7	0
6+	- 1.3	- 4.9	- 17.8

Southern Plateau	Dec 1991-92	Dec 1992-93
Females		
2	- 0.7	+ 1.9
3	0	+ 0.3
4	+ 0.5	0
5	+ 0.7	+ 2.3
6	0	+ 1.7
7+	+ 3.6	+ 5.4
Males		
2	- 1.0	+ 2.0
3	0	0
4	- 0.4	0
5	- 2.8	+ 2.1
6+	+ 6.1	+ 6.3

\+ Indicates plus group of, for example 6 years and older fish.

Table 13: Cohort* numbers of hoki (millions) from pre-*Tangaroa* surveys of the Chatham Rise (CR) and Southern Plateau (SP) (numbers scaled up to estimated population size after Vignaux (1994)

Vessel	*Shinkai Maru*	*Shinkai Maru*	*Amaltal Explorer*	*Amaltal Explorer*	*Shinkai Maru*	*Shinkai Maru*	*Amaltal Explorer*
Date (month/year)	3-5/1982	10-11/1983	11-12/1989	11-12/1990	3/1983	7/1986	10-11/1989
Area	SP	SP	SP	SP	CR	CR	CR
birth year							
1988	–	–	0.1 [1]	2.9 [2]	–	–	72.8 [1]
1987	–	–	2.1 [2]	6.2 [3]	–	–	75.8 [2]
1986	–	–	1.2 [3]	3.0 [4]	–	–	29.0 [3]
1985	–	–	4.3 [4]	5.8 [5]	–	–	20.2 [4]
1984	–	–	14.6 [5]	25.3 [6+]	–	23.1 [1]	19.4 [5+]
1983	–	–	25.0 [6+]	–	–	312.0 [2]	–
1982	–	–	–	–	–	132.0 [3]	–
1981	–	5.4 [1]	–	–	47.8 [1]	38.9 [4]	–
1980	17.6 [1]	0.4 [2]	–	–	129.7 [2]	97.3 [5+]	–
1979	2.7 [2]	7.6 [3]	–	–	207.0 [3]	–	–
1978	60.2 [3]	40.7 [4]	–	–	59.9 [4]	–	–
1977	55.6 [4]	56.6 [5]	–	–	35.8 [5+]	–	–
1976	38.8 [5]	84.4 [6+]	–	–	–	–	–
1975	60.7 [6+]	–	–	–	–	–	–

* Estimated using length intervals (cm TL) as follows: 1 = 30–42, 2 = 43–54, 3 = 55–64, 4 = 65–70, 5 = 71–76, 6+ = 76+.

\+ Indicates plus group of, for example 6 years and older fish.

Figure 1: Chatham Rise survey area and strata.

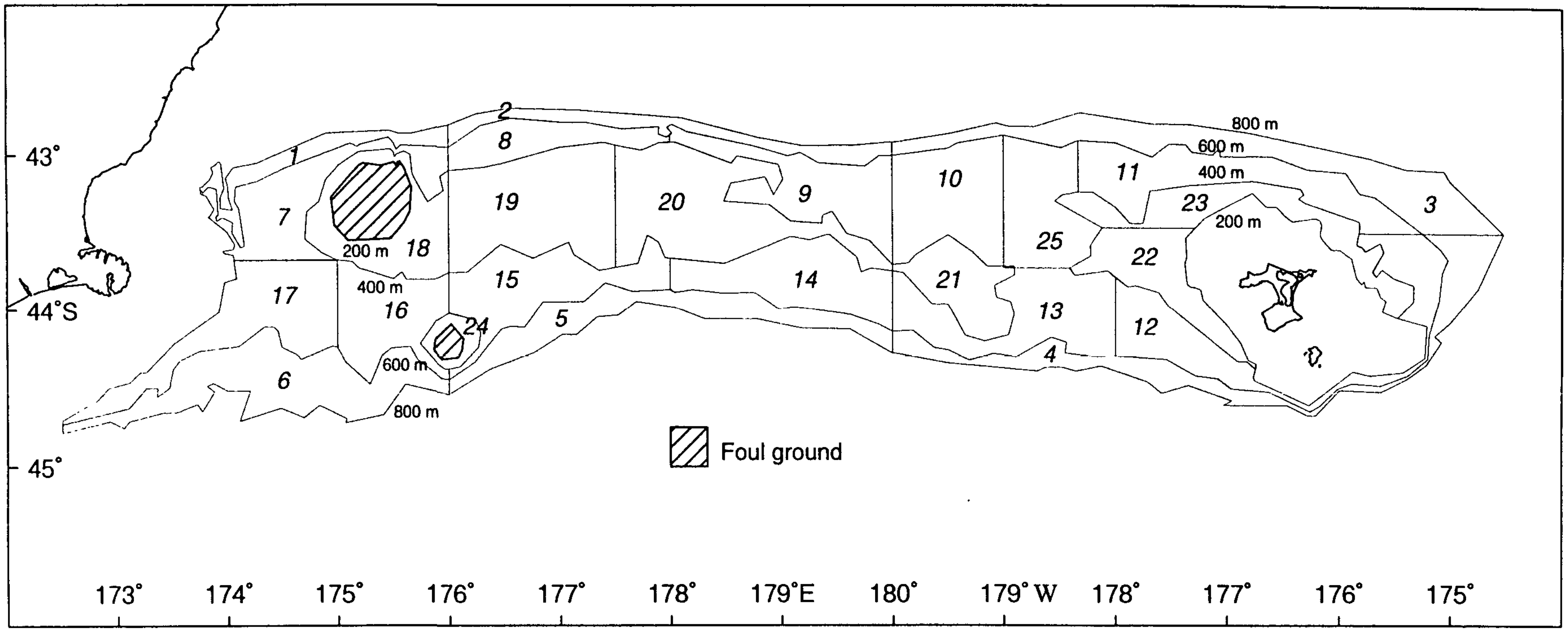
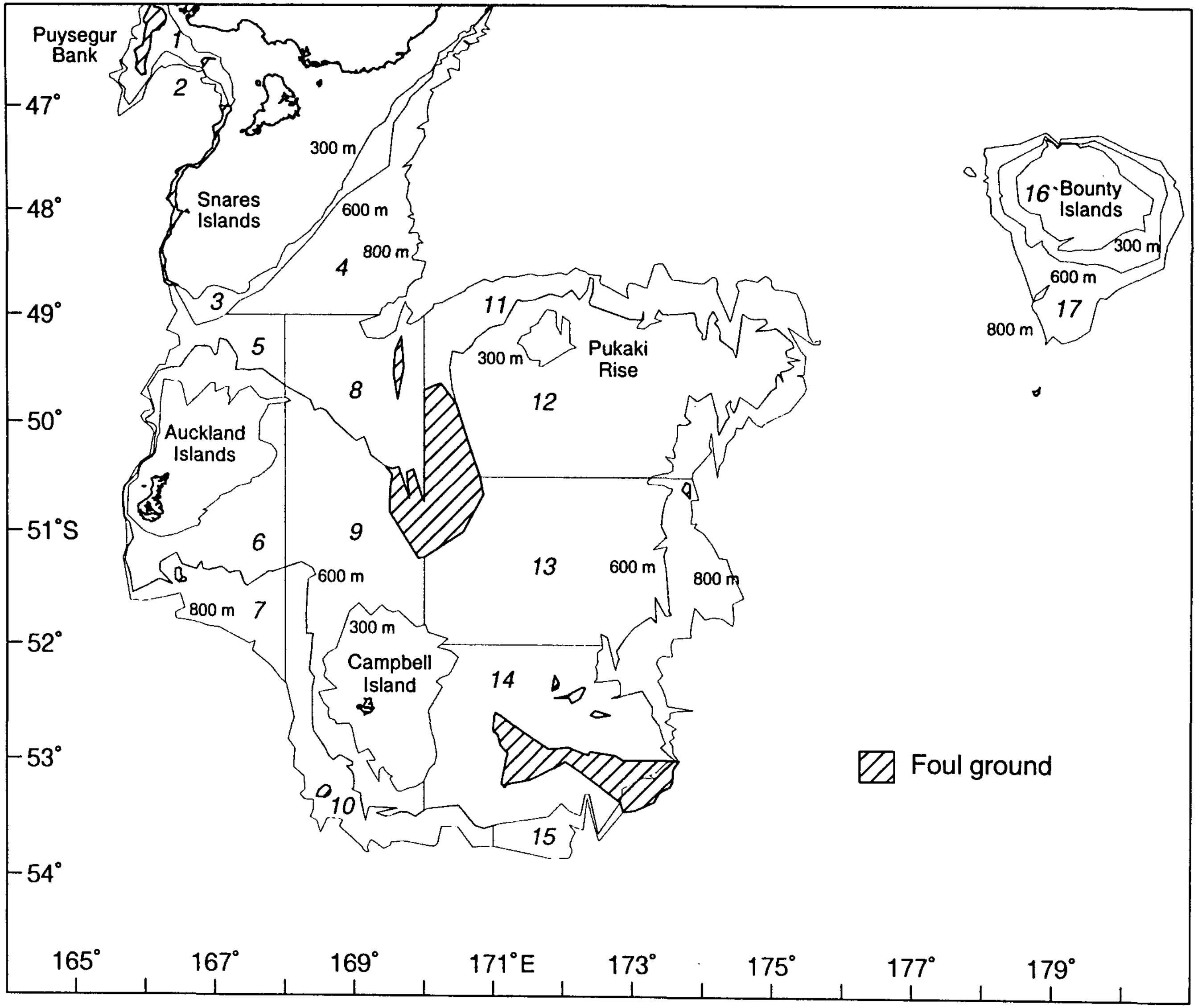


Figure 2: Southern Plateau survey area and strata.



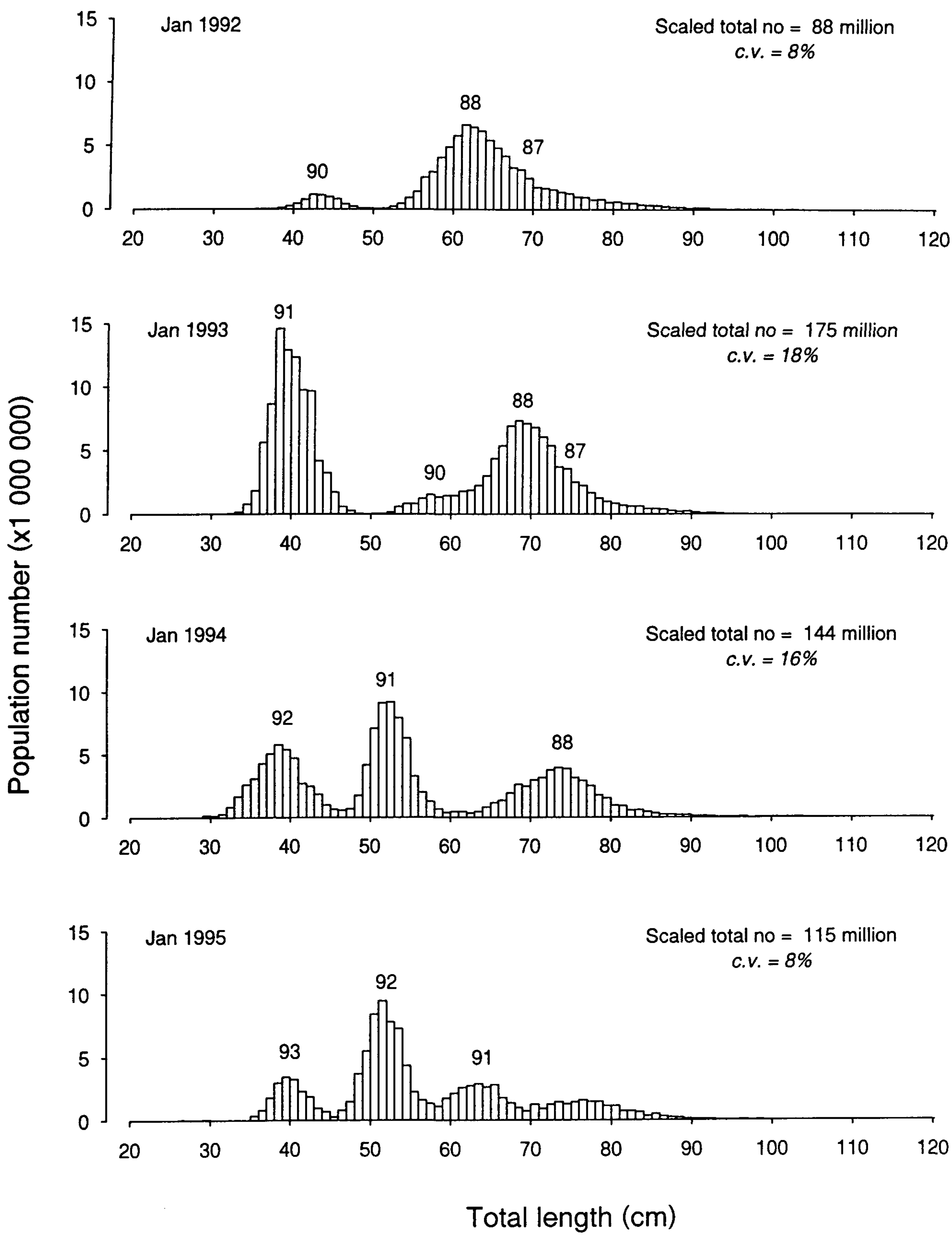


Figure 3: Scaled length frequencies of female hoki for the January surveys of the Chatham Rise.

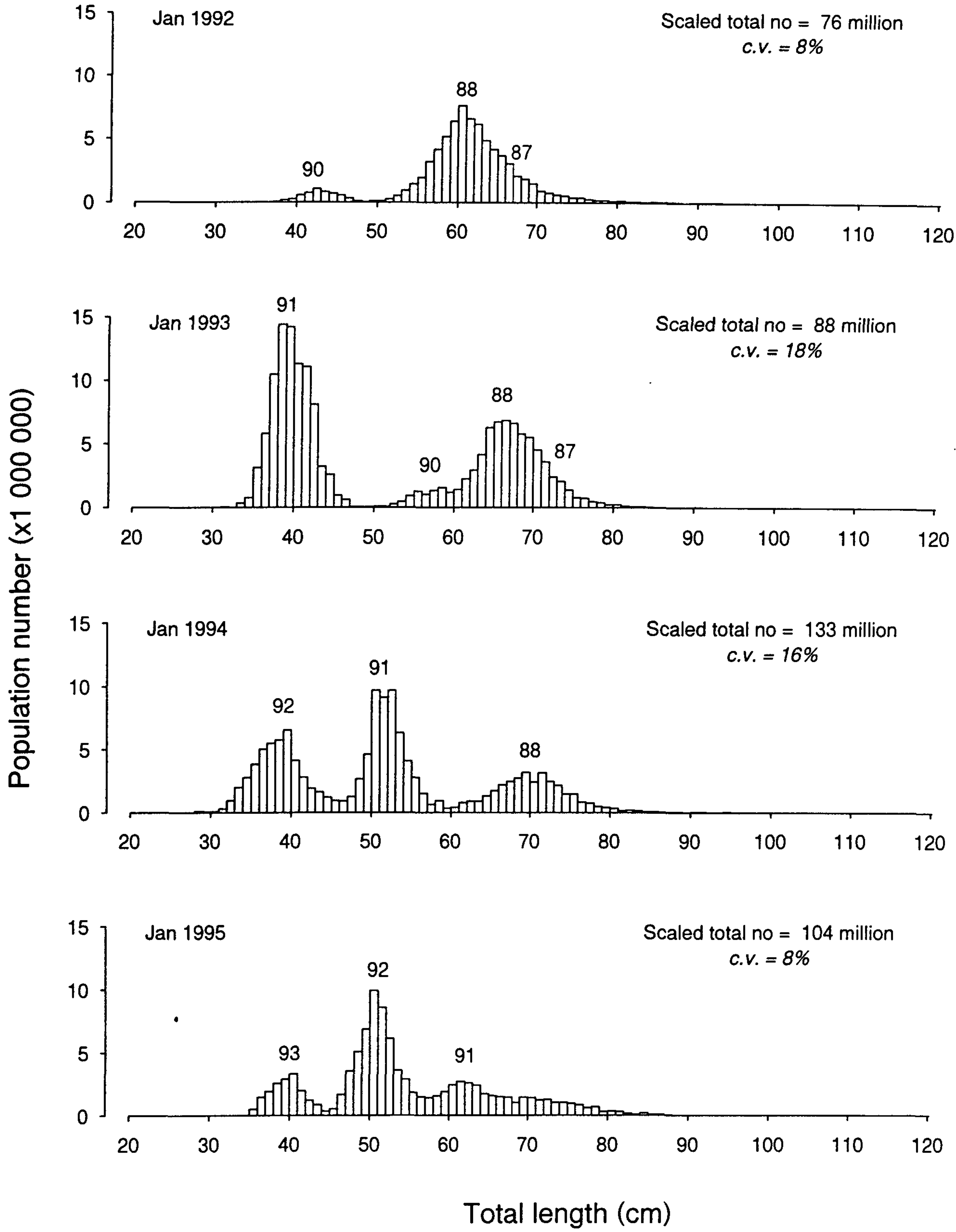


Figure 4: Scaled length frequencies of male hoki for the January surveys of the Chatham Rise.

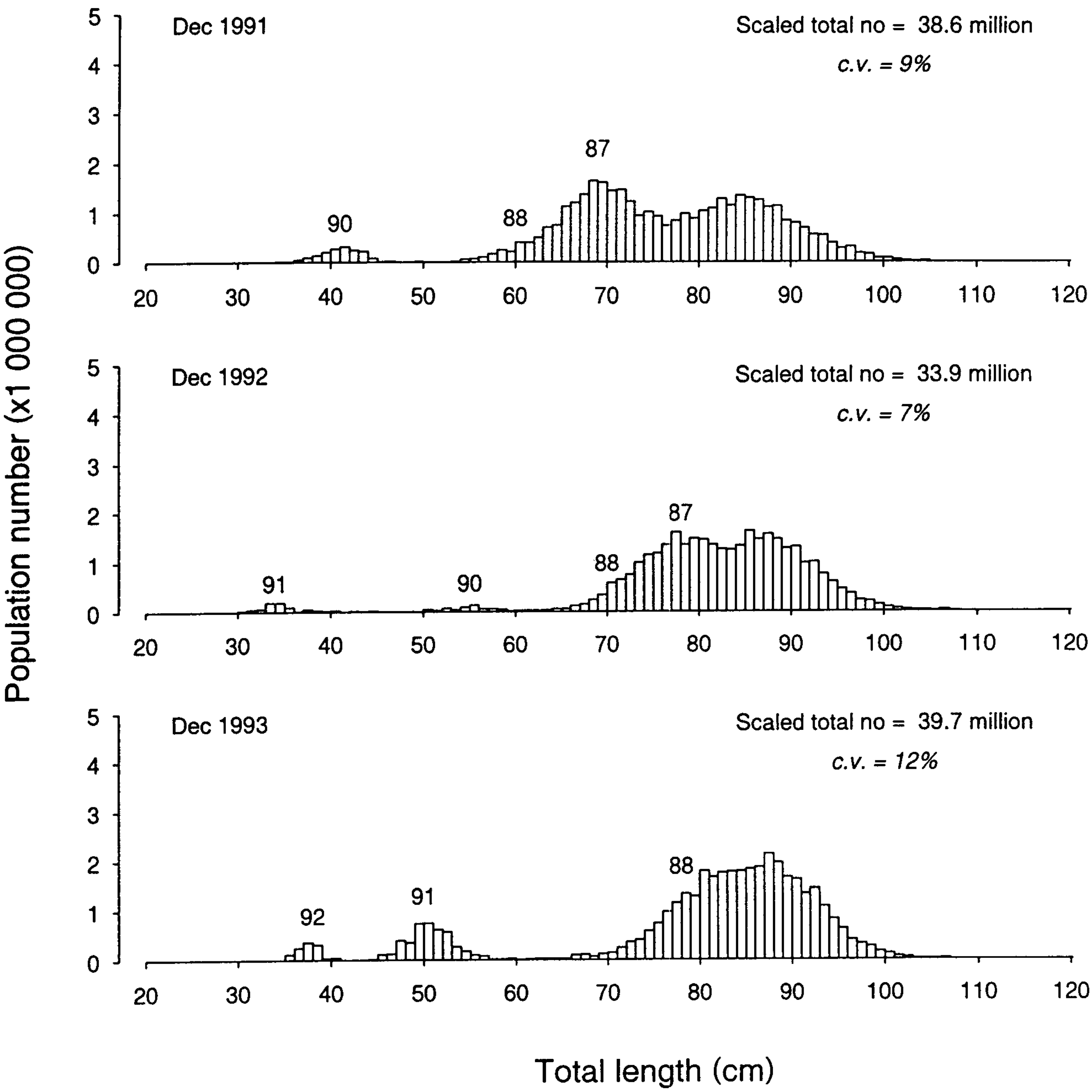


Figure 5: Scaled length frequencies of female hoki for the December surveys of the Southern Plateau.

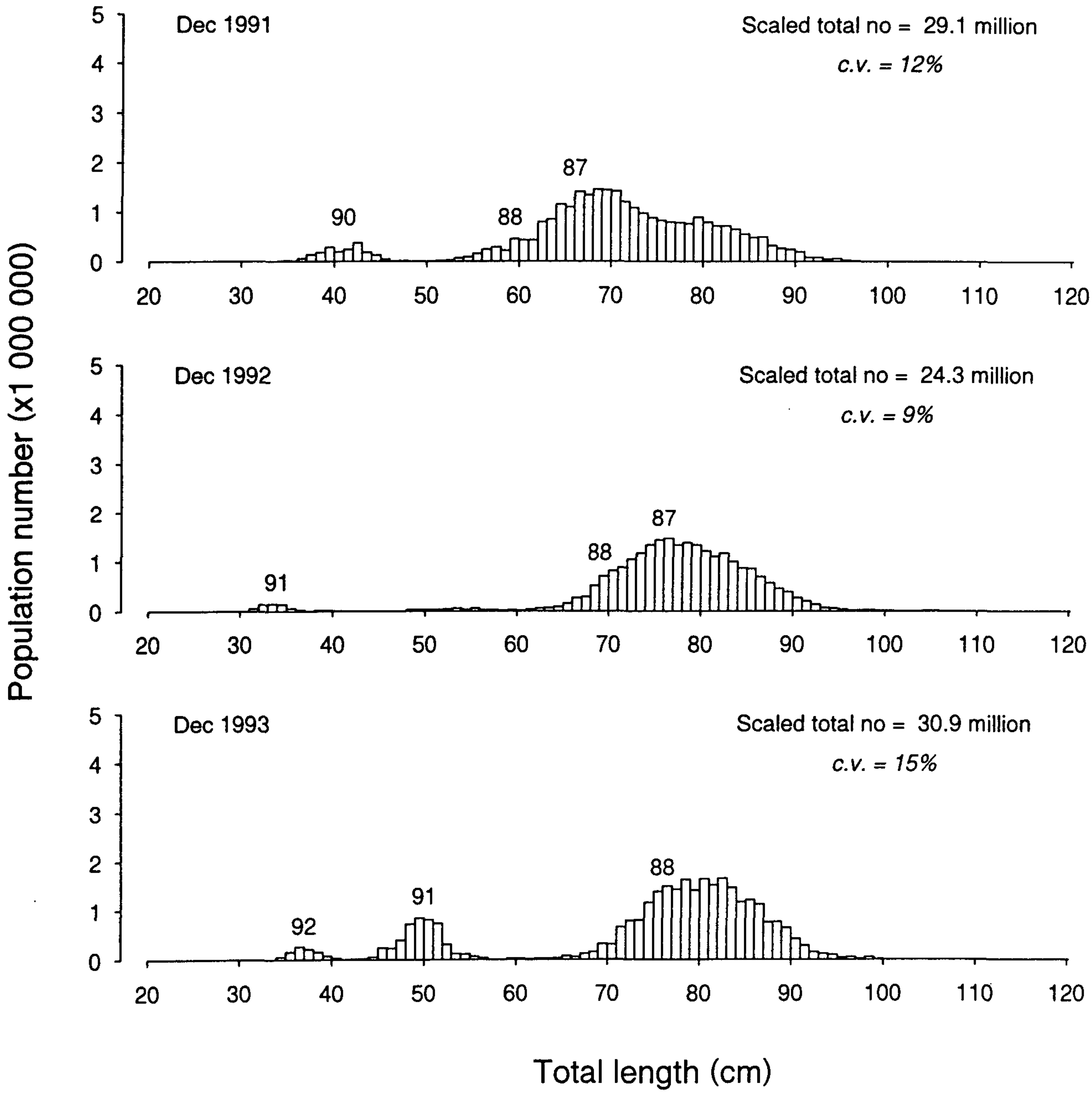


Figure 6: Scaled length frequencies of male hoki for the December surveys of the Southern Plateau.

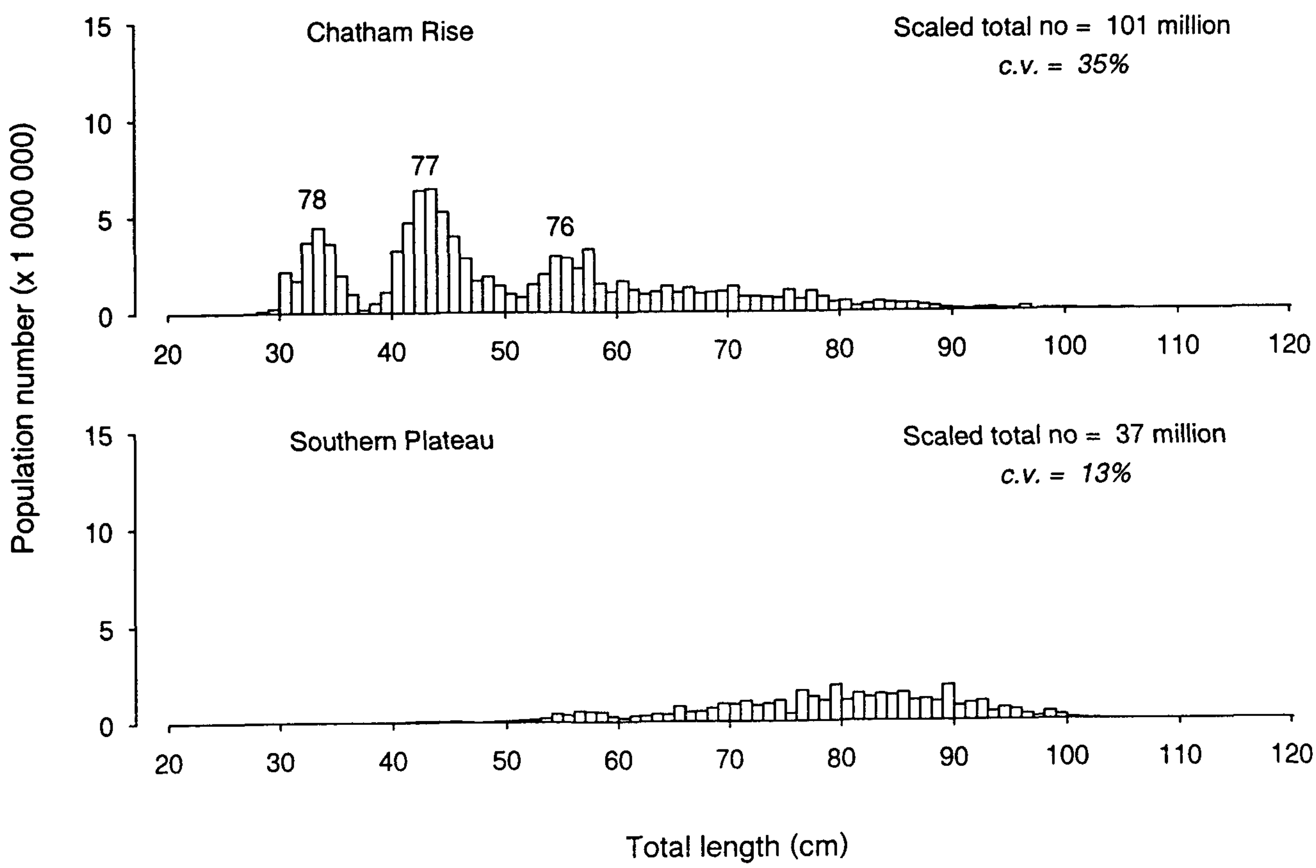


Figure 7: Scaled length frequencies of hoki (sexes combined) from Chatham Rise and Sub-Antarctic surveys, in Oct-Nov 1979 (Wesermunde).

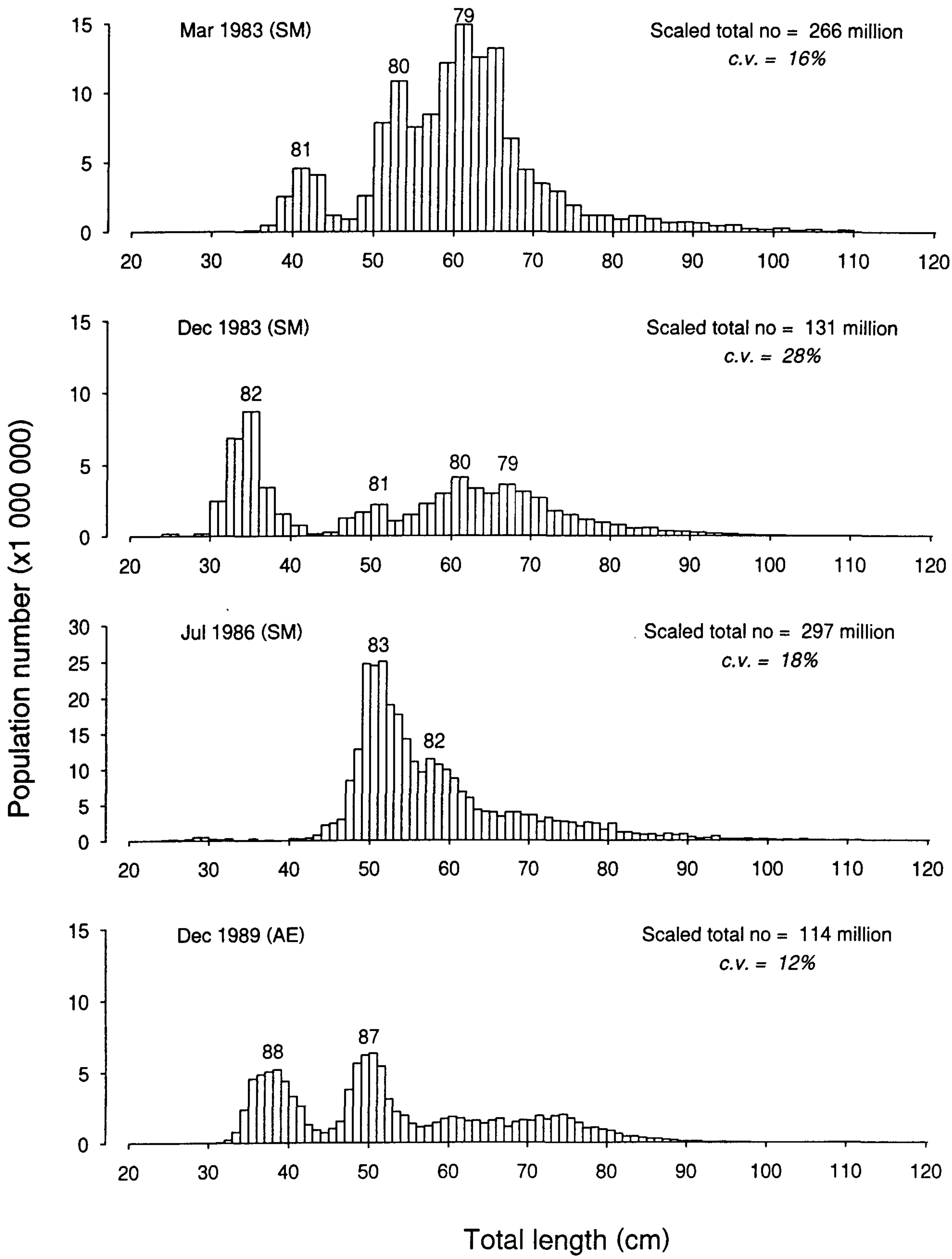


Figure 8: Scaled length frequencies of female hoki for surveys of the Chatham Rise (SM, Shinkai Maru; AE, Amaltal Explorer).

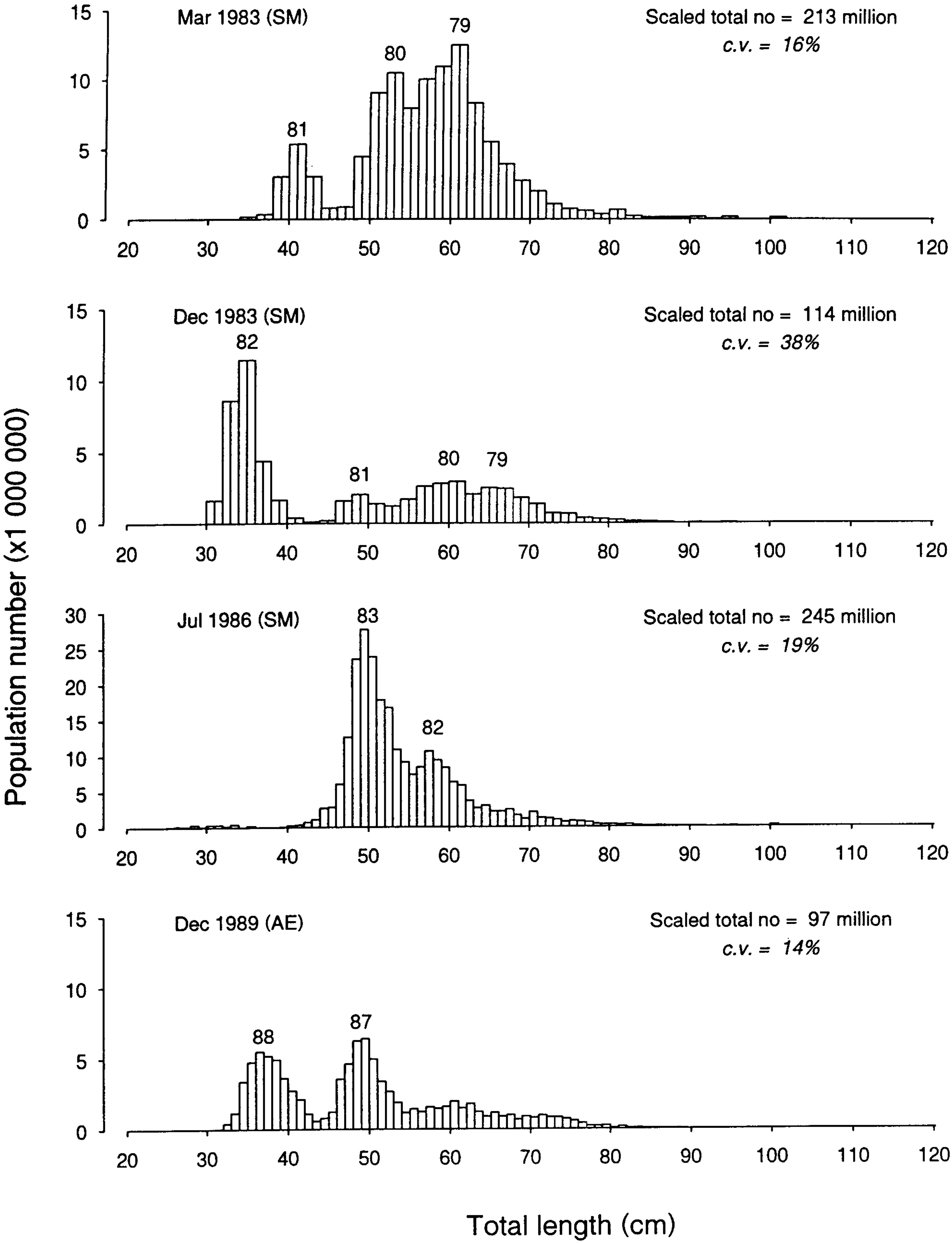


Figure 9: Scaled length frequencies of male hoki for surveys of the Chatham Rise (SM, Shinkai Maru; AE, Amaltal Explorer).

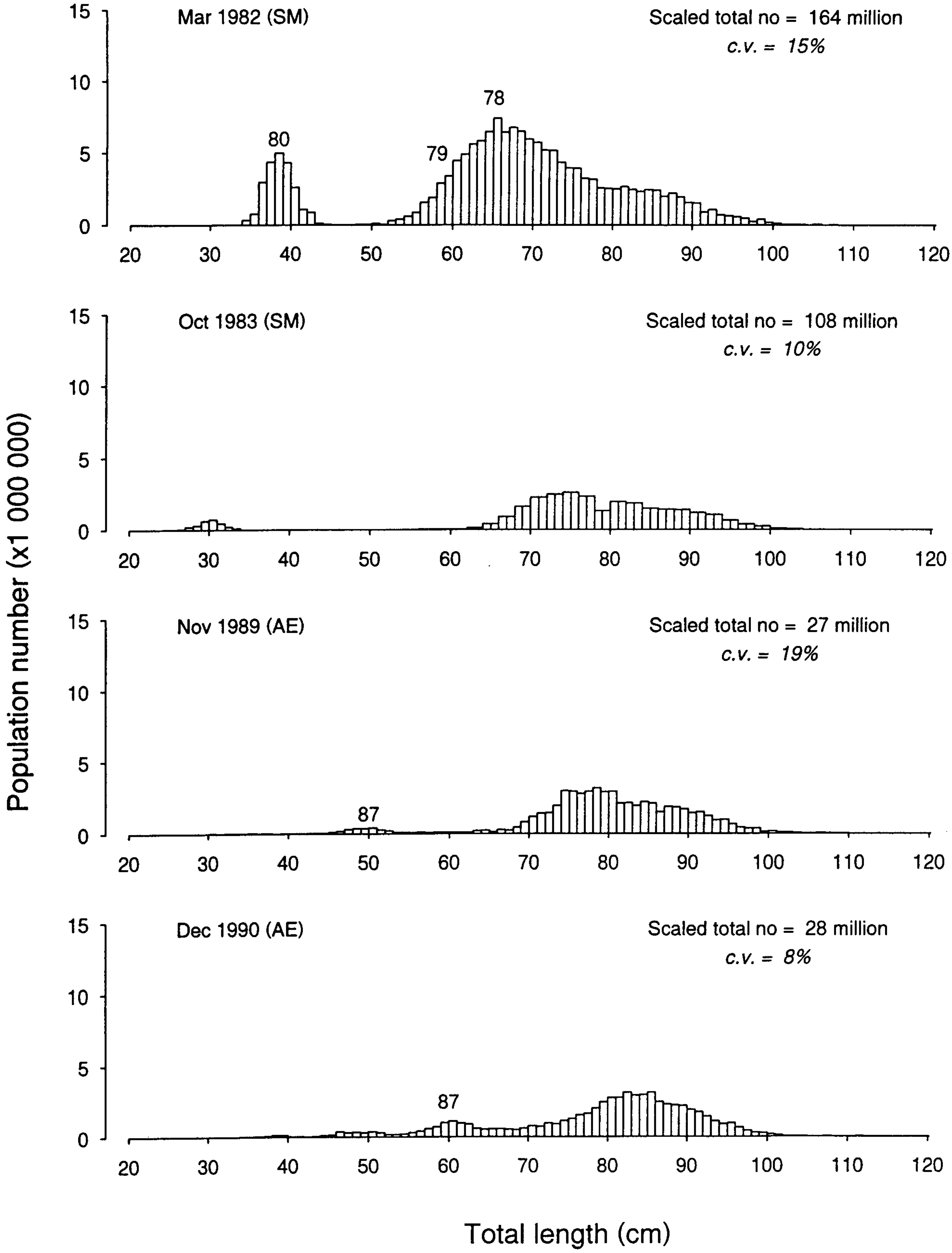


Figure 10: Scaled length frequencies of female hoki for surveys of the Southern Plateau (SM, Shinkai Maru; AE, Amaltal Explorer).

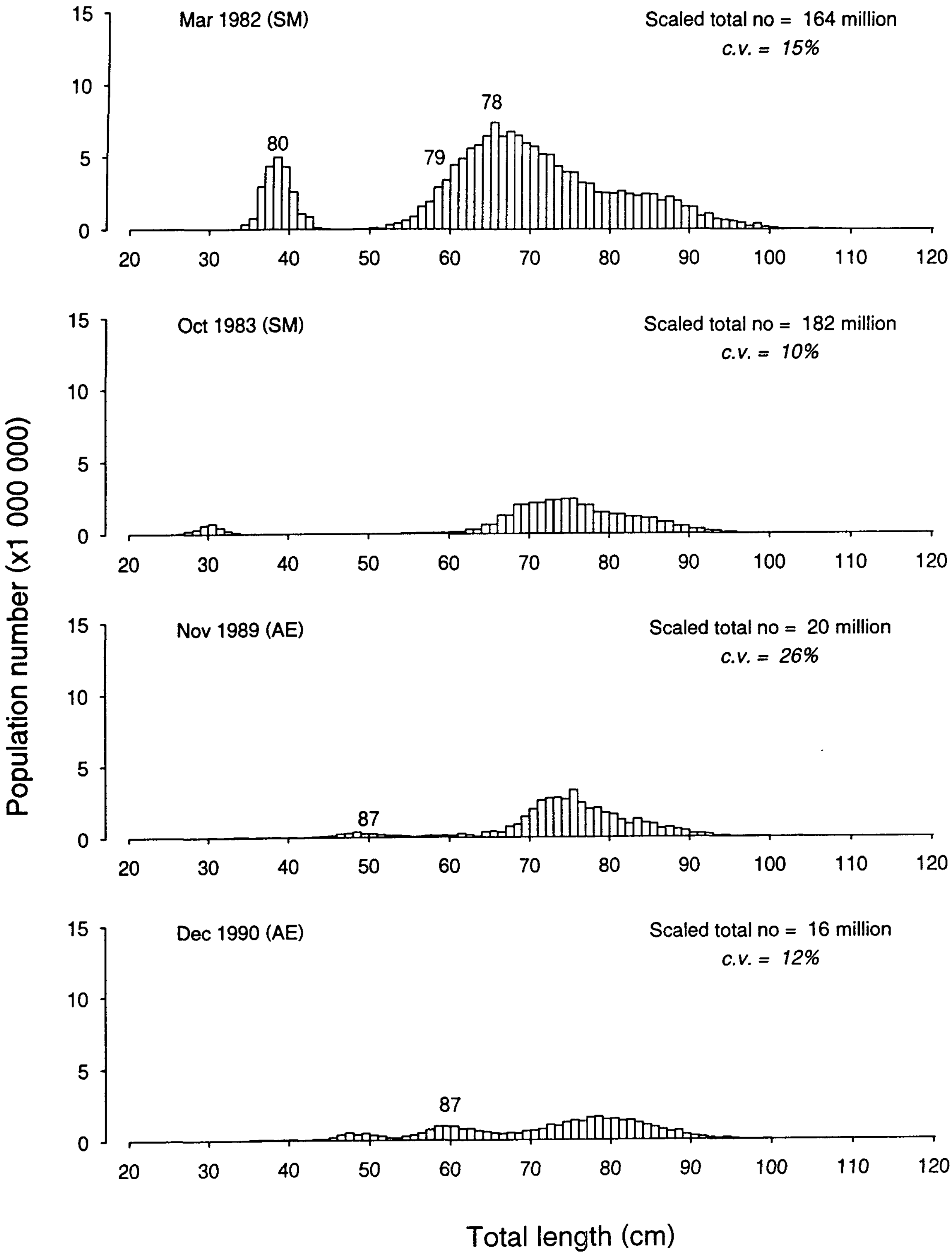


Figure 11: Scaled length frequencies of male hoki for surveys of the Southern Plateau (SM, Shinkai Maru; AE, Amaltal Explorer).

Appendix 1: Reference chart to show age of individual year classes in January of each year

Birth date July/August	Age in January each year							
	1988	1989	1990	1991	1992	1993	1994	1995
1987	0+	1+	2+	3+	4+	5+	6+	7+
1988	–	0+	1+	2+	3+	4+	5+	6+
1989	–	–	0+	1+	2+	3+	4+	5+
1990	–	–	–	0+	1+	2+	3+	4+
1991	–	–	–	–	0+	1+	2+	3+
1992	–	–	–	–	–	0+	1+	2+
1993	–	–	–	–	–	–	0+	1+

Appendix 2: Number of stations by area along the Chatham Rise in surveys, January 1992-95

Area	1992 No.	1992 %	1993 No.	1993 %	1994 No.	1994 %	1995 No.	1995 %
Western Rise (< 176 °E)	56	(30)	61	(31)	67	(41)	31	(25)
Central Rise (176 °E–180°)	73	(40)	82	(42)	53	(32)	34	(28)
Eastern Rise (180–175 °W)	55	(30)	52	(27)	45	(27)	57	(47)

Numbers of stations per depth zone in each Chatham Rise survey, January 1992–95

	1992 No.	1992 %	1993 No.	1993 %	1994 No.	1994 %	1995 No.	1995 %
200–400 m	46	(25)	71	(36)	57	(35)	33	(27)
400–600 m	103	(56)	94	(48)	84	(51)	66	(54)
600–800 m	35	(19)	30	(15)	24	(14)	23	(19)
Total	184		195		165		122	

Wind and tow direction data from Chatham Rise surveys, January 1992–95

	1992	1993	1994	1995
Average wind direction	161.7° (SE)	225.8° (SW)	199.9° (SW)	185.1° (S)
Average tow direction	174.7° (S)	168.3° (SE)	168.4° (SE)	204.8° (SW)
Wind force*	5	5	5	5
Wind speed $m.s^{-1}$	–	10.2	9.3	9.2

* Beaufort Scale

Appendix 3: Number of stations per depth zone in each Southern Plateau survey, December 1991–93

	1991		1992		1993	
	No.	%	No.	%	No.	%
300–600 m	85	(55)	85	(53)	75	(54)
600–800 m	65	(42)	69	(43)	59	(43)
800–1000 m	4	(3)	6	(4)	4	(3)
Total	154		160		138	

Wind and tow direction data from Southern Plateau surveys, December 1991–93

	1991	1992	1993
Average wind direction	220.5° (SW)	194.1° (SW)	197.7° (SW)
Average tow direction	188.6° (S)	183.1° (S)	166.9° (SE)
Wind speed $m.s^{-1}$	11.2	10.2	10.6
Wind force	5	5	6

Appendix 4: Scientific and common names and species codes of species mentioned in this report

Scientific name	Common name	Species code
Chondrichthyes		
Squalidae: dogfishes		
Deania calcea	shovelnosed dogfish	SND
Squalus acanthias	spotted spiny dogfish	SPD
Triakidae: smoothhounds		
Galeorhinus galeus	school shark	SCH
Rajidae: skates		
Raja innominata	smooth skate	SSK
Chimaeridae: chimaeras, ghost sharks		
Hydrolagus novaezelandiae	dark ghost shark	GSH
Hydrolagus sp. B	pale ghost shark	GSP
Rhinochimaeridae: longnosed chimaeras		
Harriotta raleighana	longnosed chimaera	LCH
Osteichthyes		
Argentinidae: silversides		
Argentina elongata	silverside	SSI
Moridae: morid cods		
Mora moro	ribaldo	RIB
Pseudophycis bachus	red cod	RCO
Gadidae: true cods		
Micromesistius australis	southern blue whiting	SBW
Merlucciidae: hakes		
Macruronus novaezelandiae	hoki	HOK
Merluccius australis	hake	HAK
Macrouridae: rattails, grenadiers		
Caelorinchus aspercephalus	oblique-banded rattail	CAS
C. bollonsi	bigeyed rattail	CBO
C. oliverianus	Oliver's rattail	COL
Lepidorhynchus denticulatus	javelinfish	JAV
Macrourus carinatus	ridgescaled rattail	MCA
Ophidiidae: cusk eels		
Genypterus blacodes	ling	LIN
Trachichthyidae: roughies		
Hoplostethus atlanticus	orange roughy	ORH
Berycidae: alfonsinos		
Beryx splendens	slender beryx	BYS
Zeidae: dories		
Cyttus traversi	lookdown dory	LDO
Oreosomatidae: oreos		
Allocyttus niger	black oreo	BOE
Neocyttus rhomboidalis	spiky oreo	SOR
Pseudocyttus maculatus	smooth oreo	SSO
Scorpaenidae: scorpionfishes		
Helicolenus sp.	sea perch	SPE
Percichthyidae: temperate basses		
Polyprion oxygeneios	hapuku	HAP
Carangidae: jacks, trevallies, kingfishes		
Trachurus murphyi	slender mackerel	JMM
Cheilodactylidae: tarakihi, morwongs		
Nemadactylus macropterus	tarakihi	TAR

Appendix 4: ***continued***

Uranoscopidae: armourhead stargazers		
Kathetostoma giganteum	giant stargazer	STA
Gempylidae: snake mackerels		
Rexea solandri	gemfish	SKI
Thyrsites atun	barracouta	BAR
Centrolophidae: raftfishes, medusafishes		
Hyperoglyphe antarctica	bluenose	BNS
Seriolella caerulea	white warehou	WWA
S. punctata	silver warehou	SWA
Bothidae: lefteyed flounders		
Neoachiropsetta milfordi	finless flounder	MAN
Cephalopoda		
Ommastrephidae		
Nototodarus sloanii	arrow squid	NOS
Onychoteuthidae		
Moroteuthis ingens	warty squid	MIQ

Appendix 5: Sea temperature and Southern Oscillation data

Years of relatively strong hoki recruitment arrowed