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# Ageing methodology, growth parameters, and estimates of mortality for giant stargazer (*Kathetostoma giganteum*) from the east and south coasts of the South Island

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# Ageing methodology, growth parameters, and estimates of mortality for giant stargazer (*Kathetostoma giganteum*) from the east and south coasts of the South Island

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**New Zealand Fisheries Assessment Research Document 99/15. 19 p.**

## 1. EXECUTIVE SUMMARY

Giant stargazer are aged by counting zones in sectioned otoliths. Von Bertalanffy growth parameters are estimated for giant stargazer sampled from the east and south coasts of the South Island. Fish growth is rapid for about the first 8 years, and is negligible after about 12 years. Females have a significantly faster growth rate and reach a greater maximum length than males. Differences in growth parameters between fish from the east and south coasts of the South Island were not significant at the 95% level of confidence. However, differences in population age distributions were notable suggesting that there may be separate stocks in these two areas. It was not possible to validate the ageing methodology by using marginal state or marginal increment analysis. However, a substantial variation in year class strength is indicated for fish from the east coast, and this supports the ageing methodology. No pattern is evident for fish sampled from the south coast. A value for $M$ of 0.23 is proposed.

## 2. INTRODUCTION

Giant stargazer (*Kathetostoma giganteum*) is the most commercially important of the five species of Uranoscopidae found in New Zealand waters. It is widely distributed, but is most abundant around the South Island, particularly to the west of Stewart Island and on the Chatham Rise.

Giant stargazer occurs over muddy or sandy substrates to depths exceeding 500 m, but is most plentiful in waters of 50–300 m (McGregor 1988).

Livingston & Berben (1986) observed *Kathetostoma giganteum* from the Chatham Rise to have maturing and running-ripe gonads in June–July, and concluded from this that the species spawns in winter.

From 1970 to 1980 annual reported landings of stargazer from the New Zealand EEZ never exceeded 750 t, and were usually below 500 t (McGregor 1988). Landings increased from 1981, peaked at 3426 t in 1990–91, and have fluctuated around 3200 t since then. A significant, but unknown, proportion of these landings is likely to have been the undescribed banded giant stargazer (*Kathetostoma* sp.), particularly in FMA 5. However, the otoliths used in this study are known to have come from *K. giganteum* only. Most of the stargazer catch is taken from the South Island in FMAs 3, 5, and 7, and is largely a bycatch of trawl fisheries targeting red cod, tarakihi, flatfish, and barracouta. Target fisheries exist for stargazer to the west of Stewart Island and on the Chatham Rise (Annala *et al.* 1998).

This paper presents the only ageing work undertaken for any Uranoscopidae species.

Accurate ageing of individual members of a fishstock is fundamental to yield estimation. The present study aimed to develop a validated ageing methodology for giant stargazer. Growth parameters for east coast, South Island (ECSI) and south coast, South Island (SCSI) giant stargazer are presented for the first time. Length and age-frequency distributions were calculated and instantaneous natural mortality rates were estimated.

## 3. METHODS

### 3.1 Initial approach to ageing giant stargazer

Initially, growth checks in giant stargazer otoliths appeared difficult to interpret. In particular, the first year's growth comprised a number of inconsistently spaced bands making interpretation difficult. Furthermore, only the dorsal axis provided reliable age estimates as the growth bands were irregular on the ventral axis, particularly in fish older than about age 5. Therefore, checks in dorsal spines were examined. While these spines showed a clear regular banding pattern, it is probable that degradation of the outer surface, particularly at the spine tip, would have lead to fish being under-aged. This conclusion is supported by the small sample of fish aged using both otoliths and spines inwhich more zone counts were made in the otoliths.

Further examination of otoliths extracted from fish representing a wide length range showed that it was possible to interpret regular checks and that otoliths could be used to obtain age estimates.

### 3.2 Otolith collection, preparation, and reading

Giant stargazer otoliths (sagittae) and length-frequency data were collected during trawl surveys conducted by R.V. *Kaharoa* off ECSI during May–June 1992, 1993, 1994, and 1996, and during December 1996. Otoliths and length-frequency data were also collected by R.V. *Tangaroa* off SCSI 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.

In preparation for reading, otoliths were baked in an oven until amber-coloured (275 °C for about 4 min), embedded in clear epoxy resin (Araldite K142), and cut transversely through the nuclear region with a revolving diamond-edged saw. The cut surface of the resin block was sanded with P1200 carborundum and coated in paraffin oil. Otoliths were then examined under a binocular microscope (x25) illuminated by reflected light at an incident angle of about 30°. A pattern of hyaline (dark) and opaque (light) brown zones was evident. The number of complete hyaline zones (i.e., hyaline zones with opaque material outside them) was counted. For young fish (35 cm or shorter) whole otoliths were read as they produced clearer zones than the sectioned preparations. Fish length and sex were always unknown to the otolith reader, but there was no distinguishable differences between otoliths collected from male and female fish. Otoliths collected from the five ECSI ($n$ = 1032) and four SCSI ($n$ = 522) surveys were aged.

Determining the age of giant stargazer was not straightforward with the most difficult aspect being the interpretation of the first years growth. However, by examining otoliths of small fish (16–20 cm) believed to be about age 1+ (from length frequency data) it was possible to detect where the first "annual" band was deposited (Figure 1).

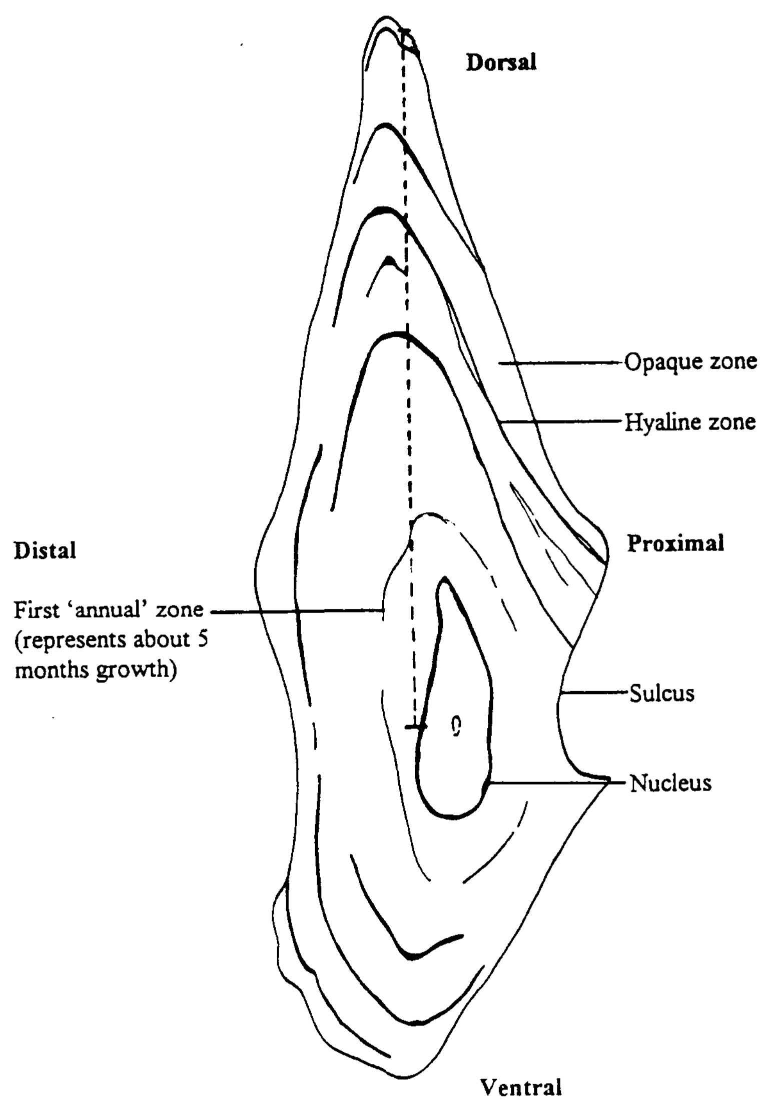


**Figure 1: Generalised dorso–ventral cross–section of a giant stargazer otolith from an age class 5+ fish. The dashed line denotes the readable axis.**

Subsequent years were then estimated by counting regular hyaline zones along the dorsal axis of the otolith. This axis was the only readable one as after about age 5 material appears to be deposited mainly dorsally. Zones on both sides of the prepared section were examined, and a count from the clearest side was recorded.

Counting growth rings in otoliths is subjective; two readings of a single otolith often produce different results. To assess the "within-reader" variability of the results, 100 otoliths representing a range of ages and both sexes were read twice by the author. First and second readings were made 1 month apart. "Between-reader" variability was assessed by having another worker read a sample of 99 otoliths.

### 3.3 Validation

To convert otolith zone counts to age estimates, it is necessary to determine how frequently, and when, hyaline and opaque bands are deposited. Validation of the ageing technique was undertaken using two methods.

(a) Marginal state analysis – otoliths sampled from SCSI by Ministry of Fisheries Observers at regular intervals throughout a year were examined to determine whether the margin was hyaline (dark) or opaque (light). It was expected that if one zone was being deposited annually, then most otoliths examined from the same period of the year would have the same marginal state. For example, during winter, fish growth rates are slower than in summer and therefore growth checks are deposited closer together. This is reflected by the formation of a hyaline band.

(b) Marginal increment analysis – otoliths used for the marginal state analysis were also examined to determine whether the outer margin became increasingly larger as the year progressed. This was achieved by measuring the distance between the outer margin and the ultimate ring, and the distance between the ultimate and penultimate rings. The proportion of the outer zone width to the inner was then calculated as a decimal fraction. This method aimed to illustrated a consistent increase in the width of the outer zone as the year progressed.

These two techniques are dependent on obtaining enough otoliths (representing a wide spread of age classes) from successive months. These methods could not be used for ECSI stargazer as most data for this area have been collected during *Kaharoa* trawl surveys in May–June.

Therefore, scaled length and age frequency data were used to examine modal progressions. The presence of consistent strong and weak year classes, both between years from the same sex, and between sexes in the same year, would support the ageing methodology.

### 3.4 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;

(iii) when sampling was conducted.

Giant stargazer have an annual reproductive cycle with a winter spawning season (Annala *et al.* 1998), so it was appropriate to select a "birthday" of 1 July for all the fish examined in this study.

Generally, fish sampled from SCSI in January–February by *R . V. Tangaroa* showed a thin opaque margin. Based on the width of completed opaque zones, in otoliths with clear margins, 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 5 months old on the completion of the first hyaline 'annual' zone.

All sampling from ECSI was conducted between May and June (except for the 1996 summer survey in December) and between January and February on SCSI. Sampling dates of 1 June and 1 December were used for ECSI, while 1 February was used for SCSI.

The information on time of spawning, time of zone formation, and sampling time can then be used to obtain an appropriate age from otolith zone counts. For example, an otolith sampled on 1 June, with opaque material outside one complete hyaline zone would be allocated an age of 1 year and 11 months (1.9 years). This is because the time elapsed between completion of the hyaline zone (1 November) and time of sampling (7 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). Separate equations, standard errors, and mean lengths at age were calculated for each sex.

The standard errors were estimated using a resampling technique. This technique involved selecting a sample (with replacement) of the same size as the original sample. The Von Bertalanffy growth parameters were then estimated for this sample. This process was repeated 1000 times. The standard error of the estimates was calculated from the standard deviation of the values in 1000 replicates.

Length-frequency histograms from research trawl surveys often show clear modes in young fish, suggesting distinct year classes. The length distribution of giant stargazer sampled from ECSI during 1991, 1992, 1993, 1994, and 1996, and from the SCSI during 1993, 1994, 1995, and 1996 were constructed.

Age distributions of stargazer in each of the five *Kaharoa* surveys during 1992, 1993, 1994, and 1996, and for males only, in the four *Tangaroa* surveys during 1993, 1994, 1995, and 1996 were constructed from the length-frequency distributions (scaled to represent the whole population in the survey areas) and the otoliths read, from:

$$A_t = \sum_{x=1}^{n} L_x \, p_{tx}$$

where

$A_t$ = estimated proportion of fish of age class $t$ in the survey area
$L_x$ = proportion of fish of length $x$ in the length frequency distribution
$p_{tx}$ = proportion of aged fish of length $x$ which were age $t$
$n$ = number of length classes in the length-frequency

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 limited age data available, particularly for some of the smaller and larger length classes, may have caused atypical age-at-length data to be over emphasised in the analysis.

In the current work, the trawl survey analysis program used to generate scaled length frequency data has provided slightly different biomass estimates from those outlined in *New Zealand Fisheries Data Reports*. This is because trawl doorspread has been estimated using Scanmar and this method has been introduced on R .V. *Kaharoa* only recently.

Estimates of instantaneous natural mortality ($M$) were calculated for both male and female fish. $M$ was derived from the equation:

$$M = \frac{\ln(100)}{A_{max}}$$

where

$A_{max}$ = maximum age reached by 1% of an unfished population (Sparre *et al.* 1989).

## 4. RESULTS

### 4.1 Age replication

The results of the within-reader comparison show that of the 100 otoliths examined 85 were aged identically, and all but 3 of the remaining 15 differed by only 1 year (Table 1). Futhermore, no systematic bias was detected in the results, and ageing error appeared to be negligible over the aggregated age range.

**Table 1: Within-reader comparison of 100 otoliths. Age: represents age at first reading; Difference (Diff): represents the extent by which the second reading differed from the first; Agree: shows the percentage of fish by age for which both readings were the same**

| | Age | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diff | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 13 | Total |
| 2+ | | | | | | | 1 | | | | 1 |
| 1+ | | | 1 | 2 | 1 | 1 | 2 | 1 | | | 8 |
| 0 | 15 | 20 | 6 | 23 | 7 | 7 | 4 | 2 | | 1 | 85 |
| 1- | | | | 1 | | | 1 | 1 | 1 | | 4 |
| 2- | | | | | 1 | | | | | 1 | 2 |
| Agree (%) | 100 | 100 | 85 | 88 | 77 | 87 | 50 | 50 | 0 | 50 | 100 |

The results of the between–reader comparison show that of the 99 otoliths examined 71 were aged identically, and all but 5 of the remaining 28 differed by only 1 year (Table 2). Ageing error appeared to be negligible over the aggregated age range.

**Table 2: Between-reader comparison of 99 otoliths. Age: represents age at first reading; Difference (Diff): represents the extent by which the second reading differed from the first; Agree: shows the percentage of fish by age for which both readings were the same**

| | Age | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Diff | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 3+ | | | | | | | | | 1 | |
| 2+ | | | | | | | | | | |
| 1+ | | | | | | | 2 | | 1 | 3 |
| 0 | 1 | 1 | 6 | 4 | 5 | 11 | 8 | 14 | 5 | 9 |
| 1- | | | | | | 2 | 1 | 1 | | 1 |
| 2- | | | | | | | | | | |
| Agree (%) | 100 | 100 | 100 | 100 | 100 | 85 | 73 | 93 | 71 | 69 |

| | Age | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Diff | 10 | 11 | 12 | 13 | 14 | 15 | 17 | Total |
| 3+ | | | | | | | | 1 |
| 2+ | | | 2 | | | | 1 | 3 |
| 1+ | | | 2 | 1 | 3 | 2 | | 13 |
| 0 | 2 | 4 | | 1 | | | | 71 |
| 1- | | 1 | | | | 3 | | 10 |
| 2- | | 1 | | | | | | 1 |
| Agree (%) | 100 | 67 | 0 | 50 | 0 | 0 | 0 | 99 |

### 4.2 Validation of ageing interpretation

The results of the marginal state analysis and marginal increment analysis are presented in Figures 2 and 3. It is unclear why these results are inconclusive, however, difficulties in obtaining enough otoliths (representing a wide spread of age classes) from successive months is a probable factor. Furthermore, the marginal interpretation was highly subjective because it was often difficult to determine whether an otoliths margins was opaque or hyaline – it may be opaque in one region of the margin and hyaline in another area.

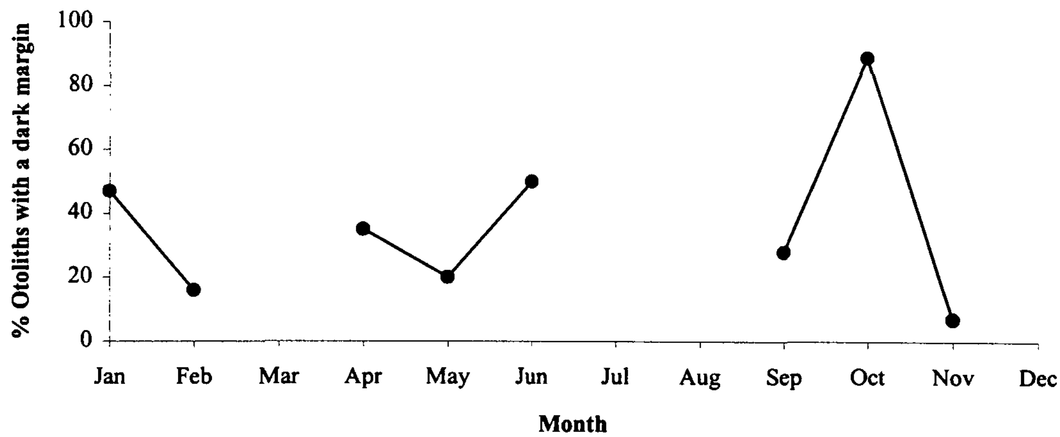


**Figure 2. Results of the marginal state analysis.**

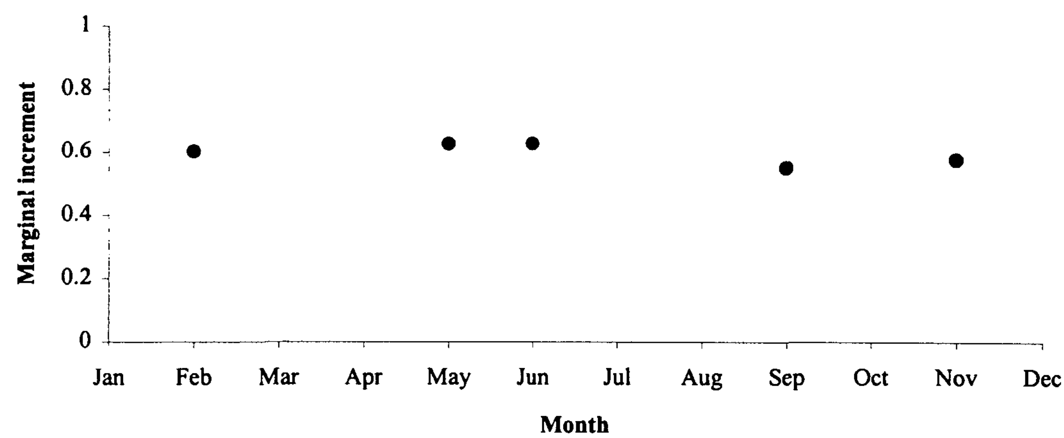


**Figure 3. Results of the marginal increment analysis.**

### 4.3 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 fish from the east and south coasts of the South Island (Table 3). The raw data, mean lengths-at-age, and calculated von Bertalanffy curves are plotted in Figure 4.

**Table 3: Von Bertalanffy growth parameters (with 95% confidence intervals) for giant stargazer sampled from the east and south coasts of the South Island**

| | East coast | | South coast | |
|---|---|---|---|---|
| | Male | Female | Male | Female |
| $L_\infty$ | 61.49 | 78.11 | 59.12 | 73.92 |
| | (58.82–64.33) | (72.71–83.84) | (58.18–61.16) | (69.16–79.00) |
| $k$ | 0.20 | 0.14 | 0.19 | 0.18 |
| | (0.18–0.22) | (0.12–0.16) | (0.17–0.21) | (0.14–0.23) |
| $t_0$ | –0.97 | –1.25 | –1.19 | –0.22 |
| | (–1.15 to –0.80) | (–1.48 to 1.03) | (–1.79 to –0.82) | (–0.85 to 0.51) |
| Age range | 0–22 | 0–20 | 0–18 | 0–20 |
| $n$ | 530 | 502 | 384 | 138 |

Male giant stargazer sampled from ECSI and SCSI reached a maximum age of 22 years and 18 years, respectively. However, only about 5% of ECSI fish reached an age greater than 8 years, whereas 13+ years was attained by 5% of SCSI fish. Females were aged to a maximum of 20 years in both areas, but less than 5% of fish from the ECSI and SCSI were older than 10 and 13 years, respectively.

In both areas females appeared to be larger than males at corresponding ages from about 3 years old and had significantly greater $L_\infty$ values. In contrast, the difference in $L_\infty$, $k$, and $t_0$ between the ECSI and SCSI was not significant at the 95% level of confidence.

Male and female fish demonstrated rapid initial growth for about the first 8 years, but growth was negligible after about 12 years.

Previously, it was considered that giant stargazer reach sexual maturity at age 3 years, and at a length of 45–50 cm total length (TL) (Annala *et al.* 1998). However, this work shows that fish are likely to be between 4 and 7 years old before reaching sexual maturity at 45–50 cm.

There was considerable overlap in the age-at-length data from about 4 years of age for both sexes and areas. 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 4 fit these data reasonably well.

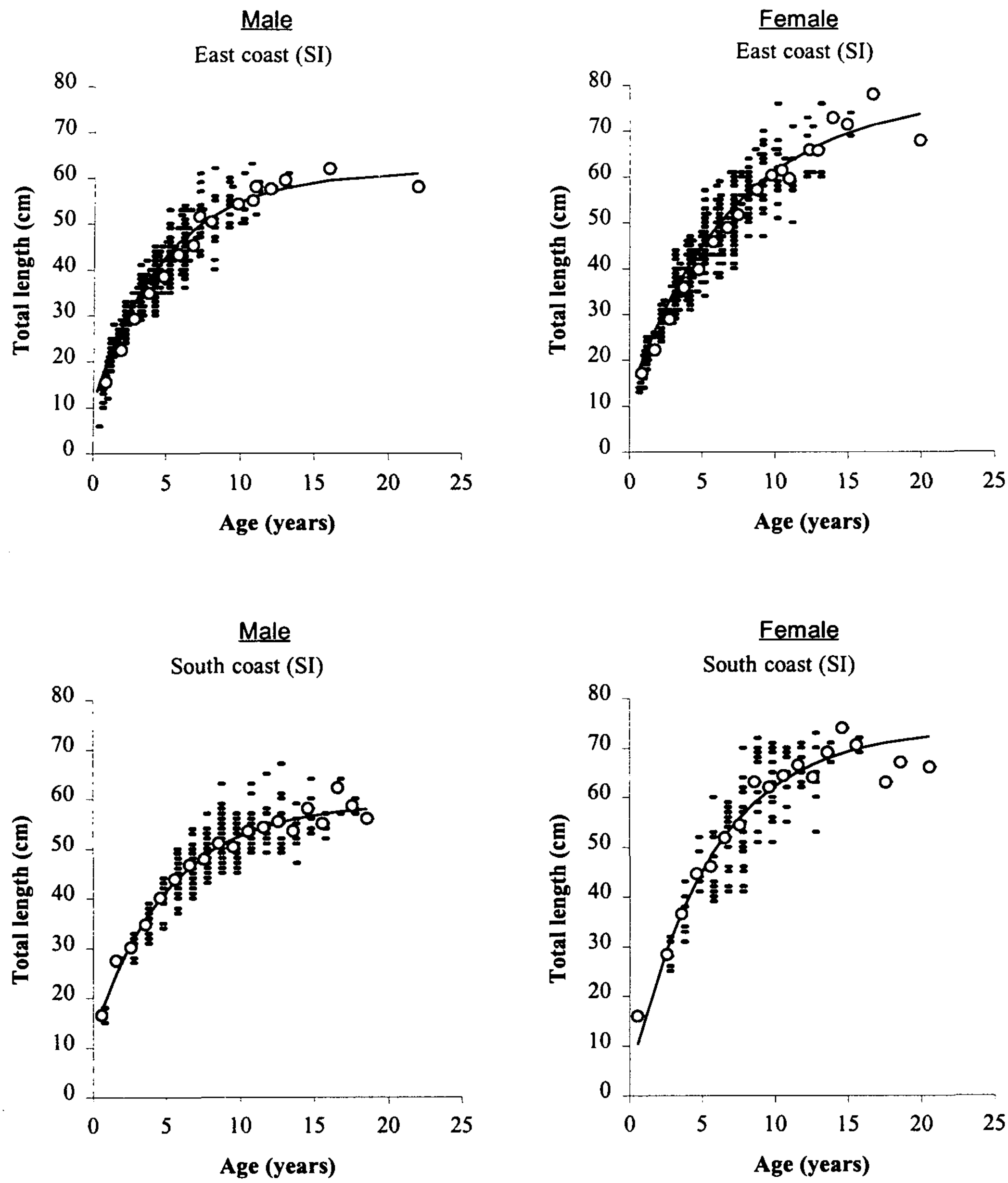


**Figure 4: Age–length data, calculated mean lengths–at–age (o), and von Bertalanffy growth curves for male and female giant stargazer sampled from the east and south coasts of the South Island.**

**Table 4: Mean lengths at age (cm, with standard deviation, S.D., and sample size, *n*) for fish sampled from the east and south coasts of the South Island, respectively.**

| | East coast | | | | | | South coast | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | | Female | | | Male | | | Female | | |
| Age class | Mean | S.D. | N | Mean | S.D. | N | Mean | S.D. | N | Mean | S.D. | N |
| 0+ | 15.6 | 3.4 | 27 | 17.1 | 2.6 | 18 | 16.5 | 2.1 | 2 | 16.0 | – | 1 |
| 1+ | 22.4 | 3.4 | 55 | 22.2 | 2.5 | 28 | 27.5 | 0.7 | 2 | – | – | 0 |
| 2+ | 29.3 | 3.1 | 45 | 28.9 | 2.5 | 44 | 30.2 | 2.6 | 5 | 28.4 | 3.1 | 5 |
| 3+ | 34.8 | 2.8 | 105 | 35.8 | 3.6 | 85 | 34.8 | 2.6 | 14 | 36.5 | 4.6 | 6 |
| 4+ | 38.5 | 3.2 | 119 | 39.8 | 4.2 | 75 | 40.1 | 2.3 | 24 | 44.6 | 3.7 | 9 |
| 5+ | 43.2 | 4.0 | 64 | 45.8 | 5.1 | 59 | 43.8 | 3.4 | 43 | 46.0 | 6.6 | 11 |
| 6+ | 45.2 | 3.8 | 55 | 48.9 | 4.4 | 70 | 46.8 | 3.2 | 60 | 51.8 | 5.6 | 20 |
| 7+ | 51.7 | 5.0 | 17 | 51.7 | 5.8 | 38 | 47.8 | 3.3 | 53 | 54.4 | 6.8 | 26 |
| 8+ | 50.4 | 6.0 | 13 | 57.1 | 4.9 | 28 | 51.0 | 4.0 | 59 | 63.1 | 6.8 | 13 |
| 9+ | 54.3 | 3.8 | 14 | 60.3 | 6.3 | 17 | 50.3 | 3.1 | 35 | 62.1 | 6.4 | 16 |
| 10+ | 55.0 | 5.6 | 6 | 61.5 | 6.0 | 17 | 53.4 | 4.0 | 32 | 64.4 | 5.5 | 8 |
| 11+ | 58.0 | 0.8 | 4 | 59.6 | 6.5 | 7 | 54.2 | 4.3 | 13 | 66.5 | 3.3 | 8 |
| 12+ | 57.5 | 0.7 | 2 | 65.9 | 5.3 | 7 | 55.4 | 5.0 | 13 | 64.0 | 7.2 | 6 |
| 13+ | 59.5 | 2.1 | 2 | 65.8 | 7.3 | 4 | 53.5 | 3.7 | 8 | 69.0 | 2.0 | 3 |
| 14+ | – | – | 0 | 73.0 | – | 1 | 58.0 | 4.3 | 9 | 74.0 | – | 1 |
| 15+ | – | – | 0 | 71.5 | 3.5 | 2 | 55.0 | 2.1 | 5 | 70.5 | 2.1 | 2 |
| 16+ | 62.0 | – | 1 | 78.0 | – | 1 | 62.3 | 3.5 | 4 | – | – | 0 |
| 17+ | – | – | 0 | – | – | 0 | 58.5 | 2.1 | 2 | 63.0 | – | 1 |
| 18+ | – | – | 0 | – | – | 0 | 56.0 | – | 1 | 67.0 | – | 1 |
| 19+ | – | – | 0 | – | – | 0 | – | – | 0 | – | – | 0 |
| 20+ | – | – | 0 | 68.0 | – | 1 | – | – | 0 | 66.0 | – | 1 |
| 21+ | – | – | 0 | – | – | 0 | – | – | 0 | – | – | 0 |
| 22+ | 58.0 | – | 1 | – | – | 0 | – | – | 0 | – | – | 0 |

## 4.4 Length-frequency modal progression

Length-frequency histograms for giant stargazer caught during *Kaharoa* trawl surveys off ECSI and *Tangaroa* trawl surveys off SCSI are presented in Figures 5 and 6, respectively.

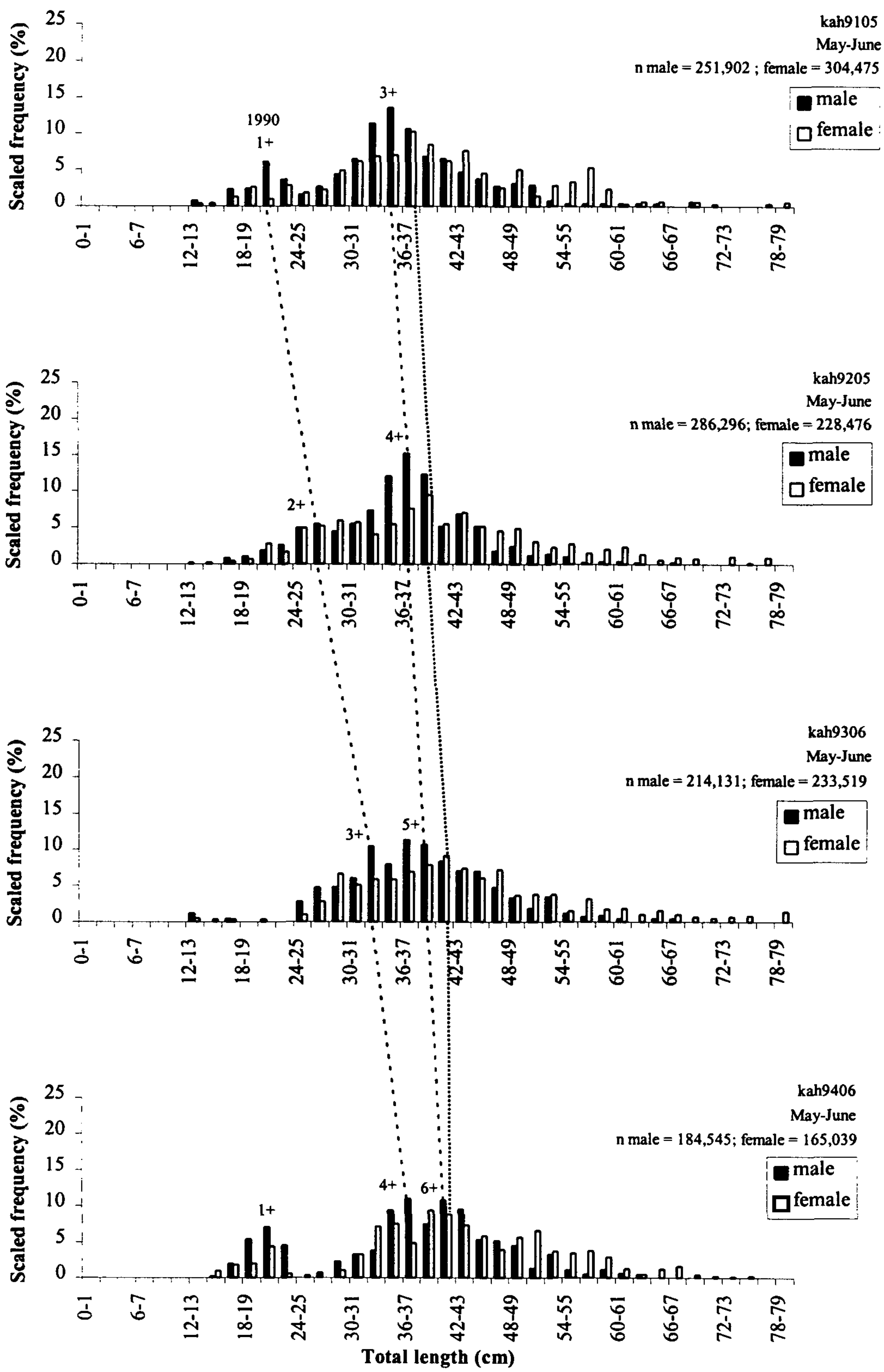


**Figure 5: Scaled length frequencies for stargazer surveyed from the ECSI. Trip code, month of trip, and scaled sample size are provided above the legend. Length frequency peaks are labelled with year of spawning and age class.**

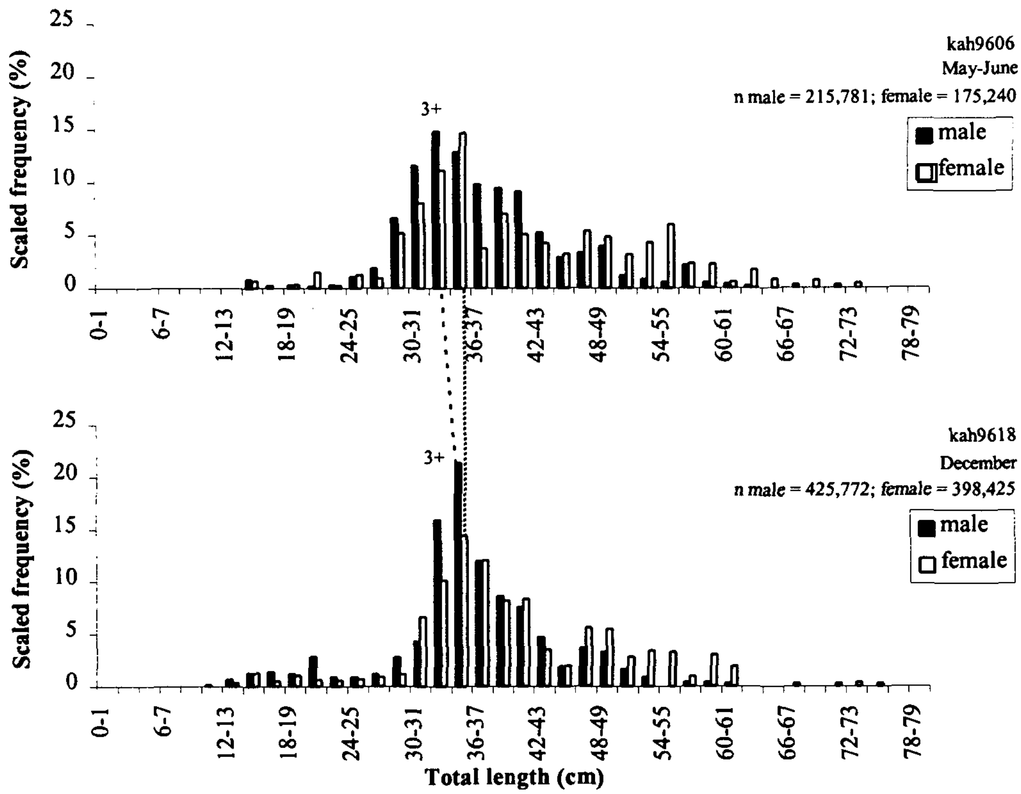


**Figure 5 (continued): Scaled length frequencies for giant stargazer surveyed from the ECSI. Trip code, month of trip, and scaled sample size are provided above the legend.**

The data have been scaled by size of catch and area trawled to represent the total population of stargazer in each survey area. For ECSI it is possible to follow the progression of the 1990 year class clearly, as 1+ fish (20–21cm TL) from 1991 through to 4+ fish (36–37cm TL) in 1994. Similarly, in 1994 a modal peak for fish 18–23cm TL (aged 1+) progresses as a strong representation of fish 32–35cm TL (aged 3+) in 1996. Using scaled age frequency histograms it is also possible to detect a relatively strong 3+ year class (33–37cm TL) in 1991 which progresses through to 6+ fish in 1994. These data indicate that giant stargazer grow to about 21 cm after year 1+, to 28 cm a year later, to 34 cm at age 3+, and 37cm by age 4+.

In contrast, the SCSI samples show consistent length-frequency distributions from 1993 to 1996, so individual age classes cannot be followed through (see Figure 4). This is mainly because most fish are older than age 5, by which time the length frequency modes of individual cohorts have merged.

## 4.5 Age-frequency *distribution*

Scaled age-frequency histograms are presented for male and female giant stargazer sampled off the ECSI between 1992 and 1996 (Figure 7) and for males only, sampled off the SCSI between 1993 and 1996 (Figure 8). There was a relatively strong 4+ year class on the east coast in 1992 for both male and female fish which progressed as strong 5+ and 6+ cohorts in 1993 and 1994, respectively (Figure 7).

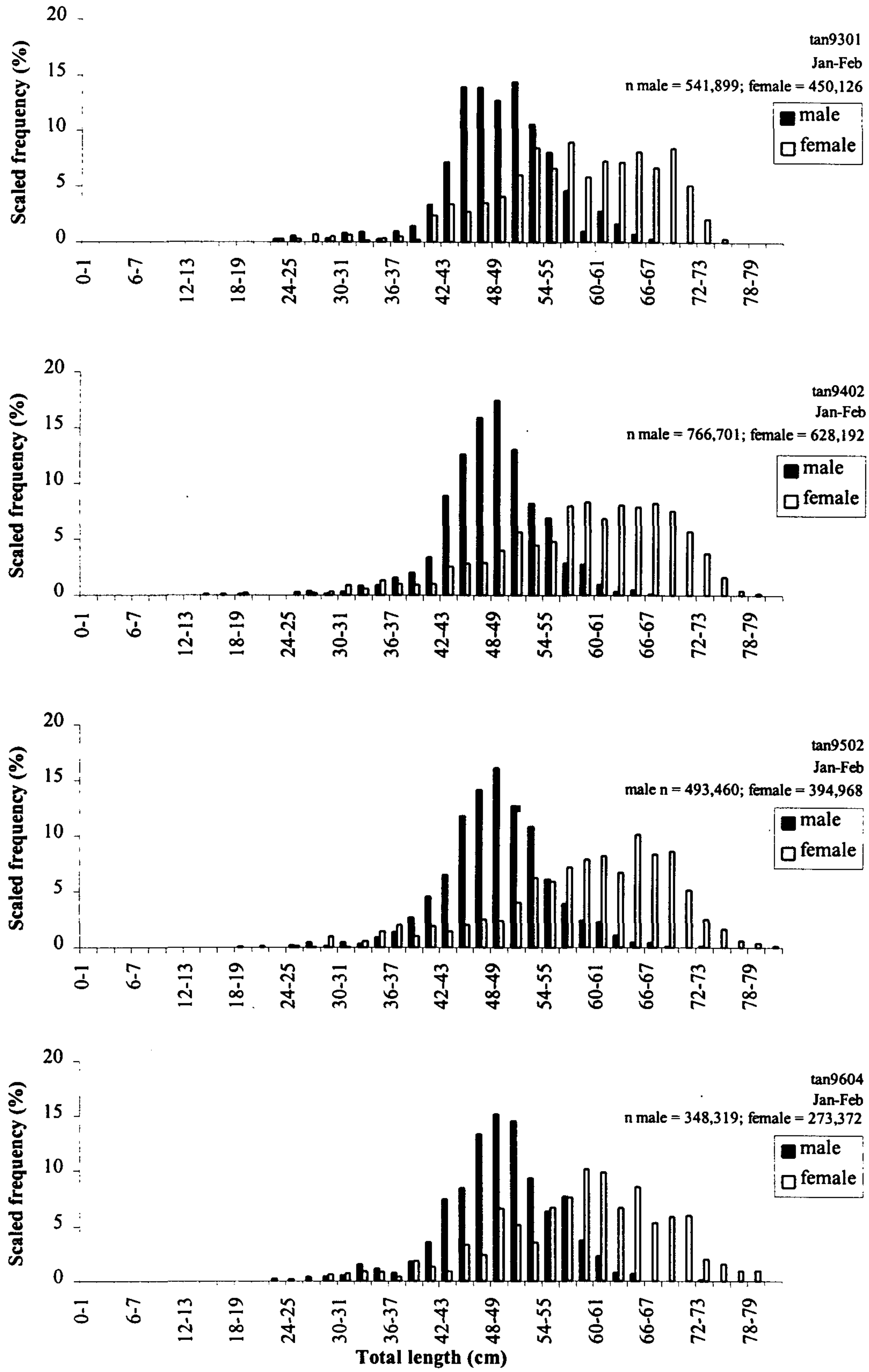


**Figure 6: Scaled length–frequencies for giant stargazer surveyed from the SCSI. Trip code, month of trip, and scaled sample size are provided above the legend.**

The 2+ year class progressed as strong 3+ and 4+ cohorts in the following two years. In 1994 the 1+ year class was well represented for male and female fish which is consistent with a modal peak in the 1994 length frequency histogram for fish between 18–21cm (see Figure 5). This strong 1+ year class appeared as a strong 3+ cohort in all the 1996 samples. Similarly, the strong 4+ year class evident in 1994 progressed as a well represented 6+ cohort in 1996, particularly for female fish.

Some minor discrepancies exist in the ECSI histograms, for example, 5+ females are well represented in 1992, but they do not progress as strong 6+ and 7+ cohorts over the following two years. Furthermore, in 1992 males do not show the same strong 5+ year class which is evident for females. However, length frequency modes are generally consistent with age frequency modes in all ECSI samples.

The SCSI males do not show any clear modal progression (see Figure 8), and this is consistent with the absence of a trend in the length frequency data (see Figure 6).

### 4.6 Instantaneous natural mortality rates

The ECSI samples aged suggest an $A_{max}$ of about 22 years for male and 20 years for female giant stargazer giving estimates for $M$ of 0.21 and 0.23, respectively. SCSI samples indicate an $A_{max}$ of about 18 years for males and 20 years for females, giving estimates for $M$ of 0.26 and 0.23, respectively. These samples were not from virgin populations, so $M$ may be slightly overestimated. It is likely that $M$ is in the range 0.21–0.26, and 0.23 is probably a satisfactory estimate at this stage.

## 5. DISCUSSION

This is the first study dealing directly with giant stargazer age and growth in New Zealand waters.

The present work indicates that growth rate is initially rapid but slows dramatically after the first 8 years, and is negligible after about 12 years. For both the ECSI and SCSI, that female giant stargazer are, on average, larger than males at corresponding ages (after age 3) and have a significantly greater $L_{\infty}$. Differences in stargazer growth rates between these two areas are not statistically significant.

Validation of the ageing methodology was attempted using marginal state and marginal increment analysis. Unfortunately, the results were inconclusive – possibly because for many of the otoliths it was difficult to interpret where the margin began. In some samples it was also difficult to determine whether the margin was opaque or hyaline.

The current study proposes a validated ageing methodology (to age 6) by examining scaled length and age frequency data to show modal progressions. However, it is logical to assume that if hyaline zones are formed annually up to age 6, then this will continue throughout life. Validation was achieved initially by studying length frequency histograms (see Figure 6) and age frequency histograms (see Figure 8) for SCSI males only. However, no trends were evident and it was apparent from the length frequency data that small fish (35 cm or less), which are most likely to show modal progressions (as growth is more consistent during the first 3–4 years) are poorly represented in the SCSI surveys. Furthermore, there is increasing error with increasing age which means older cohorts will tend to merge.

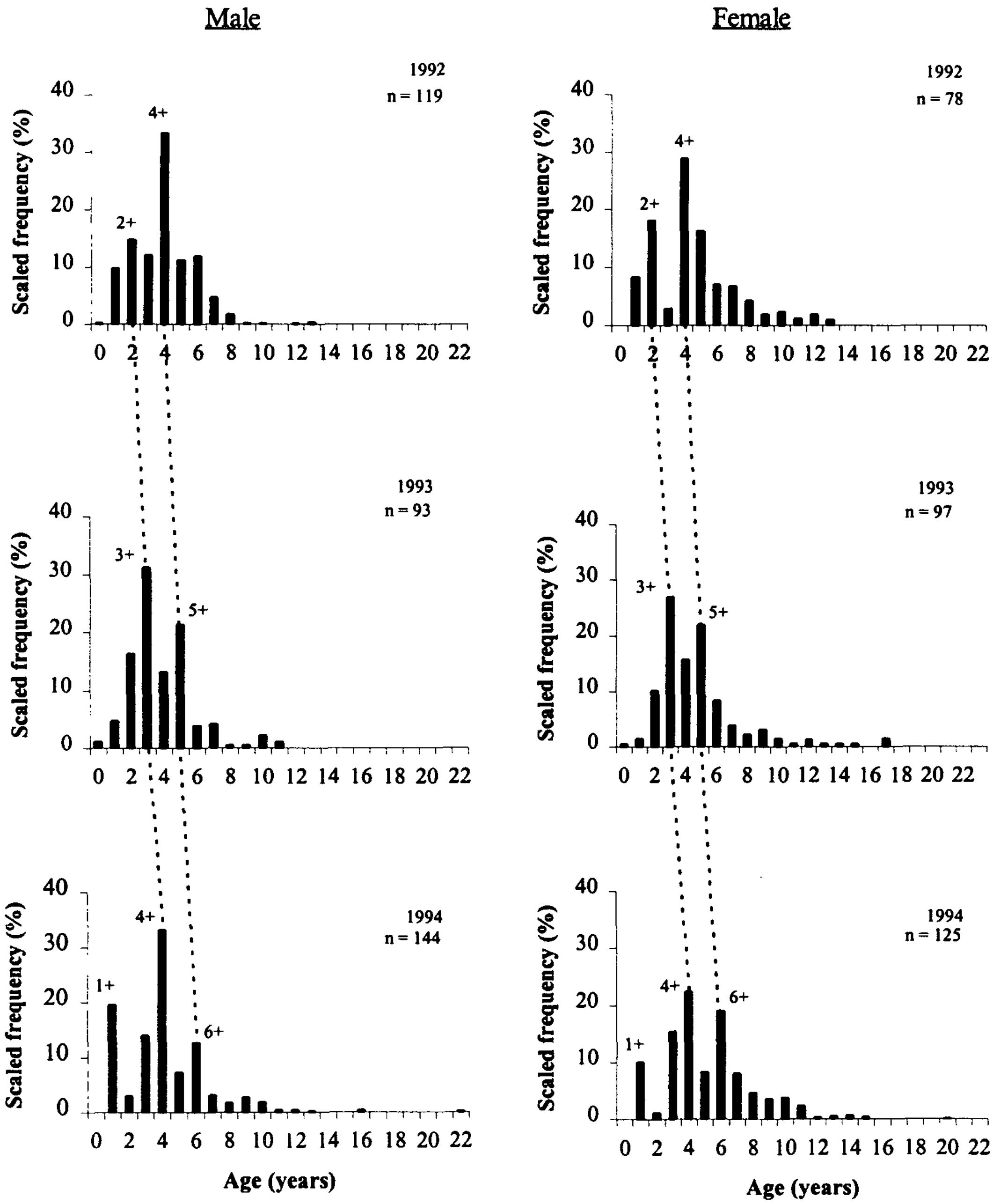


**Figure 7: Scaled age frequency histograms for male and female giant stargazer sampled from the east coast, South Island from 1992–94. Year and number of otoliths read (n) are shown on the histograms. Dashed lines represent the progression of relatively strong year classes.**

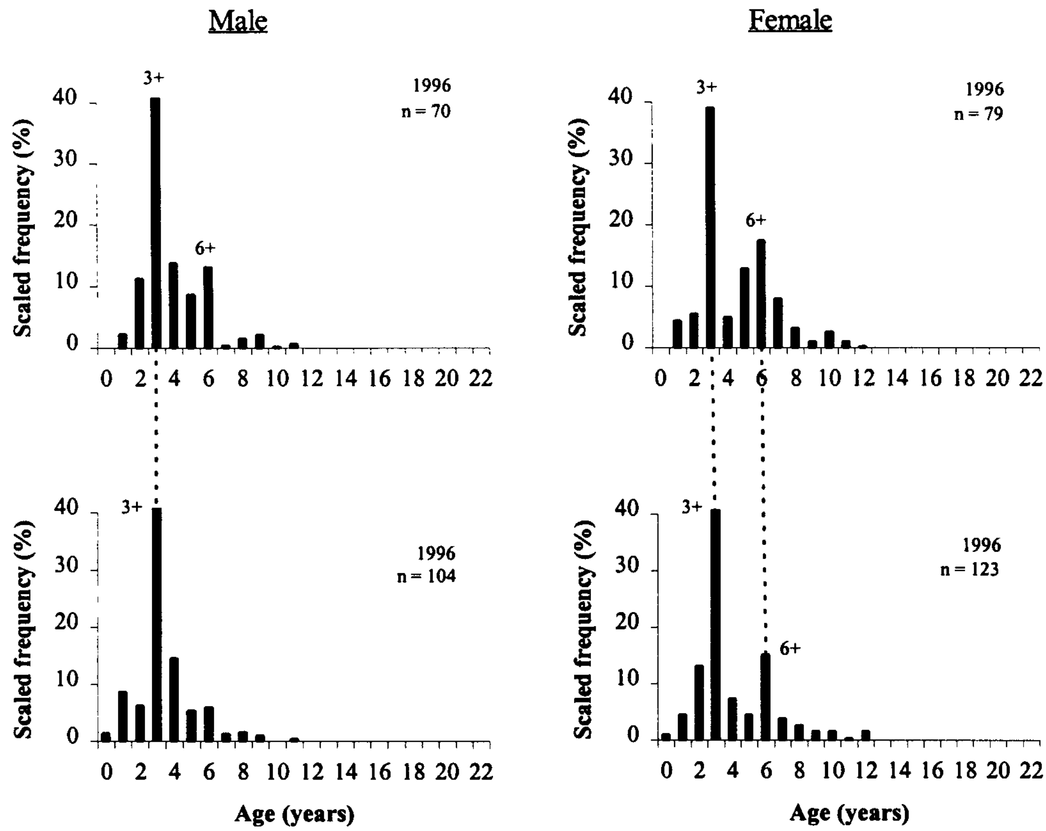


**Figure 7 (continued): Scaled age frequency histograms for male and female giant stargazer sampled from the east coast, South Island during 1996. Year and number of otoliths read (n) are shown on the histograms. Dashed lines represent the progression of relatively strong year classes.**

Given the lack of any clear cohort progression for SCSI males it was considered appropriate to focus on data from ECSI rather than studying females from SCSI. The ECSI scaled length frequency data show consistent progressions in year class strength both between years for the same sex and between sexes in the same year. This consistency strongly supports the ageing methodology. Some minor inconsistencies are evident but are probably a result of the limited sample sizes and, more particularly, ageing error.

It is unclear why giant stargazer from ECSI show clear length and age progressions whereas fish from SCSI do not. However, small fish (35 cm or less) are poorly represented in SCSI surveys. This may be because they are poorly sampled by *Tangaroa*'s trawl gear as the larger ground gear is more likely to jump over small dermersal stargazer than *Kaharoa*'s gear. Also, they maybe absent from the area. Depth is unlikely to be a feature as the depth range surveyed is generally consistent between areas.

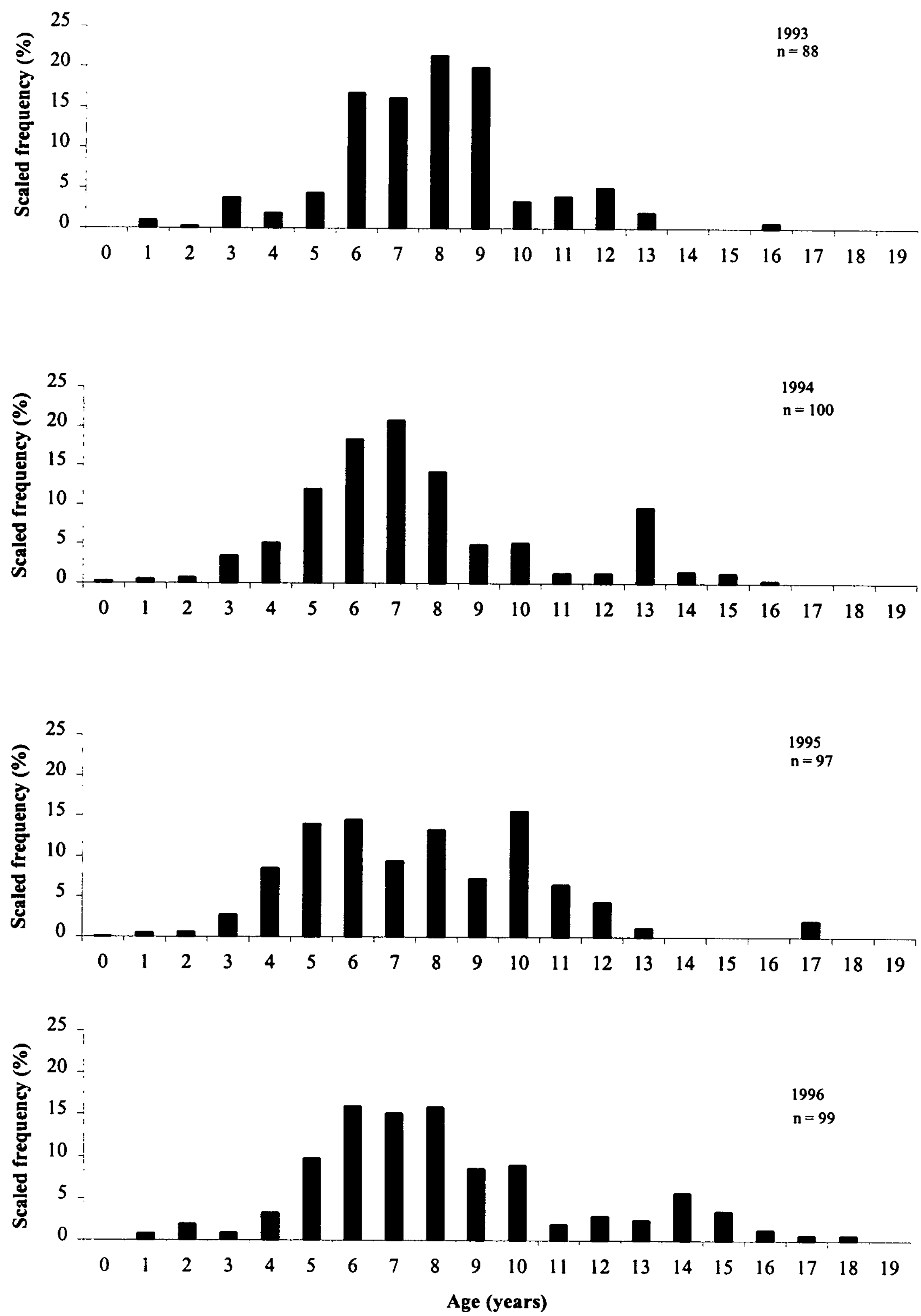


**Figure 8: Scaled age frequency histograms for male giant stargazer sampled from the south coast, South Island from 1993–96. Year and number of otoliths read (n) are shown on the histograms.**

## 6. CONCLUSIONS

A consistent and reproducible method to age giant stargazer by counting zones in sectioned otoliths has been developed. The technique was validated for fish from the ECSI using the progression of length and age modes. Growth parameters have been calculated for stargazer from FMAs 3 and 5, and while there is a significant difference between males and females in both areas the differences are not significant between area. In contrast, population age distributions between area differed notably, suggesting that the ECSI and SCSI may contain discrete stocks. An estimate for natural mortality has been derived.

## 6. ACKNOWLEDGMENTS

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## 7. REFERENCES

Annala, J.H., Sullivan, K.J., O'Brien, C.J., & Iball, S.D. (Comps.) 1998: Report from the Fishery Assessment Plenary, May 1998: stock assessments and yield estimates, 409 p. (Unpublished report held in NIWA library, Wellington).

Livingston, M. E. & Berben, P. H. 1986: Winter survey of hoki and other middle depth species, Chatham Rise, 1986. Fisheries Research Division Internal Report No. 51. 20 p. (Unpublished report held in NIWA library, Wellington).

McGregor, G. A. 1988: Stargazer. N.Z. Fisheries Assessment Research Document 88/43. 5 p.

Ralston, M. L. & Jennrich, R. I. 1978: DUD, a derivative-free algorithm for nonlinear least squares. *Technometrics 20*: 7–14.

Sparre, P., Ursin, E., & Venema, S. C. 1989: Introduction to tropical fish stock assessment. Part 1. Manual. *FAO Fisheries Technical Paper 306.* 337 p.