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EXECUTIVE SUMMARY

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This report is in fulfilment of Objective 3 of Project STA2000/01 – "To age giant stargazer otoliths collected from Southland trawl surveys from 1993 to 1996."

Counts of growth zones in sectioned giant stargazer otoliths were used to determine ages, von Bertalanffy growth parameters, population length and age structures, and total mortality. Fish growth is rapid for about the first 7 years, and is negligible after about 13 years. Females reached a significantly greater maximum length than males, but differences in growth rate were not significant at the 95% level of confidence. Similarly, differences in population age distribution were not evident, and there was no conclusive pattern of year class strength for fish sampled from successive years. A maximum age of 23 years was obtained for both sexes. The Chapman and Robson estimator of total mortality was used to derive Z values of 0.20 for females and 0.35 for males.

1. INTRODUCTION

Giant stargazer *(Kathetostoma giganteum)* is widely distributed throughout New Zealand waters, but is predominantly caught around the South Island to depths of 500 m (Annala et al. 2004). Since the introduction of the Quota Management System (QMS) in 1986–87, the annual commercial catch has fluctuated between 2000 t and 4150 t.

The biological stock structure of giant stargazer is unknown. Currently, the species is divided into Fishstocks based on Quota Management Areas (QMAs). QMA boundaries were chosen following a general review of stargazer historical catch information (Annala et al. 2004).

A method for ageing giant stargazer has been developed by Sutton (1999). Consistent and repeatable hyaline zone counts are obtained from sectioned otoliths using this technique.

Evidence that the hyaline zones are annual is supported by cohort analysis of fish sampled from the east coast South Island (ECSI) between 1992 and 1996 (Sutton 1999). Year class progression was not evident for male fish sampled from Southland between 1993 and 1996, possibly because small fish (35 cm or less) were poorly represented in these surveys.

For this study, modified von Bertalanffy growth parameters and total mortality rates (Z) were calculated using Southland research survey data collected between 1993 and 1996.

2. METHODS

2.1 Otolith collection, preparation, and reading

Giant stargazer otoliths (sagittae) and length-frequency data were collected during trawl surveys by RV *Tangaroa* off Southland during January–February 1993, 1994, 1995, and 1996. Total length (TL, measured to the nearest whole centimetre below actual length) and sex were recorded for all fish from which otoliths were extracted. Otoliths were cleaned and stored dry in paper envelopes.

Giant stargazer otoliths (622 male and 866 female) collected from the four Southland surveys were prepared and read using the technique outlined by Sutton (1999). The length and sex of each fish were unknown to the otolith reader.

2.2 Ageing precision

Determining the age of giant stargazer was not straightforward, the most difficult aspect being the interpretation of the first year's growth. However, by examining otoliths of small fish (less than 20 cm) believed to be about age 1 (from length frequency data) an assumption was made as to the location of the first "annual" band.

Otolith zone counts were assessed for ageing bias and precision. To assess the within-reader variability of the results, 112 otoliths sampled from the four surveys and representing a range of lengths and both sexes were read twice by the author. First and second readings were made 3 weeks apart. An index of average percentage error (IAPE) was produced for comparison between the two readings (Beamish & Fournier 1981). The advantage of this index is that it is independent of fish age.

2.3 Growth parameters

To convert zone counts in otoliths to estimates of age it is necessary to know (i) when spawning occurs; (ii) when the formation of the hyaline zone in the otolith is completed; and (iii) when sampling was conducted.

Giant stargazer have an annual reproductive cycle with a winter spawning season (Annala et al. 2004), so it was deemed appropriate to select a "birthday" of 1 July for all the fish examined in this study.

Generally, fish sampled in January–February by *Tangaroa* showed a thin opaque margin. Based on the width of completed opaque zones, it was assumed that this deposit represented about 2 months growth. Therefore, the hyaline zone in the otoliths appears to be complete by November, and hence fish are about 4 months old on the completion of the first hyaline 'annual' zone.

All sampling was conducted between January and February off Southland. Therefore, a sampling date of 1 February was assigned.

The information on time of spawning, time of zone formation, and sampling time was used to obtain an appropriate age for the otolith zone counts. For example, an otolith sampled on 1 February with opaque material outside one complete hyaline zone would be allocated an age of 1 year and 7 months (1.6 years). This is because the time elapsed between completion of the hyaline zone (1 November) and time of sampling (3 months) is added to the time elapsed between spawning (1 July) and formation of the dark zone (4 months).

Von Bertalanffy growth curves were fitted to the age-length data using a non-linear least-squares regression procedure (Ralston & Jennrich 1978). Maximum likelihood methods were used to calculate separate parameters and standard errors for each survey and sex (Kimura 1980). This technique assumed independent and identically distributed normal errors. A randomisation test was used to determine the significance of the differences in von Bertalanffy parameters between sexes.

2.4 Population length and age structures

Length-frequency histograms from research trawl surveys often show clear modes in young fish, suggesting distinct year classes. The length distributions of giant stargazer sampled from Southland during 1993, 1994, 1995, and 1996 were constructed.

Age distributions of male and female stargazer in each of the four *Tangaroa* surveys during 1993, 1994, 1995, and 1996 were constructed using the "catch-at-age" software developed by NIWA (B. Bull, NIWA, pers. comm.) The software constructs an age-length key from otolith data and applies it to the length frequencies to yield age frequencies.

The length strata, x, were grouped in 2 cm intervals (i.e., 10–11 cm, 12–13 cm) up to 72–73 cm for males and 80–81 cm for females. Intervals of 2 cm were selected because it is likely that the small sample sizes and the limited age data available, particularly for some of the smaller and larger length classes, may have caused atypical age-at-length data to be overemphasised in the analysis.

2.5 Estimating total mortality

Following the advice of the Inshore Working Group estimates of total mortality (Z) were calculated for both male and female fish. The Chapman and Robson estimator of total mortality, $\hat{Z}$, was used (Chapman & Robson 1960), where

$$\hat{Z} = -\log_e \hat{S}$$

where

$$\hat{S} = \frac{\sum_{i=1}^{N} y_i}{N + \sum_{i=1}^{N} y_i - 1}$$

and

y_i = true age of an individual in terms of years after recruitment
N = total size of recruited population

It was assumed that giant stargazer would be fully recruited to the fishery at a length of 45–50 cm and an age of 6 years. Therefore, age 6 was used as the recruited age in the Chapman and Robson equation.

3. RESULTS

3.1 Ageing precision

The results of the within-reader comparison are shown in Figure 1. There is no systematic bias in the results, and the ageing error appears to be negligible over the aggregated age range. The index of average percentage error (IPAE) is 4.8%.

3.2 Growth parameters

Data from all examined otoliths were used to calculate von Bertalanffy growth curve parameters (with asymptotic 95% confidence intervals for the estimates) for male and female fish from Southland (Table 1). These data were compared with the parameters derived by Sutton (1999) (Tables 2 & 3) and are consistent with this earlier work.

The raw data, mean lengths-at-age, and calculated von Bertalanffy curves for the current study are plotted in Figure 2.

Both male and female giant stargazer reached a maximum age of 23 years. However, only about 4% of males and 10% of females reached an age greater than 14 years.

Females appeared to be larger than males at corresponding ages from about 6 years old and had a significantly greater L_∞ value. In contrast, the difference in k, and t_0 between sexes was not significant at the 95% level of confidence (Table 1). These results are largely consistent with those of Sutton (1999).

Male and female fish grew rapidly for about the first 7 years, but growth was negligible after about 13 years (Figure 2).

There was considerable overlap in the age-at-length data from about 4 years of age for both sexes. This is indicated in Table 4 which shows mean lengths-at-age (with standard deviation and sample size) for all fish aged. The calculated von Bertalanffy curves in Figure 2 fit these data reasonably well.

3.3 Population length and age structures

Length-frequency histograms for giant stargazer sampled off Southland between 1993 and 1996 are presented in Figure 3. The data have been scaled by size of catch and area trawled to represent the total population of stargazer in the survey area. The length frequency distributions of males and females were relatively consistent between years (Figure 3).

The presence of strong and weak cohorts in the ageing data indicates a significant level of recruitment variability in the Southland giant stargazer stock (Figure 4). It appears that male and female stargazer do not become fully recruited to the fishery until they reach 6 or 7 years of age with the most of the fishery based on fish between 6 and 16 years. The 1993 data shows that there was a relatively strong 1987 cohort for both male and female fish (6+ year class) which remained strong in the two subsequent years but was less evident in the 1996 data. This lack of progression into the 1996 data may be due to ageing error. It is also probable that increased variability in otolith readings with increasing age results in cohorts becoming merged beyond 9 or 10 years of age. There is also a progression of relatively strong 1986 and 1985 cohorts between 1993 and 1995 with this trend being more evident in the female ageing data. Otoliths extracted from female fish may provide more precise readings than those sampled from males of the same age.

3.4 Total mortality rates

The Chapman and Robson estimator of total mortality was used to derive Z values of 0.35 for male fish and 0.20 for female fish. This difference between the sexes is due to the different proportions at each age class. Uncertainties about the age at recruitment make it difficult to estimate Z more precisely at present.

4. DISCUSSION

This is the third study dealing with giant stargazer age and growth in New Zealand waters. Sutton (1999) undertook similar work on fish sampled from Southland and the east coast South Island and his findings were consistent with those presented here. Manning and Sutton (2004) examined giant stargazer otoliths collected off the west coast South Island, and found growth was slower and fish tended to be larger, on average, than for other areas.

The present work shows that growth is initially rapid but slows dramatically after the first 7 years, and is negligible after about 13 years. Female fish are, on average, larger than males at corresponding ages (after

age 5) and have a significantly greater L_∞ value. Differences in giant stargazer growth rates between sexes are not statistically significant.

This study attempts to support the ageing methodology by examining scaled length and age frequency data to show modal progression. However, as with Sutton (1999), and Manning and Sutton (2004) clear trends were limited and it was apparent from the length frequency data that small fish (35 cm or less), which are most likely to show modal progression (as growth is more consistent during the first 3–4 years) are poorly represented in the survey. Furthermore, there is increasing error with increasing age which means older cohorts will tend to merge. This poor representation of small fish may be because they are inadequately sampled by *Tangaroa's* trawl gear or are absent from the area. This will affect the mean-length-at-age values for younger fish and reduce the estimates of k. It is also probable that the gear selects large fish poorly and the estimates of L_∞ are biased low. The degree of this bias is currently difficult to determine.

The current work produced a maximum age of 23 years for both male and female giant stargazer. Sutton (1999) aged males to a maximum age of 18 years and females to 20 years. Manning and Sutton (2004) obtained maximum ages of 18 years and 25 years for males and females, respectively. The greater maximum ages obtained by Manning and Sutton (2004) and in this study are likely to be a function of the larger sample sizes.

5. ACKNOWLEDGMENTS

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Table 1: Von Bertalanffy growth parameters (with 95% confidence intervals) for giant stargazer sampled from Southland between 1993 and 1996.

	male	female
L_∞	60.76	72.61
	(59.4–62.6)	(71.9–74.1)
k	0.18	0.17
	(0.16–0.19)	(0.16–0.18)
t_0	-1.16	-0.02
	(-1.81 to –0.91)	(-0.42 to –0.04)
Age range	0–23	1–23
n	662	866

Table 2: Von Bertalanffy growth parameters (with 95% confidence intervals) for giant stargazer sampled from Southland (from Sutton 1999)

	male	female
L_∞	59.12	73.92
	(58.2–61.2)	(69.2–79.0)
k	0.19	0.18
	(0.17–0.21)	(0.14–0.23)
t_0	-1.19	-0.22
	(-1.79 to –0.82)	(-0.85 to 0.51)
Age range	0–18	1–20
n	384	138

Table 3: Von Bertalanffy growth parameters (with 95% confidence intervals) for giant stargazer sampled from the east coast of the South Island (from Sutton 1999)

	male	female
L_∞	61.49	78.11
	(58.8–64.3)	(72.7–83.8)
k	0.20	0.14
	(0.18–0.22)	(0.12–0.16)
t_0	-0.97	-1.25
	(-1.15 to –0.80)	(-1.48 to 1.03)
Age range	0–22	1–20
n	530	502

Table 4: Mean lengths at age (cm, with standard deviation, S.D., and sample size, *n*) for fish sampled from Southland.

	Male			Female		
Age class	Mean	S.D.	n	Mean	S.D.	n
0+	16.9	-	1	-	-	0
1+	-	-	0	22.7	4.0	4
2+	26.8	1.8	11	27.4	1.8	9
3+	35.2	3.3	25	33.4	3.5	26
4+	40.3	2.7	44	40.3	3.1	30
5+	44.1	2.8	74	44.0	3.9	40
6+	46.9	2.8	100	50.4	4.6	71
7+	48.5	2.9	110	54.3	4.5	96
8+	50.0	2.8	85	56.8	4.9	106
9+	51.7	3.6	62	59.4	5.4	81
10+	53.1	3.2	51	60.8	5.3	96
11+	54.2	3.7	35	63.6	4.9	59
12+	55.7	3.8	19	65.4	5.4	65
13+	58.0	2.9	9	66.0	4.8	62
14+	57.8	3.9	13	67.2	4.3	31
15+	61.6	1.8	3	68.4	5.7	19
16+	58.3	3.7	5	69.2	4.6	31
17+	58.1	2.2	4	70.3	3.9	14
18+	61.7	1.7	2	69.7	3.1	5
19+	61.9	4.5	3	67.5	4.3	8
20+	59.8	1.6	2	68.2	1.1	6
21+	65.0	4.2	2	69.8	5.3	3
22+	-	-	0	72.3	3.9	3
23+	66.0	2.1	2	64.6	-	1

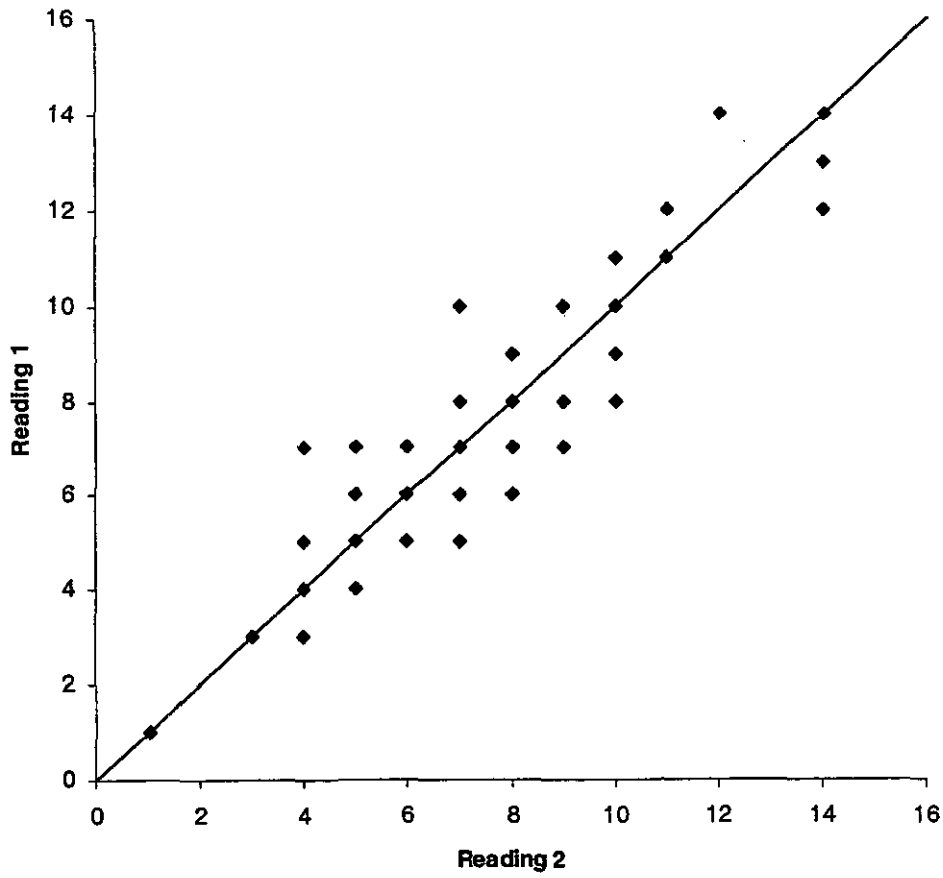

Figure 1: Comparison of giant stargazer age estimates between readings (n = 112). The solid line is the 1:1 regression line. An even distribution of points above and below the line indicates a lack of bias between readings.

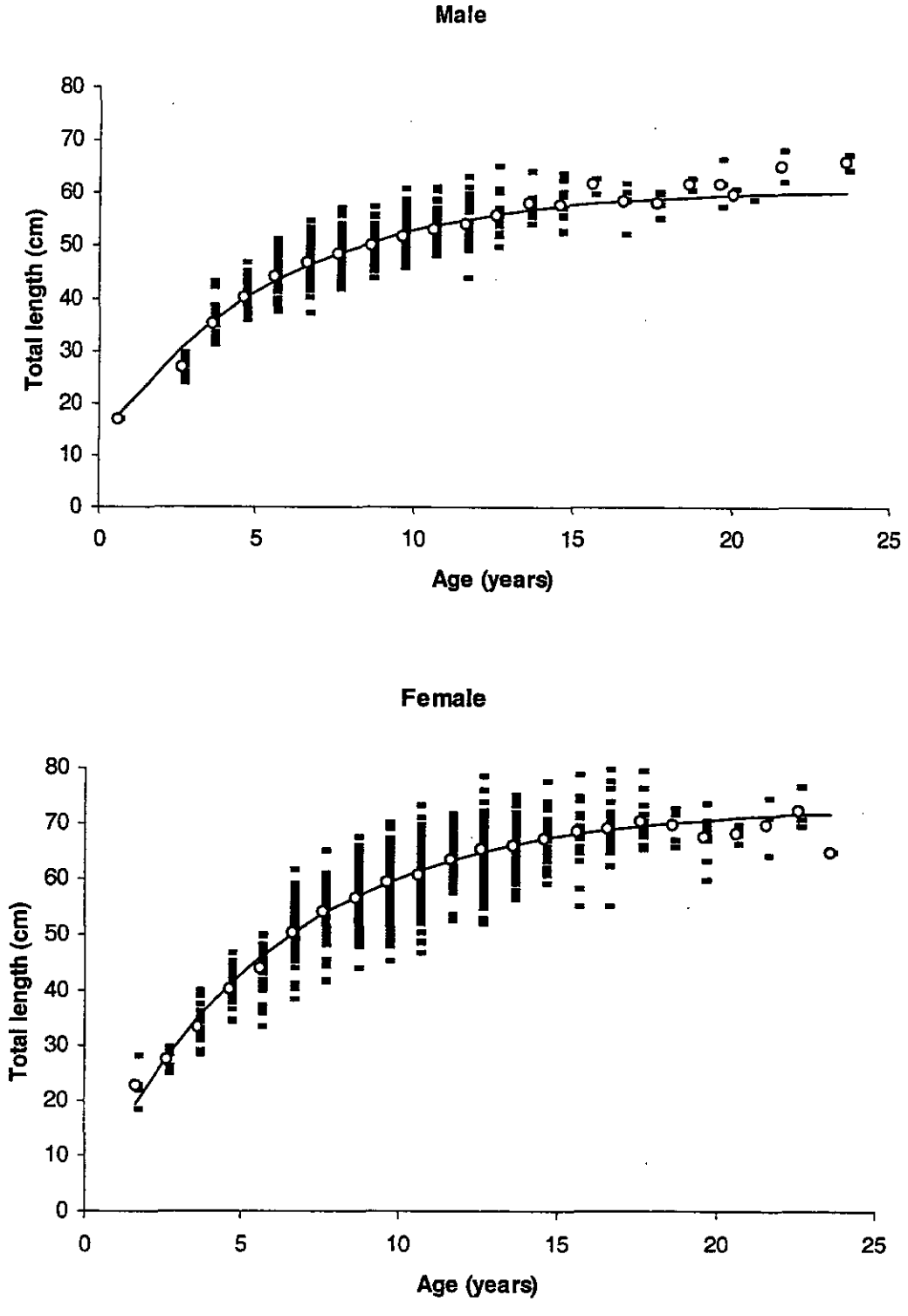

Figure 2: Age-length data, calculated mean lengths-at-age (o), and von Bertalanffy growth curves for male and female giant stargazer sampled from Southland during 1993, 1994, 1995, and 1996.

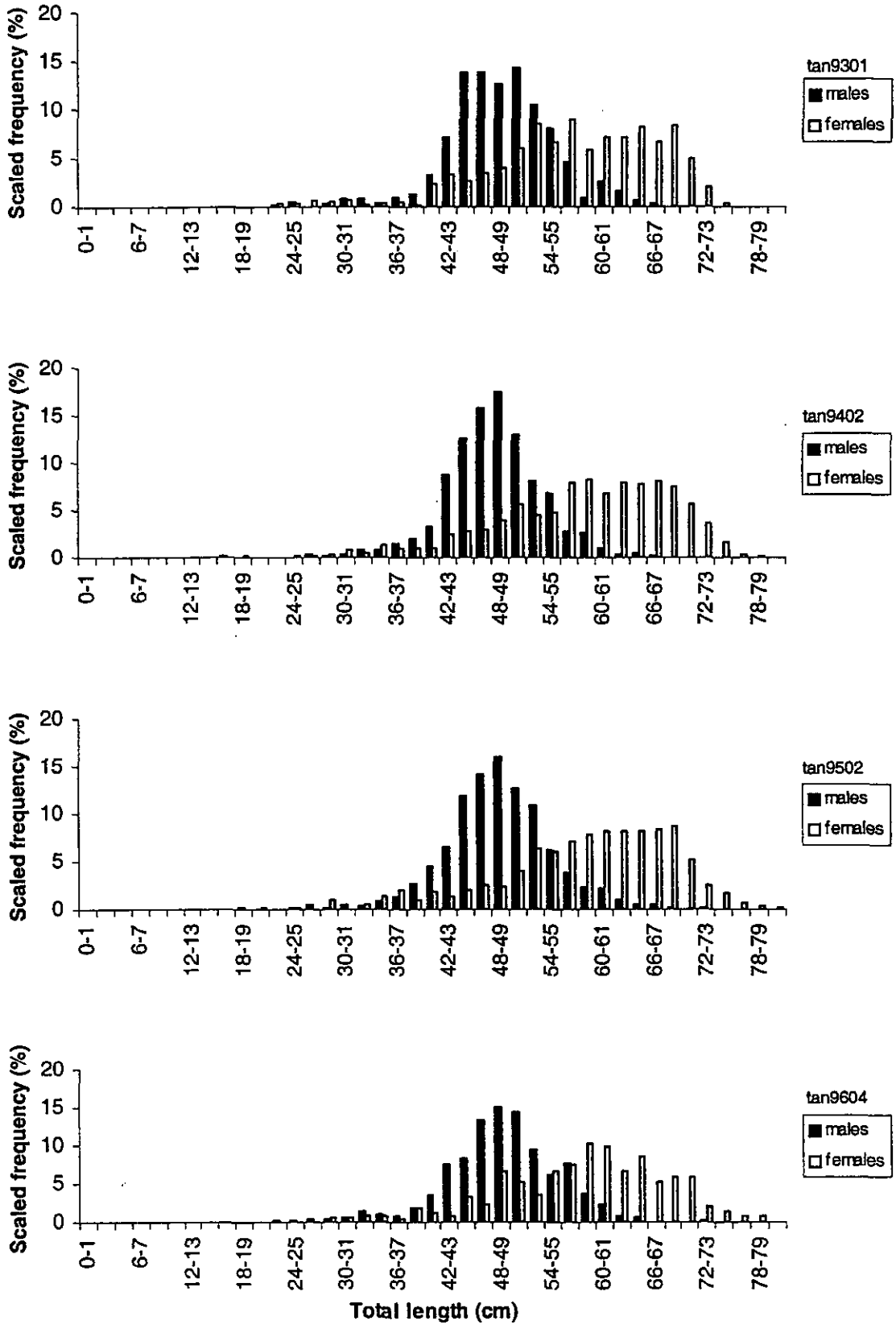

Figure 3: Scaled length-frequencies for giant stargazer surveyed from Southland between 1993 and 1996.

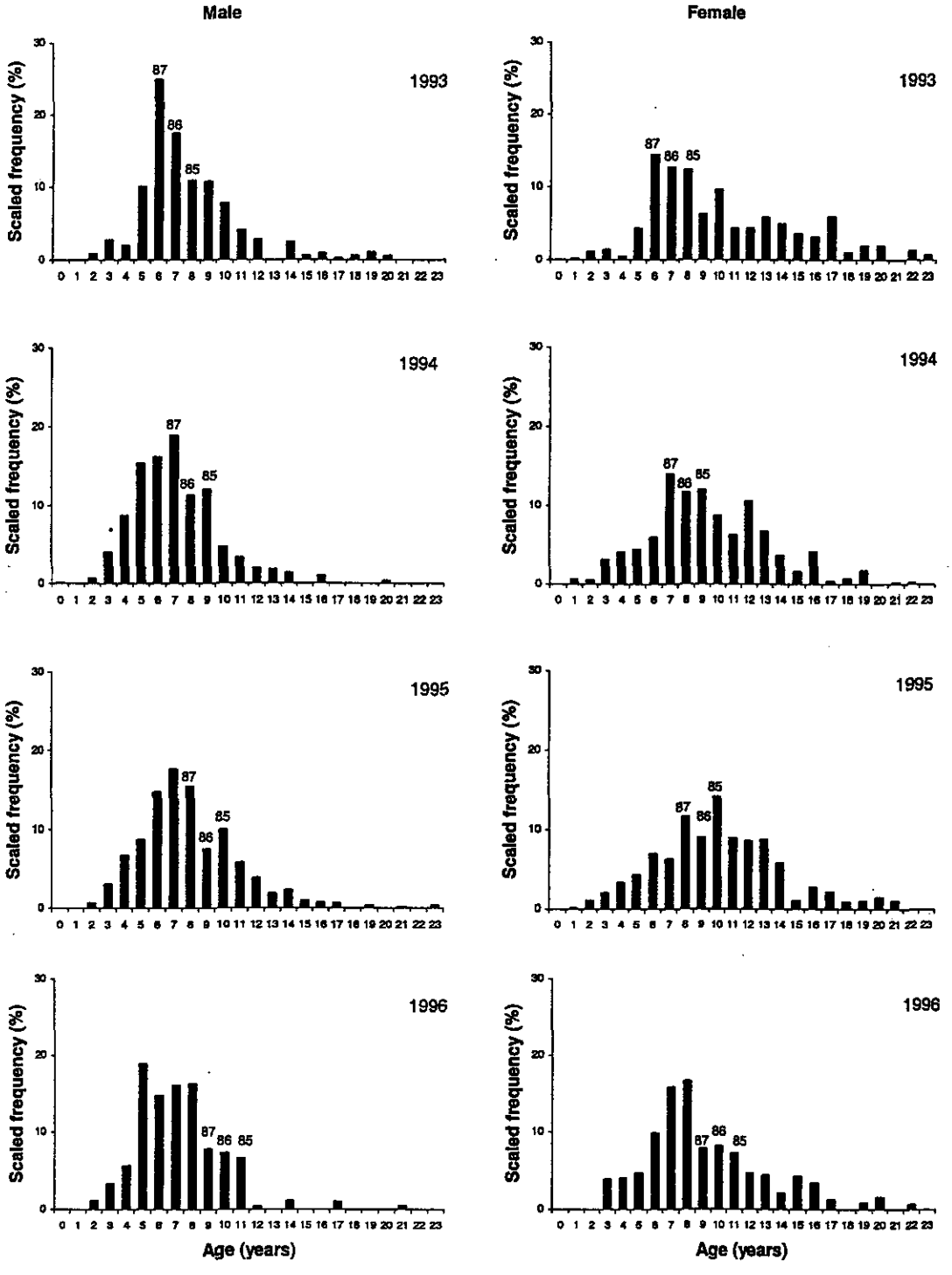

Figure 4: Scaled age frequency histograms for male and female giant stargazer sampled from Southland between 1993 and 1996.