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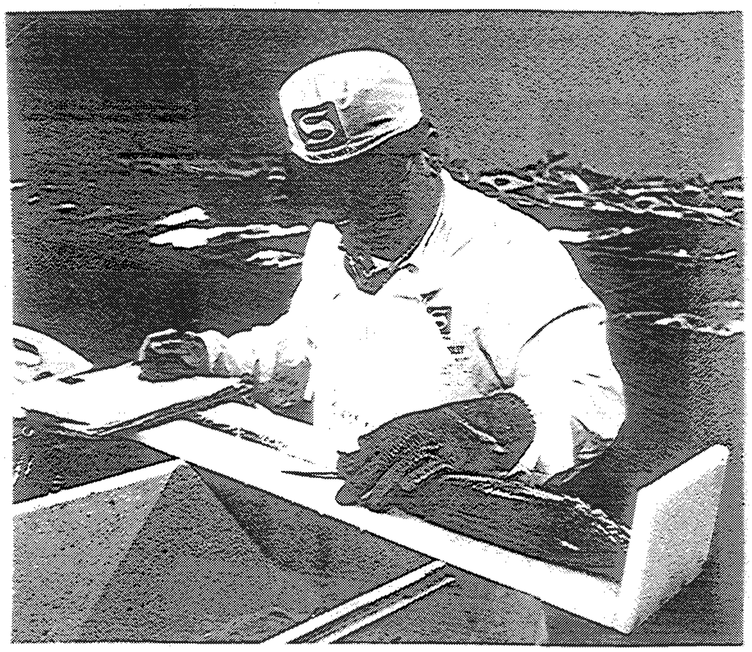

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Cover photograph of Bene Su sampling trevally inside a chiller at Sanford Ltd, Auckland, by Cameron Walsh

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Abstract

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Length frequency samples were collected from purse-seine and single trawl catches in TRE 1 and single trawl and pair trawl catches in TRE 7. These were combined with age-length keys to produce estimates of catch-at-age for respective stock-method strata. There were considerable differences in the length frequency distributions sampled from the TRE 1 and TRE 7 fisheries in the 1997–98 fishing year. The west coast single trawl fishery in particular exhibited variability in length composition with area and season. The age distributions of the TRE 1 and TRE 7 fisheries were generally broad and contained relatively similar year class strengths. Similarities in age-at-length data for both stocks has resulted in similar estimates of growth rates. However, no evidence exists that recruitment variation in either stock is similar to that in snapper. Sample size optimisation suggests that the otolith collection should be increased to achieve a mean weighted coefficient of variation below 20%.

Introduction

Trevally, *Pseudocaranx dentex,* is an important inshore finfish species commercially harvested in New Zealand, with an estimated $7 million earned in exports in 1996 (information from N.Z. Seafood Industry Council) and a Total Allowable Commercial Catch (TACC) of 3932 t. The trevally fishery has been managed under the Quota Management System (QMS) since 1986.

Trevally are both pelagic and demersal in behaviour. They are a long-lived species, growing at a moderate rate for the first few years and slowing down at the onset of sexual maturity (James 1984). The commercial trevally fishery developed in the late 1960s to early 1970s with the main methods of capture being single trawl, pair trawl, and purse-seine. These methods are still in common use today.

Trevally is caught predominantly in northern New Zealand from the quota management stocks TRE 1 and TRE 7 (Figure 1). The TACC for trevally in the 1997–98 fishing year was 1506 t in TRE 1 and 2153 t in TRE 7, which combined makes up over 90% of the national TACC. It is considered that current levels of exploitation on the TRE 1 and TRE 7 stocks are probably sustainable (Annala *et al.* 1998). However, it also recognised that regular stock monitoring is needed to ensure future sustainability. Catch sampling of the TRE 1 and TRE 7 commercial landings for length and age compositions took place intermittently from 1972 to 1978 (James 1984, unpublished data) and was resumed in the 1997–98 fishing year as part of a new stock monitoring programme. This report presents a summary of trevally market sampling data collected between October 1997 and September 1998 from TRE 1 and TRE 7 under Ministry of Fisheries contract TRE9701.

The objective of the market sampling was to conduct the sampling and determine the length and age composition of commercial catches in TRE 1 and TRE 7 during the 1997–98 fishing year from samples collected in fish sheds. The target coefficient of variation (*c.v.*) for the catch-at-age was 20% (mean weighted *c.v.* across all age classes).

Methods

Otolith preparation and ageing

Literature review

There is a paucity of data in the literature on age and growth in *Caranx* species. Most references concern growth in tropical or subtropical waters (Williams 1965, Chabanne 1972, Chen & Jiang 1990, Sudekum *et al.* 1991, Brewer *et al.* 1994), which contain the majority of *Caranx* species. The trevally, *Pseudocaranx dentex*, is an exception, with an antitropical distribution in all warm temperate waters, occurring both sides of the Atlantic, Mediterranean, Indo-Pacific east to Hawaii (Randall *et al.* 1990), and more locally in New Zealand, southern Australia, Lord Howe Island, Norfolk Island, and the Kermadec Islands (James & Stephenson 1974).

James (1984) reported extensively on otolith morphology, age determination, population biology, and the New Zealand fishery for trevally. Gauldie & Radtke (1990) examined precipitation of crystal in otoliths.

James (1984) examined several trevally hard parts and found that otoliths were most useful for age determination. The fish were aged primarily from whole otoliths which were immersed in paraffin oil or microscope immersion oil and viewed with a binocular microscope and reflected lighting or on a black background. Zone counts were generally made along the posterior region of the otolith. Otoliths from older fish (12 years or more) were often difficult to read whole, and were broken through the centre, ground, burnt with a naked flame until amber coloured, and mounted in plasticine.

By examining seasonal changes in otolith edges, juvenile length frequency modalities, and observing otoliths from a dominant cohort in subsequent years, James (1984) confirmed that opaque and hyaline zones were laid down annually.

One aim of the present study is to clarify the ageing methodology used by James (1984) for trevally and so ensure that interpretation of the zones is consistent between the two studies. This included establishing the position of the first annual zone, re-reading a selection of James's archived otoliths, and comparing a range of preparation techniques.

Preparation

Three methods were used to prepare trevally otoliths for reading: breaking, grinding, and burning; baking, embedding, and sectioning; and embedding and thin sectioning. All otoliths were broken or sectioned transversely through the nucleus. Ageing of whole trevally otoliths was not attempted due to the difficulty in reading otoliths from older fish and the presence of extra (false) zones or checks in some otoliths (James 1984). Each of the methods used closely follows those used for kahawai, *Arripis trutta* (Stevens & Kalish 1998).

Broken and burnt otoliths were marked, split, and polished across the nucleus. An alcohol flame was used to burn each otolith until opaque and translucent (hyaline) zones were visible. The otoliths were mounted in plasticine for reading. The polished otolith surface was covered lightly with immersion or paraffin oil and read with reflected lighting under a binocular microscope (Paul 1976, James 1984, Stevens & Kalish 1998).

Baked otoliths were marked, baked for about 4 min at 280 °C, and embedded in ordered rows in epoxy resin (Araldite K 142) blocks. Each resin block was cut along each row with a low speed saw, providing transverse sections of up to 60 otoliths per block (Horn & Sullivan 1996, Stevens & Kalish 1998). Hemi-sectioned otolith faces were read under reflected light, and paraffin oil was used to increase the visibility of bands.

Thin sections were prepared following the method described by Stevens & Kalish (1998) and Tracey & Horn (1999). The straightest dorso-nuclear otolith prism was marked on the distal surface with a fine pen. Four or five otoliths were then embedded with their marked surfaces in alignment in an expoxy resin mould. The mould was then sectioned using a dual-bladed diamond saw. After adhering to a microscope slide, the section was polished before viewing with both reflected and transmitted light.

Reading protocols

Each otolith was read twice by different readers. If the readings differed markedly the otolith was re-read by a third reader. Each otolith was given a readability value according to the following scale:

1 excellent - no doubt about age
2 very good - some doubt about age, no more than 1 year out
3 okay - may be up to 2 years out
4 difficult - little more than an informed guess
5 Not readable - guess

Otoliths with readability scales of 5 which differed markedly were removed from the dataset. All other otoliths with markedly different readings were re-read by the third reader, with access to the original two readings, and a final age was determined.

In thin otolith sections a series of opaque (dark) and translucent (clear) growth zones were visible under transmitted light. These zones corresponded to the white (opaque) and light brown (translucent) zones respectively in baked and burnt preparations. The pattern of opaque and translucent zones was best observed in the regions either side of the longitudinal sulcus and this is where counts were generally made (*see* Figures 2 and 3). Both sides were counted if possible. The number of complete translucent zones (i.e., hyaline zones with opaque material outside them) was counted. Fish length was unknown to the otolith readers. If there was a discrepancy between the counts, it was rechecked, and the higher count used. Clear growth zones were followed along the proximal face to help ensure that increments were not omitted or misinterpreted. Split zones and checks were sometimes evident, but they were usually easily identified because of the regularly decreasing distance between true annuli with increasing age.

Defining the nucleus, the region inside the first hyaline zone, was an important factor in determining the first annual growth zone. At times this first zone was not obvious. James concluded that the opaque zone (on the outside of the hyaline zone) first becomes visible in December–January in younger fish, so that formation of the hyaline zone must take place during the preceding few months, that is, in winter or spring. Therefore, the first hyaline zone must represent about 6–9 months of growth. James's guidelines defining the first annual zone were followed.

The interpretation of the otolith margin is often contentious. The following methodology was used to grade each marginal increment. If the marginal increment was opaque with no translucent border it was not counted as an extra year, but an "l" (light opaque zone) was assigned to its age. These readings were later amended if the capture date was later than the nominal birth date of 1 January (James 1984). If there was a completed opaque zone with at least a narrow translucent border it was counted as an extra year, and graded as either wide (w) or narrow (n). In older fish, with their correspondingly narrower marginal increments, this required a degree of subjectivity.

Between-technique comparisons

To compare the merits of thin sections with broken and burnt, or broken and baked preparations, 60 otolith pairs were randomly selected. The left otolith of each otolith pair was broken, baked, embedded in resin, and sectioned. Thirty right otoliths were thin sectioned and 30 were broken and burnt. This enabled direct comparisons between each preparation technique.

Comparison of James's readings and current readings

To assess the level of between-reader variability, 100 baked otoliths were selected and re-read from the archival otolith series of Gavin James.

Sample collections

Landings from the trevally fishery were stratified by stock and fishing method. The biological stocks are thought to correspond to fishery management areas TRE 1 and TRE 7 (*see* Figure 1). The weight and percentage of the annual trevally catch for TRE 1 and TRE 7 are given in Table 1, illustrating the relative catch by method for the stocks. Sampling was restricted to the dominant fishing methods, purse-seine and single trawl for TRE 1 and pair trawl and single trawl for TRE 7. Landings collected from the TRE 7 single trawl fishery were further stratified on the basis of historical seasonal fishing patterns to determine whether any differences exist. The seasonal strata were defined as "peak" (October–May) and "off-peak" (June–September).

Length frequency samples were collected sporadically from the TRE 1 fishery throughout the year and are considered representative of October–September 1997–98. The purse-seine fishery is typically concentrated around periods when more valuable species such as skipjack tuna are absent, while single trawl landings are generally only a bycatch of other targeted species, although some targeting can occur during summer.

Most TRE 7 length frequency samples were collected during the peak season, which incorporates the period when schools of spawning trevally become more vulnerable to fishing. The height of the season usually occurs during January–February, which is about one month after the peak of the snapper fishery. The possibility of spatial differences in length composition over the TRE 7 stock was investigated for the single trawl peak fishery. Where possible, landings were identified as coming from one of four zones: Ninety Mile Beach; Kaipara and Manukau coastline; North Taranaki Bight; South Taranaki Bight (*see* Figure 1). Zonal stratification of the TRE 7 fishery was based on findings by James (1984).

A two-stage sampling procedure was used to obtain length frequencies (West 1978). A random selection of landings and a random sample of bins within landings represent the first and second stages respectively. All fish in sampled bins were measured to the nearest centimetre below the fork length. As trevally show no differential growth between sexes (James 1984), sex was not determined. The sampling design used for snapper (Davies & Walsh 1995) was used. Sampling of purse-seine catches was slightly modified in that each hold (from a total of four) was treated as a separate stratum. A random sample of two bins of trevally was collected from the top, middle, and bottom of each hold as the fish were unloaded.

A fixed number of otoliths was collected per size interval from pair trawl and single trawl landings from TRE 1 from January to April, and from single trawl landings from TRE 7 during January to create fixed allocation age-length keys. The purpose of the keys was to convert catch length frequency information to age frequency for the respective stocks. It was assumed that age was distributed randomly within each sampled length class (Southward 1976). Size classes that were uncommon had about 5 otolith samples collected per size interval and more common size classes had 15–20 otolith samples. The total number of otoliths collected was roughly proportional to the abundance of size classes in the single trawl length frequency for the respective stocks. A maximum of 300–400 otoliths was collected for each stock to produce an age-length key as described by Davies & Walsh (1995).

The calculation of stratum proportions and variances at length and age from the length frequency samples and age-length keys followed that of Davies & Walsh (1995). Proportions at age were calculated for the age classes recruited to each stratum, with the maximum age being an aggregate of all age classes over 19 years.

Trevally length and age data were stored on the Ministry of Fisheries *market* and *age* databases respectively, held by NIWA.

Data analysis

Proportions at length and age

Amalgamated length frequency distributions with associated coefficients of variation (*c.v.*s) were obtained for each stock-method stratum using the statistical approach described by Davies & Walsh (1995). Length frequency distributions were compared non-parametrically using a bootstrap procedure based on the Kolmogorov-Smirnov d-statistic (Appendix 1).

Length compositions were converted to age distributions by application of the age-length key using the approach of Gavaris & Gavaris (1983) and Davies & Walsh (1995). Otoliths were not collected across the whole fishing year, but during the peak period when trevally was the main target species. Although the collection of length frequency samples spanned a broader period of time than those of the otolith samples, the growth of those fish through time was thought not to be considerable. The assumption that the point-in-time age-length keys were broadly applicable to the combined annual length data has been made for other species with growth rates comparable to trevally (Westrheim & Ricker 1978, Davies & Walsh 1995).

Estimates of von Bertalanffy growth parameters

Fish younger than 3 years were not present in the TRE 1 or TRE 7 samples. However, data for these ages were available from spring and summer trawl surveys of the west coast of the North Island during 1986, 1987, 1989, 1991, 1994, and 1996. One and two year old length modes could be identified in the west coast trawl survey series data. A table of proportional length-at-age for 1 and 2 year old trevally was derived from these data (Appendix 2). It was not possible to identify juvenile modes in trawl survey data available for the east coast of the North Island, therefore, the length-at-age for 1 and 2 year olds derived from west coast trawl survey data was assumed representative of both the TRE 1 and TRE 7 fisheries.

Accurate estimates of mean length-at-age are required to derive von Bertalanffy (VB) growth parameters. Although fixed allocation age-length keys may be assumed to provide unbiased estimates of age-at-length they cannot be assumed to accurately represent length-at-age. It is necessary to adjust the length-at-age allocations to reflect the "true" population length proportions in order to obtain unbiased estimates of length-at-age. Proportional length frequency information was available from TRE 1 and TRE 7 sampled trawl catches. Various estimates of VB growth parameters for each stock were calculated relative to the trawl catch-at-length and age-length key data. Trawl-caught samples contain a wide range of sizes of fish (James 1985) and may be assumed to provide a roughly random sample of the population length composition. Pair trawl samples were also included as their selectivity characteristics may be more uniform than those of single trawl, as has been suggested for snapper (K. J. Sullivan, Ministry of Fisheries, pers comm). Purse-seines are thought to be size selective, being dependent on the size structure of the targeted school, and are therefore unlikely to provide representative samples of stock length structure and were not used to derive VB estimates.

Von Bertalanffy parameter estimates were obtained by least squares minimisation of age-length frequency data generated relative to TRE 1 and TRE 7 trawl methods. Catch length frequency was converted to age-frequency by application of the appropriate age-length key. Larger older fish were rare in the trawl catches, therefore the greatest proportion of the length-at-age data tended to be concentrated over the younger age classes which thus carried more weight in the VB fitting process. Length-at-age proportions derived for 1 and 2 year old trevally were scaled to have the same number of observations as the most common age class observed in the commercial trawl data.

Sample size optimisation

Sample sizes were optimised to obtain a mean weighted coefficient of variation (MWCV) over all age classes in the age distribution less than or equal to 20%. Length and age data collected from the TRE 7 single trawl fishery in 1997–98 were considered best for the optimisation because of the many (55) landings sampled. For each combination of landing and otolith sample size option investigated, a set of 500 bootstraps was carried out. In each bootstrap, landings and bins within landings were randomly resampled with replacement to derive a landing length frequency. Similarly, otoliths within each length class interval of the age-length key were randomly resampled with replacement to produce an age-length key for the specified total sample size. The variance and MWCV of the 500 bootstrap catch-at-age estimates were calculated.

Results

Otolith preparation and ageing

Between-technique comparisons

Broken and burnt preparations were rejected as a primary tool for three main reasons. (1) Because trevally otoliths are small there was a likelihood of breakage during manual grinding and consequent sample loss; (2) differential darkening to ground faces due to over burning led to inconsistencies of interpretation, especially marginally where (3) the edges became increasingly friable and likely to disintegrate over time. The re-reading of broken and burnt otolith sets was also difficult, predominantly due to disintegration of the otolith edge. This problem was highlighted when attempting to read James's archival material.

Baking and embedding and thin section preparation were preferred for ease of examination and resolution. Baked and embedded preparations had complex primordia and early growth zones that were difficult to interpret (*see* Figures 2a and 3a). There was some degree of movement in the curing process so that not all baked otoliths were in perfect alignment. This "drift" is exacerbated by the small otoliths, making them difficult to successively orientate in multiple-layered and embedded blocks. Standard baking times delivered inconsistent results between otoliths. Larger and older otoliths have richly contrasted banding structures (*see* Figures 2a and 3a), but otoliths from smaller fish had less contrast and were consequently more difficult to age, hence precision was lower. Errors in counts between readers were due to the inherent difficulties of identifying marginal rings. Sulcally oriented marginal growth zones were often indistinct (*see* Figures 2a and 3a). Thus non-alignment of otolith axes, differential baking between large and small otoliths, and loss of resolution in marginal growth zones were identified as the major reasons for any between-reader variability with this method.

Finally, thin section preparation was tried (*see* Figures 2b, 2c, 3b, 3c). As fewer otoliths could be embedded per mould (4 to 5), the orientation of otoliths was not as problematic. Early growth bands were more readily countable and the contrast between later bands was enhanced. The ability to defocus through the object plane and to magnify marginal growth zones were significant aides to resolution and "resolving" age differences. About 85% agreement (within ± 1 year) was achieved between baked and embedded, and thin section age counts in our test set of 30 otolith pairs. However, as the thin section method is more time consuming and costly, it was decided to age the trevally otolith samples collected in 1997–98 by using the bake and embedded method alone.

Otolith interpretation

All otoliths were aged from baked transverse hemi-sections, orientated through the nucleus. Generally, age was easily determined from the clear and regular banding pattern on the otolith sections. The position of the first year zone was established by the use of known-age fish, which, based on length frequency modes, were 1+ (James 1984). The first year zone was distinguished in transverse otolith sections as follows.

- The first obvious broad opaque zone outside the substantial nuclear region and after the fine transluscent zone (*see* Figures 2 and 3). There is often a smaller check within the nuclear region which may equate with larval settlement from a pelagic to more demersal habitat.

- This is further clarified by a distinctive indentation both dorsal and ventral to the nucleus along the proximal edge.

- Although a proportionality is maintained between successive growth increments, there is a noticeable reduction in growth rate between the fourth and fifth opaque bands. This allowed the position of the first year to be predicted even if it was not clearly visible by "reverse counting" the number of bands.

The otolith margin was often unclear, particularly for older fish. Where possible the margins were graded as either wide or narrow.

Comparison of James's readings and current readings

James's archived material was in poor condition and only 40 of the 100 broken and burnt sections were usable. Consistent total counts from this archived sample were not obtained as the otolith edges appeared to have disintegrated over time. However, counts from the nucleus to the first 3–4 years were consistent between the three readers for this study and with readings from a staff member who also read the otoliths in the 1970s (Brent Wood (NIWA), pers comm.).

Sample collections

Summaries of the length frequency sample sizes for the stock-method strata are given in Tables 2 and 3, and summaries of the otolith sample collections in Table 4.

The estimated proportions at length and age for the stock-method strata are shown in Appendices 3 and 4 respectively. The age-length keys for each stock are presented in Appendix 5.

TRE 1

Purse-seine and single trawl were the two most important commercial fishing methods for trevally in TRE 1 in the 1997–98 fishing year, taking 29% and 40% of the landed catch respectively (*see* Table 1). Trevally was the target species in all purse-seine landings sampled with 47% of the landings sampled containing 92% of the total landed catch (*see* Table 2). Most of the single trawl landings sampled were a bycatch where snapper was the target. Consequently, only 3% of landings were sampled containing 2% of the total landed catch (*see* Table 2).

Purse-seine. The length distribution of the purse-seine landings was characterised by one strong uniform mode between about 35 and 50 cm and had a MWCV of 0.22 (Figure 4). The mean length of trevally sampled from the fishery was 41.3 cm.

Relative year class strengths were discernible from the age compositions, with the 1987 and 1985 year classes (11 and 13 year olds, respectively) appearing strong and the 1994 to 1989 year classes (4 to 9 year olds) weak. The mean age was 10.8 years with a MWCV of 0.26 (Figure 4).

Single trawl. The length distribution of the single trawl landings was characterised by a broad mode which peaked at 33 cm with a broad tail extending to over 60 cm and a MWCV of 0.35 (Figure 5). The mean length of trevally sampled from the fishery was 40.3 cm.

Relative year class strengths were discernible from the age compositions with the 1994 and 1985 year classes (4 and 13 year olds, respectively) appearing strong and the 1992 to 1989 year classes (6 to 9 year olds) weak. The mean age was 9.2 years with a MWCV of 0.20 (Figure 5).

Size selectivity comparison between purse-seine and single trawl. The trevally size selectivity characteristics were markedly different between the purse-seine and single trawl methods (Figure 6). Purse-seine targets fish over a narrow range of sizes. There was a general absence of small and large fish from the catches, which suggests that the selectivity characteristics of purse-seine is domed: single trawl catches encompass a broader size range of fish.

TRE 7

Due to logistic constraints, samples collected from the TRE 7 fishery were almost all caught north of Cape Egmont (*see* Figure 1). This is unlikely to cause significant bias as almost 80% of the TRE 7 TACC was caught north of Cape Egmont in the 1997–98 fishing year. Single trawl was the most important commercial method for harvesting trevally (93%, *see* Table 1), with the division between peak and off-peak being 88:12 by weight (*see* Table 3). Trevally was the target species during the peak season in 60% of landings sampled, with snapper the target on the remaining 40%. Consequently, a higher percentage of the total landed catch by weight was measured compared to the number of individual landings (*see* Table 3). During the off-peak season, trevally was the target species in all landings sampled. Pair trawl accounted for only 2% of the landed catch (*see* Table 1). Almost all pair trawl landings sampled were a bycatch of snapper targeted catches.

Single trawl. The length distribution of the single trawl peak season catch was characterised by a broad mode which peaked at 41 cm with a tail extending to over 60 cm and a MWCV of 0.14 (Figure 7). The mean length of trevally sampled from the fishery was 39.4 cm. The length distribution of the single trawl off-peak catch was characterised by one large mode which peaked at 34 cm and a smaller mode which peaked at 46 cm and had a tail extending to over 55 cm (Figure 8). The distribution had a MWCV of 0.21 and a mean length of 35.7 cm. The observed KS d-statistic for the two distributions had a probability of less than 0.0001 of lying within the bootstrap range of the combined distribution, implying that the two seasonal length frequency distributions were significantly different.

Relative year class strengths were discernible from the age compositions for the peak and off-peak seasons. In the peak season, the 1994 and 1990 to 1985 year classes (4 and 8 to 13 year olds, respectively) appeared strong and the 1992 and 1991 year classes (6 and 7 year olds) weak (*see* Figure 7). In the off-peak season, the 1995 and 1994 year classes (3 and 4 year olds) were very strong and the 1992 and 1991 year classes (6 and 7 year olds) weak (Figure 8). The broad length distribution of the single trawl peak catch resulted in a broadly spanned age distribution, and the single trawl off-peak length distribution was skewed with more younger fish being caught (*see* Figures 7 and 8). Mean ages of trevally from the TRE 7 single trawl fishery of 9.4 and 6.9 years were derived for the peak and off-peak seasons respectively (*see* Figures 7 and 8). Both distributions had mean a MWCV of 0.22.

Of the 47 landings collected from the TRE 7 single trawl peak season, 30 could be stratified by area. These landings were from Ninety Mile Beach (6), Kaipara and Manukau coastline (14), and the North Taranaki Bight (10), respectively. One sample was collected from the South Taranaki Bight and was considered insufficient to be included in the analysis. The remaining 16 landings were from mixed area locations and were unable to be used in the comparisons. The length composition of catches from the Kaipara and Manukau coastline and North Taranaki Bight were similar (Figure 9). The observed KS d-statistic for the two distributions had a probability of less than 0.53 of lying within the bootstrap range of the combined distribution, which is not statistically significant. Catches from the Ninety Mile Beach zone contained more larger fish out to 65 cm (*see* Figure 9). The Kaipara and Manukau coastline, and the North Taranaki Bight length distributions were combined for comparison with the observed Ninety Mile Beach length composition. The combined Kaipara and Manukau coastline, and the North Taranaki Bight length compositions, were significantly different from that of Ninety Mile Beach (KS $P < 0.0001$). The combined length frequency of the Kaipara and Manukau coastline and North Taranaki Bight areas had a MWCV of 0.12: that for the Ninety Mile Beach area was 0.39.

Pair trawl. The length distribution of the pair trawl catch was characterised by one mode which peaked at 36 cm with a broad tail extending to over 60 cm and a MWCV of 0.27 (Figure 10). The mean length of trevally sampled from the fishery was 39.2 cm.

Relative year class strengths were discernible from the age composition with the 1994, 1990, 1989, and 1985 year classes (4, 8, 9, and 13 year olds, respectively) appearing strong and the 1992 and 1991 year classes (6 and 7 year olds) weak. A mean age of trevally from the TRE 7 pair trawl fishery of 9.0 years was derived (*see* Figure 10). The distribution had a MWCV of 0.23.

Size selectivity comparison between single trawl and pair trawl. The size selectivity characteristics of the single trawl off-peak catch and the pair trawl catch were more similar than that of the single trawl peak catch, with the latter containing more larger fish (Figure 11).

Estimates of length-at-age

Growth comparisons in TRE 1 and TRE 7

The VB growth parameters for TRE 1 and TRE 7 were similar when similar length frequency compositions were used in the fits, i.e., TRE 1 single trawl and TRE 7 pair trawl (*see* Figures 5 and 10). A plot of the unadjusted age data from both stock areas (Figure 12) shows strong correspondence in the distribution of ages within each length interval. These results suggest that the growth rates of trevally from TRE 1 and TRE 7 are similar.

TRE 1

The smallest 3 year old fish was 28 cm (Appendix 5) and the smallest 4 year old fish was only 1 cm longer (29 cm). Therefore, it is not possible to determine the minimum size for TRE 1 4 year old trevally, although the TRE 7 data indicates that 29 cm is likely to be the upper level for 3 year olds. The smallest fish observed in the purse-seine landings was 32 cm, indicating that trevally do not become fully vulnerable to the purse-seine fishery until at least 5 years of age. Trevally enter the TRE 1 single trawl fishery at about 27 cm and 3 years of age.

The VB growth parameters for the TRE 1 single trawl method are given in Table 5. The VB growth curve and associated plot of residuals (Figure 13) indicate some variability in length about age. The plot of residuals indicates that the curve did not fit well to the 3 year old and 20+ age classes.

The oldest trevally aged from TRE 1 in 1997–98 was 38 years old.

TRE 7

Fish less than 30 cm long were present in both single and pair trawl landings (Appendix 3) with all 25–29 cm fish being 3 years old. The smallest recorded 4 year old fish was 30 cm long (Appendix 5). This implies that all 4 year old fish are vulnerable to trawl, whereas 3 year old fish may be only partially vulnerable.

The VB growth parameters for the TRE 7 single and pair trawl methods are given in Table 5. The VB growth curves and associated plot of residuals for single trawl (Figure 14) and pair trawl (Figure 15) indicate some variability in length about age. As seen in the TRE 1 data, the growth of the 20+ age class was under-represented by the VB curve (*see* Figures 14 and 15).

The oldest trevally aged from TRE 7 in 1997–98 was 43 years old.

Sample size optimisation

Bootstrap simulation results indicate the collection of at least 30 landings and 600 otoliths as the best combination to achieve a MWCV precision below 0.2 for the TRE 7 single trawl fishery (Appendix 6). Precision on the MWCV was more sensitive to changes in the otolith sample size than the number of landings sampled from the fishery with the latter being an onerous and time consuming task.

Discussion

The relative year class strengths visible within each trevally stock were consistent between methods. This is to be expected as information relating to the presence of dominant or weak year classes is inherent in the age-length key which largely determines the age distribution for each fishing method (Davies & Walsh 1995). However, ageing trevally otoliths was found to be difficult, especially in age classes greater than 10 years. James (1984) estimated that the errors associated with ageing trevally older than 8–12 years increase progressively from about ± 1 year for fish up to about 25–30 years old to ± 2 years for older fish. This may have led to some smoothing of the distributions with respect to year class strength, making strong and weak year classes less apparent. Reader variation across the 1997–98 otolith data sets were consistent with James's conclusions. Baked and embedded otoliths were more difficult to read and therefore more labour intensive to interpret than thin section preparations. The thin section technique is recommended for any future ageing work as rings can be resolved more readily and fewer reading errors may result.

There was some similarity in year class strength in single trawl catches from the TRE 1 and TRE 7 stocks. The 1985 and 1994 year classes appeared to be of above average strength in both stocks, but a weak 1990 year class in TRE 1 and a strong 1989 year class in TRE 7 are not mirrored. Recruitment variation in snapper has been linked to changes in mean autumn sea surface temperature (Francis *et al.* 1995, 1997). James (1984) found some evidence that strong and weak cohorts in trevally were also related to warm and cool sea surface temperatures, respectively. However, no visible similarities in year class strength could be drawn between trevally and snapper catch-at-age data for 1997–98, or from the well documented temperature-recruit relationship that exists for snapper in the Hauraki Gulf.

There were differences in length composition between TRE 1 purse-seine catches and those from single trawl. The length compositions derived for each method are based on a reasonable number of landings taken over similar areas (East Northland and Bay of Plenty) hence the conclusion that purse-seining is comparatively size selective seems reasonable. James (1984) found the most striking feature of purse-seine landings was the preponderance of large fish in the samples, with different schools clearly showing similar size compositions and little variation. The 1997–98 combined purse-seine length frequency composition was relatively normally distributed, which indicates the fishery was based on schools of fish of uniform length. The surface schools of trevally that purse-seiners target usually comprise adult fish primarily feeding on plankton, such as the euphausid *Nyctiphanes australis* (Gilbert 1988), and tend not to be spawning aggregations. The mean size and age of fish in the 1997–98 purse-seine catches was smaller than James observed in the late 1970s. There was no evidence of spatial heterogeneity in trevally length and age samples from the TRE 1 single trawl fishery, although sample sizes were considered too low for an adequate investigation.

The time differences between the peak and off-peak seasons in the TRE 7 single trawl fishery have resulted in different size and age structures of trevally being harvested, although both seasonal harvests cover the same areas. The length and age distribution for the peak season was broad and contained a high proportion of larger and older fish and that for the off-peak season comprised more small fish. It is possible that the peak seasonal catch contained more of the larger adults or "school fish" that aggregate to spawn in high densities over the spring and summer months and then move away from these areas during the off-peak season. The off-peak fishery, where trevally was the targeted species in 100% of the landings sampled, may comprise localised populations of "resident fish" which are typically of smaller size and lower abundance, and are caught mainly during the non-spawning part of the year. This seasonal schooling behaviour is commonly seen in snapper (Longhurst 1958, Paul 1977, Vooren & Coombs 1977, Sullivan & Gilbert 1978). Another possible explanation is that vertical distribution of trevally in the water column may vary throughout the season and that fish of a particular size may become unavailable to bottom trawling. Differences were also seen in the length composition of single and pair trawl catches from TRE 7. Pair trawl catches from TRE 7 were generally small, and usually bycatch where snapper was the primary target. As the single and pair trawl landings were collected from the same general area and season, it is plausible that these differences are mainly related to gear selectivity.

Trevally captured from Ninety Mile Beach by single trawl during the peak season in 1997–98 were larger than fish caught from off either the Kaipara or Manukau Harbours or the North Taranaki Bight. This finding was supported by discussions with commercial fishers who claim that fish in the far north of the North Island appear to be much larger, on average, than those from elsewhere. Fish over 56 cm long were not found south of Ninety Mile Beach. James (1984) also found trevally length and age compositions collected by trawl survey along the west coast to vary considerably. His observations were the reverse of the 1997–98 pattern, with larger and older fish more common in the south. Although spatial differences in age and length may be explained by the presence of different substocks, this hypothesis is not supported by electrophoretic studies (Gauldie & Johnston 1980) which indicate that west coast North Island trevally probably belong to one stock. It is recommended that future TRE 7 catch sampling programmes be expanded to investigate spatial and temporal patterns in length composition.

The scatterplots of age-at-length data and the VB growth curves are similar for the TRE 1 and TRE 7 stocks. Gilbert (1988) found only minor differences in the growth rates for both stocks and could not conclude that the two areas were distinct. The VB fits to length at age data from each stock also produced similar parameter values when single trawl was chosen to represent the stock length composition in TRE 1 and pair trawl in TRE 7. The variability in length about age for 3 and 4 year old fish in the residual plots of the VB growth curves may be a result of size selectivity, whereby only the faster growing individuals of the cohort have been captured. The VB fits consistently under-represented the growth rates of trevally greater than 20 years of age in both stocks. These larger older animals were mainly from the East Northland area of TRE 1 and the Ninety Mile Beach area of TRE 7. It is possible that the larger trevally in northern New Zealand are part of a separate substock.

James (1984) derived VB parameter estimates from research trawls in the western Bay of Plenty from 1972 to 1974, which are considerably different from those found in this study, and may be a result of selectivity or area or time differences.

The mean weighted coefficient of variation (MWCV) for the length distributions from the various method-season strata sampled in 1997–98 ranged between 0.14 and 0.35, whereas the MWCV for age distributions ranged between 0.20 and 0.26. The relatively high values of MWCV that occurred within all age distributions is probably due to the broadness of the age structure in the TRE 1 and TRE 7 fisheries, inherent in the age-length key, and the high variance observed in each cohort. The within-length interval component of proportion at age variance is the most significant component of total variance, so total variance is more efficiently controlled by altering the otolith subsample size (Gavaris & Gavaris 1983). Increasing the otolith sample size is likely to lead to a lower MWCV. This view was supported by the results from the sample size optimisation analysis of the TRE 7 single trawl data.

Conclusions

1. The distribution at age for the main TRE 1 and TRE 7 fisheries in 1997–98 were similar and contained a large number of older fish.

2. There were similarities in growth rates and relative recruitment strength between the TRE 1 and TRE 7 stocks. However, there was no evidence that recruitment variation on either coast was similar to that of snapper.

3. Growth rates for larger, older (20+) trevally were under-represented by VB fits to the mean length-at-age data collected from TRE 1 and TRE 7. Most of these older animals had come from East Northland and Ninety Mile Beach areas, and may be part of a separate northern New Zealand substock.

4. The TRE 1 purse-seine fishery operated over similar broad geographical areas to the single trawl fishery. Differences in the length composition of the catches suggest purse-seine is size selective.

5. Single trawl catches from the Ninety Mile Beach area contained higher proportions of larger older trevally than catches from TRE 7 areas further south. Similarly, seasonal differences in single trawl length composition from TRE 7 were also noticeable between the peak and off-peak seasons.

6. Optimisation analysis indicates the number of landings sampled from the TRE 7 single trawl fishery in 1997–98 is likely to be adequate for future sampling programmes. However, it is recommended that the number of otoliths collected from TRE 7 be increased to 600 to achieve a MWCV of below 0.2.

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Table 1 : **Weight (t) and percentages of annual trevally catches by fishing method* for the TRE 1 and TRE 7 stocks in the 1997–98 fishing year**

	BLL	BPT	BS	BT	PS	SN	Other	Total
TRE 1	43	2	86	383	276	169	7	966
%	4	0	9	40	29	17	1	100
TRE 7	4	33	1	1 884	0	86	10	2 018
%	0	2	0	93	0	4	1	100

* BLL, bottom longline; BPT, pair trawl; BS, beach seine; BT, single trawl; PS, purse-seine; SN, set net.

Table 2 : **Summary of the catch (total number and weight of landings) and samples (number and weight of landings sampled and number of fish measured) in method–season strata for the TRE 1 fisheries for the 1997–98 fishing year**

		Number of landings			No. of fish	Weight of landings (t)		
Method*	Period	Total	Sampled	% of total	measured	Total	Sampled	% of total
BT	Whole year	479	12	3	1 927	383	9	2
PS	Whole year	15	7	47	3 289	276	254	92

* BT, single trawl; PS, purse-seine.

Table 3 : **Summary of the catch (total number and weight of landings) and samples (number and weight of landings sampled and number of fish measured) in method–season strata for the TRE 7 fisheries for the 1997–98 fishing year**

		Number of landings			No. of fish	Weight of landings (t)		
Method*	Period	Total	Sampled	% of total	measured	Total	Sampled	% of total
BPT	Whole year	48	7	15	2 329	33	13	39
BT	Peak	723	47	7	22 576	1 665	473	28
	Off-peak	92	8	9	3 206	219	31	14

* BPT, pair trawl; BT, single trawl.

Table 4 : **Details of trevally otolith samples collected in 1997–98 from the TRE 1 and TRE 7 stocks**

Area	Method*	Sampling period	Sample method†	Length range (cm)	No. aged
TRE 1	BPT, BT	Jan-98 to Apr-98	SR	28–67	387
TRE 7	BT	Jan-98	SR	25–68	375

* BPT, pair trawl; BT, single trawl.

† SR, stratified random sample.

Table 5 : **Von Bertalanffy growth parameters (with 95% confidence intervals) calculated from trevally otolith samples collected in 1997–98 from the TRE 1 and TRE 7 stocks**

Area	Method*	L_∞	k	t_o
TRE 1	BT	47.55 (47.39–47.71)	0.29 (0.28–0.29)	–0.13 (–0.16 to –0.10)
TRE 7	BT	43.74 (43.64–43.85)	0.36 (0.36–0.37)	0.09 (0.07 to 0.11)
TRE 7	BPT	46.21 (46.05–46.37)	0.28 (0.27–0.28)	–0.25 (–0.29 to –0.22)

* BPT, pair trawl; BT, single trawl.

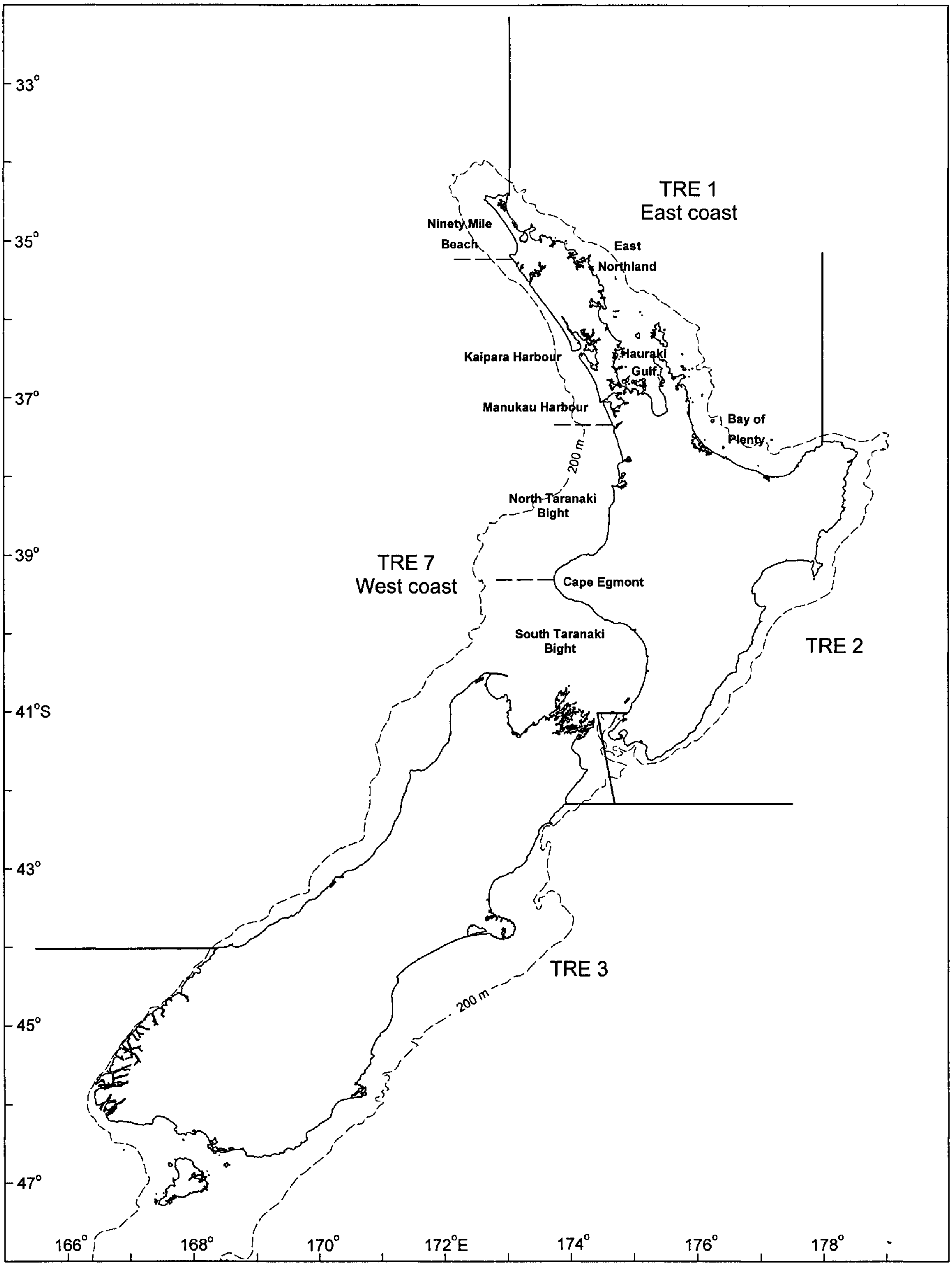


***Figure 1*: Trevally quota management areas and locations referred to in the text.**

Figure 2: **Left and right otoliths of a 44 cm male trevally prepared using baked and resin embedded (a) and thin sectioning (b & c). Counts from the baked preparation were 27 years and for the thin section 29+ years. Marginal sulcal growth zones (dorsal - DMZ and ventral - VMZ) were indistinct in baked view (a) but clearer under thin section magnification (b & c). Inner years 1–3 are still problematic in both preparations due a slight misalignment of the nucleus, but the baked preparation has a more distinct first ring followed by an indistinct complex zone (X). Scales are in µm.**

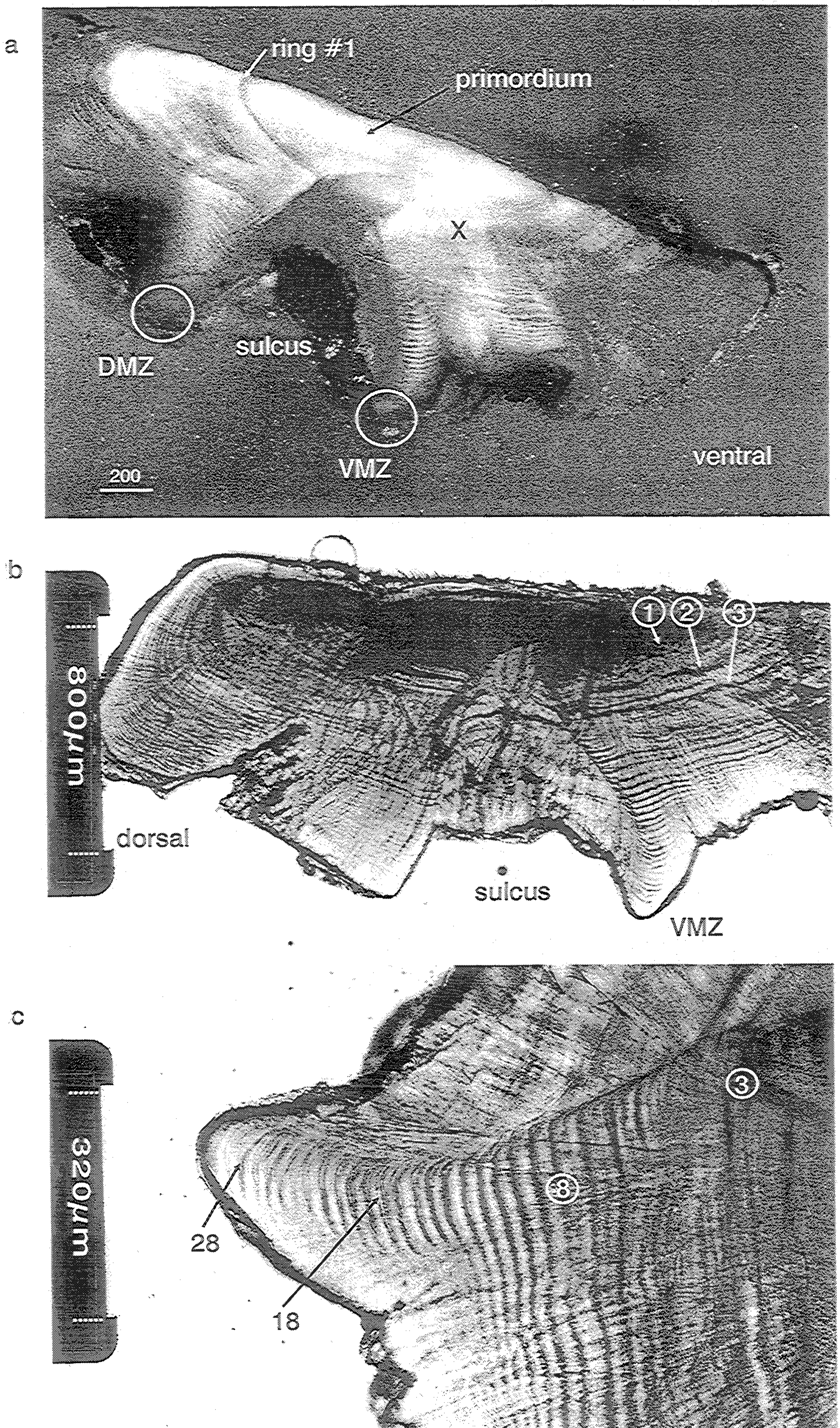
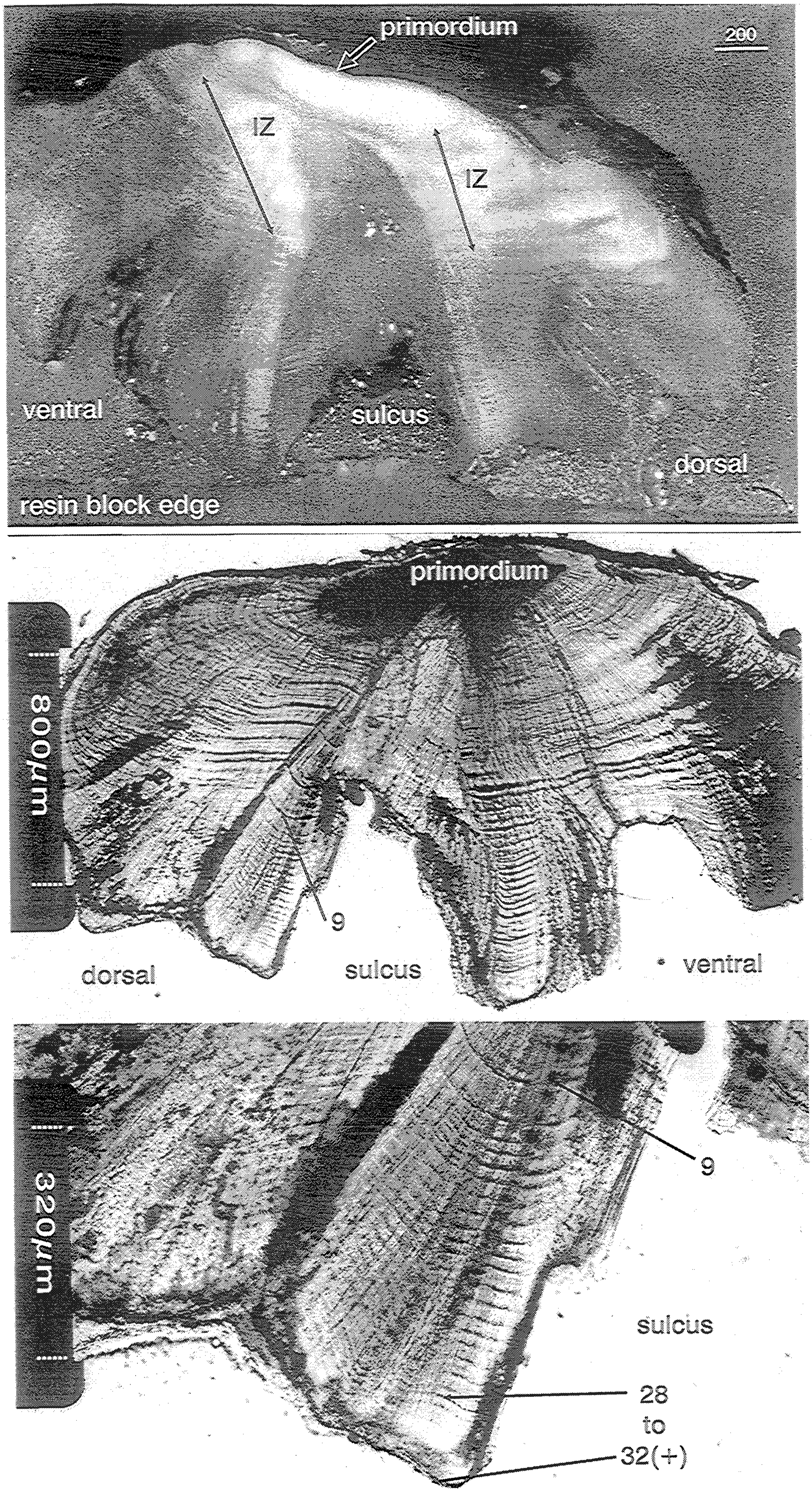

a
ring #1
primordium
X
DMZ
sulcus
VMZ
ventral
200
b
800μm
dorsal
sulcus
VMZ
1
2
3
c
320μm
3
8
28
18

***Figure 3*: Left and right otoliths from a 58 cm male trevally prepared by baking (a) and thin sectioning (b & c). Ages assigned to the baked preparation and thin section were ~30 years and 32+ years respectively. The baked preparation was not sectioned through the core and has an indistinct primordium and interstitial zone (IZ). The corresponding thin section has a well defined early growth zone with clear bands which decrease in width dramatically over 9 years. Marginal increments become clearer at higher magnifications. Scales are in μm.**

a
b
c

primordium
200
IZ
IZ
ventral
sulcus
dorsal
resin block edge
primordium
800μm
9
dorsal
sulcus
ventral
320μm
9
sulcus
28
to
32(+)

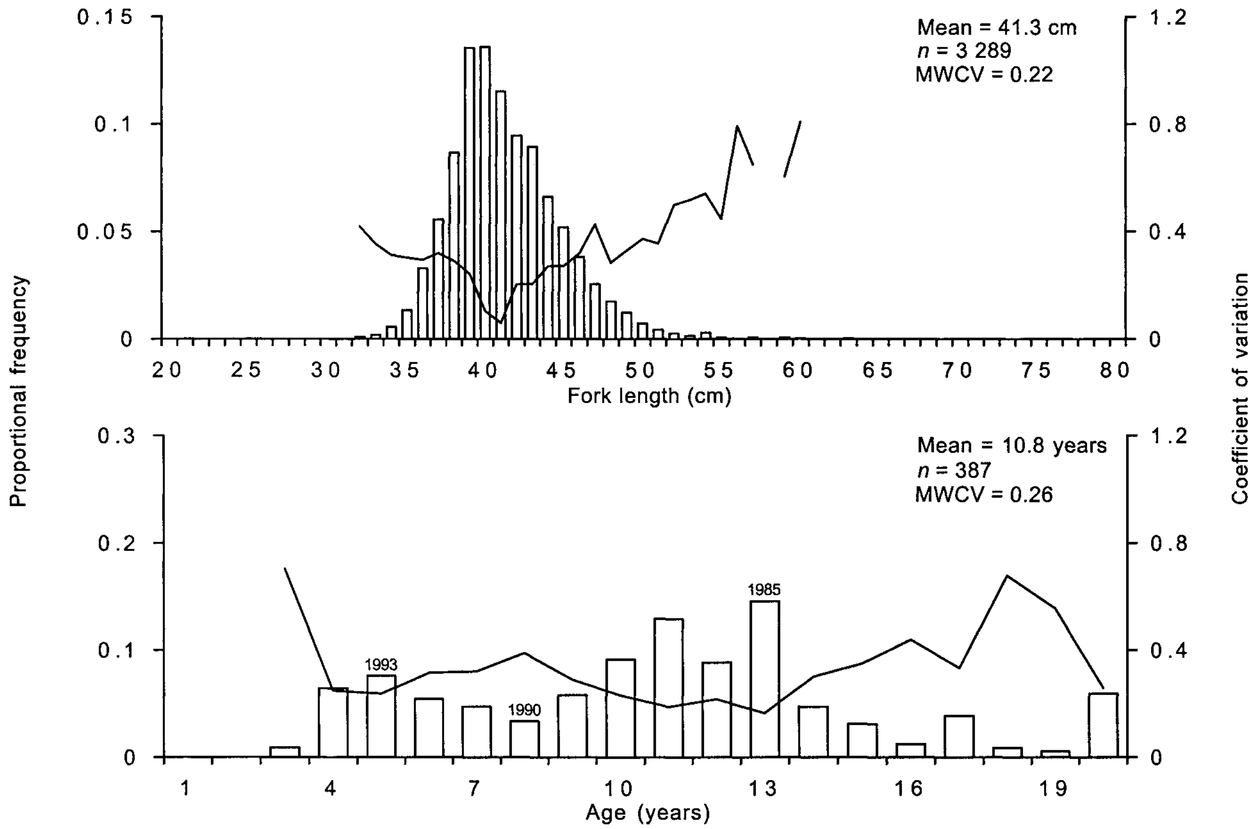


Figure 4**: Proportions at length and age (histograms) and *c.v.*s (solid lines) for the TRE 1 purse-seine fishery during 1997–98 (*n* denotes sample size).**

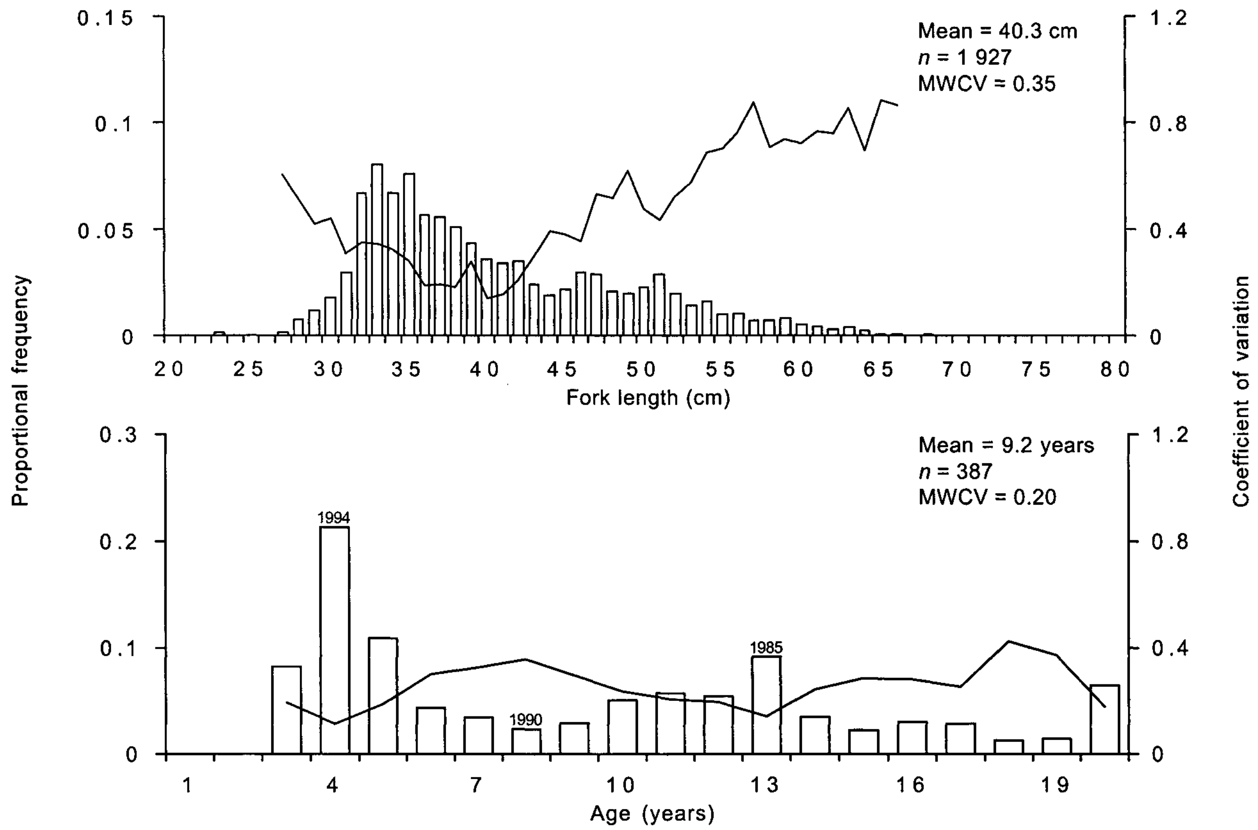


Figure 5**: Proportions at length and age (histograms) and *c.v.*s (solid lines) for the TRE 1 single trawl fishery during 1997–98 (*n* denotes sample size).**

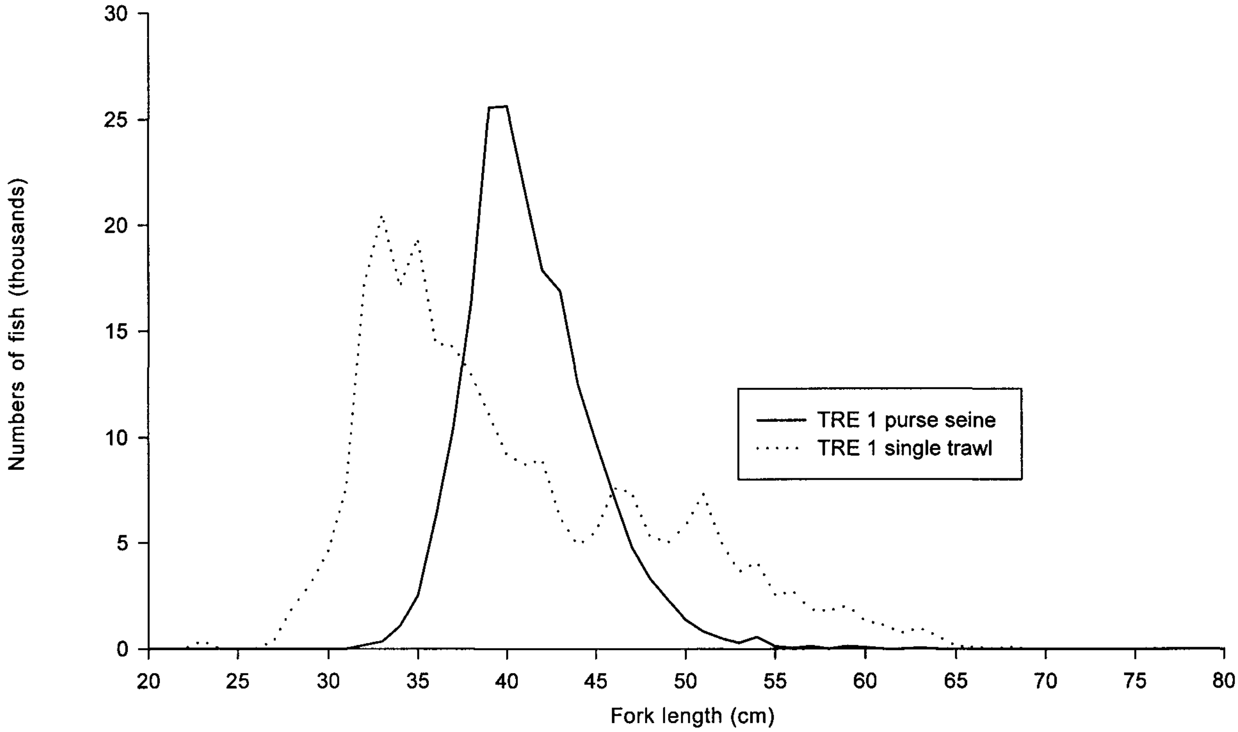


***Figure 6*: Scaled total numbers of trevally caught at length for the main methods in the TRE 1 fishery during 1997–98.**

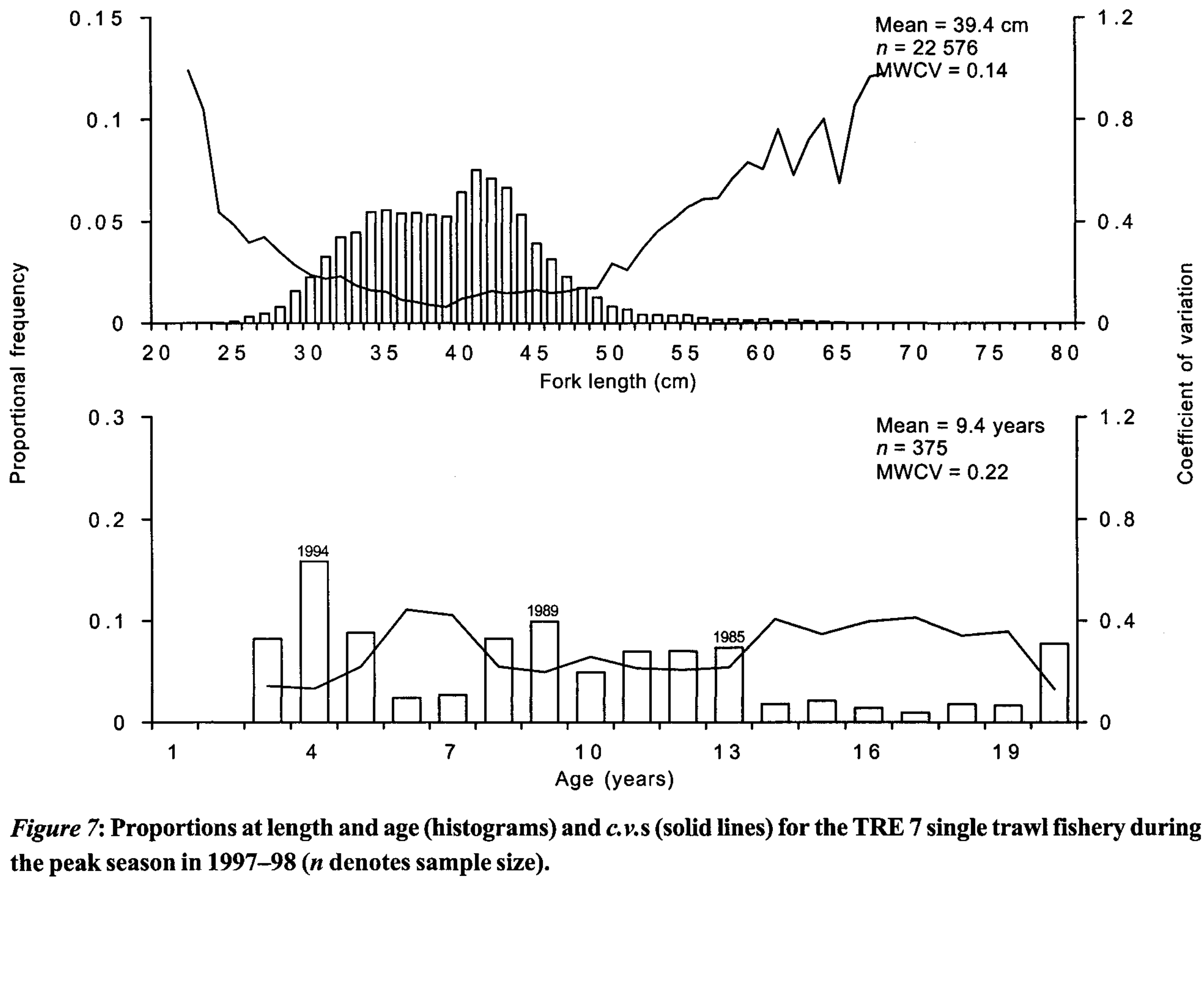


***Figure 7*: Proportions at length and age (histograms) and *c.v.*s (solid lines) for the TRE 7 single trawl fishery during the peak season in 1997–98 (*n* denotes sample size).**

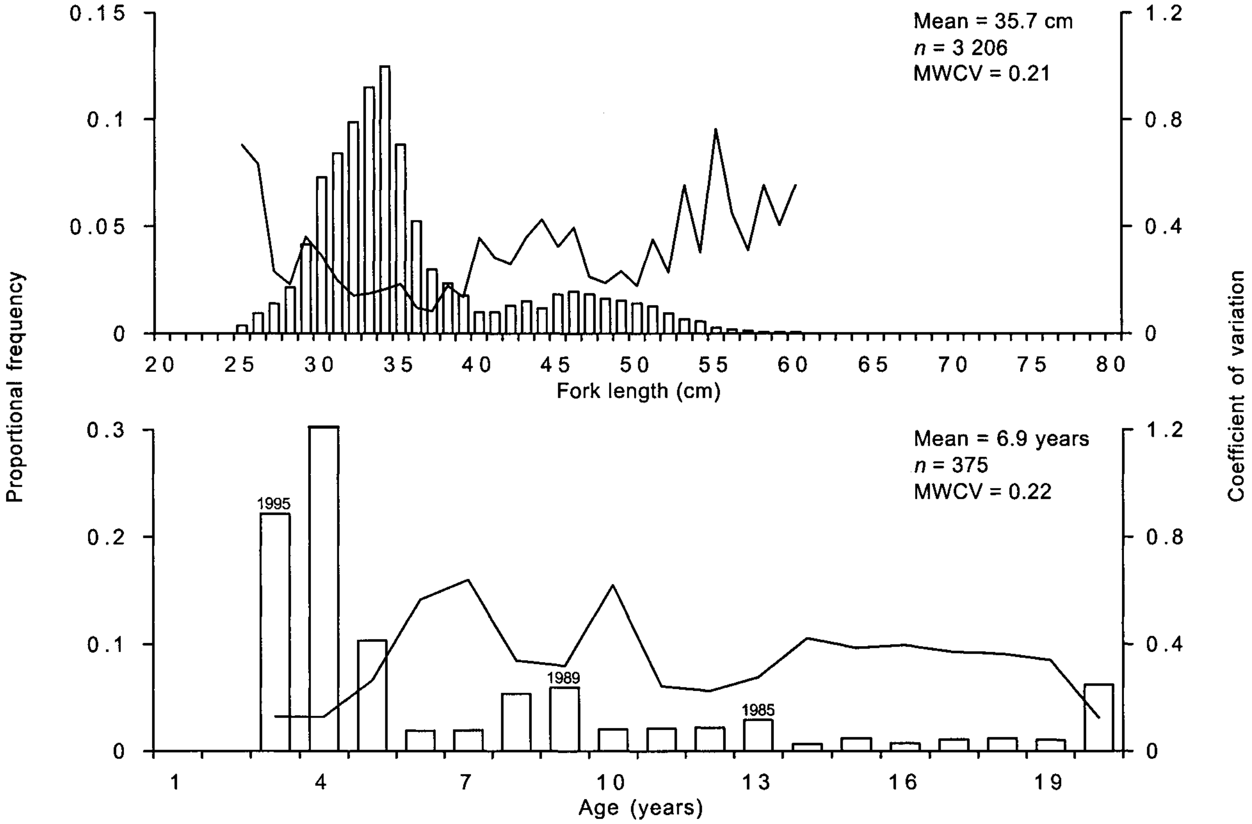


***Figure 8*: Proportions at length and age (histograms) and *c.v.*s (solid lines) for the TRE 7 single trawl fishery during the off-peak season in 1997–98 (*n* denotes sample size).**

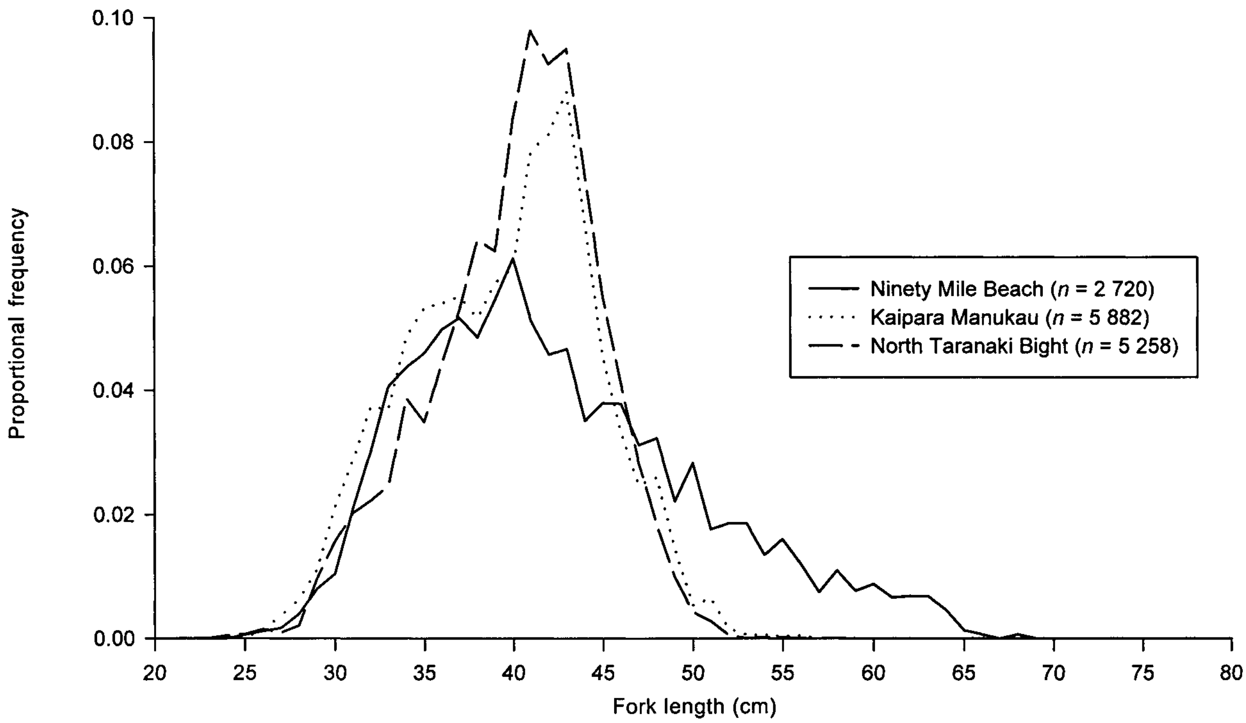


***Figure 9*: Proportions at length for single trawl landings sampled from three areas of the TRE 7 fishery during 1997–98 (*n* denotes sample size).**

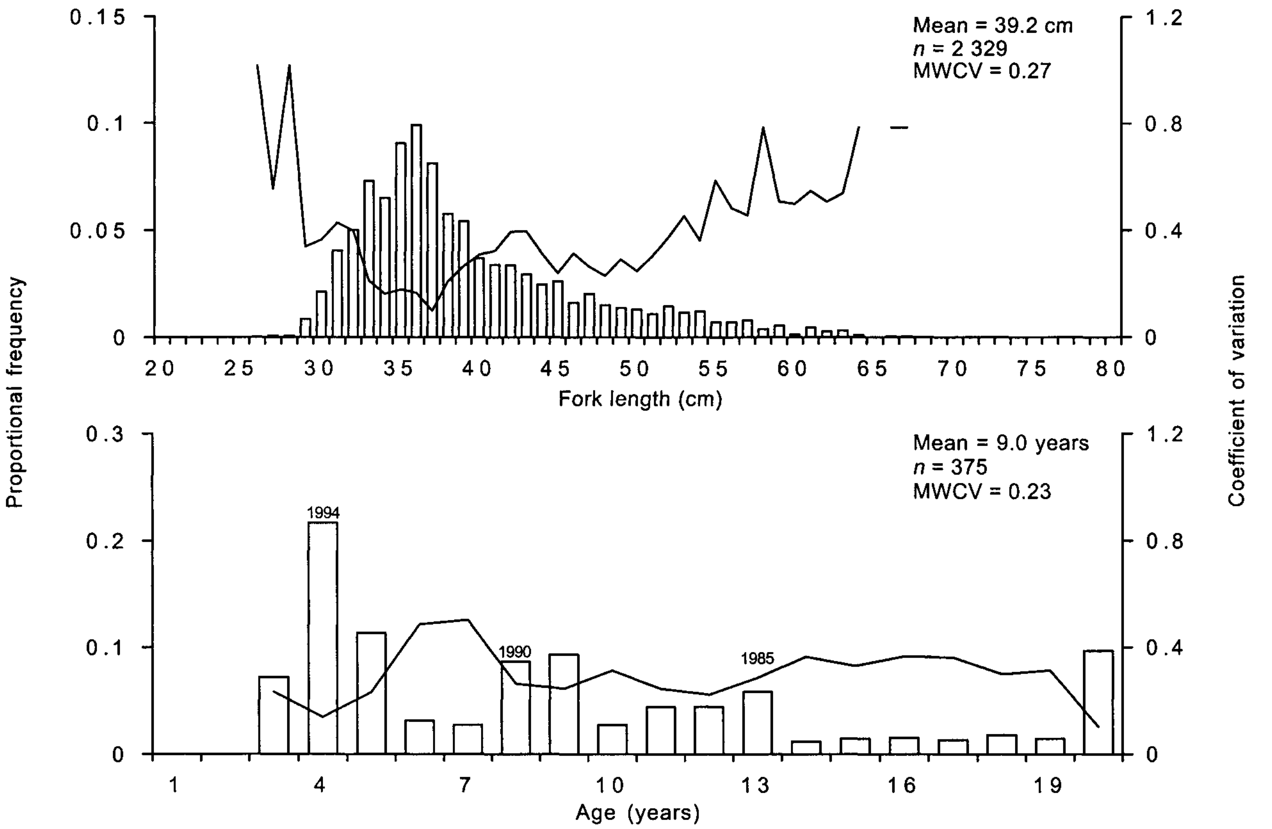


***Figure 10*: Proportion at length and age distributions (histogram) and *c.v.*s (solid line) from trevally landings sampled from the TRE 7 pair trawl fishery during 1997–98 (*n* denotes sample size).**

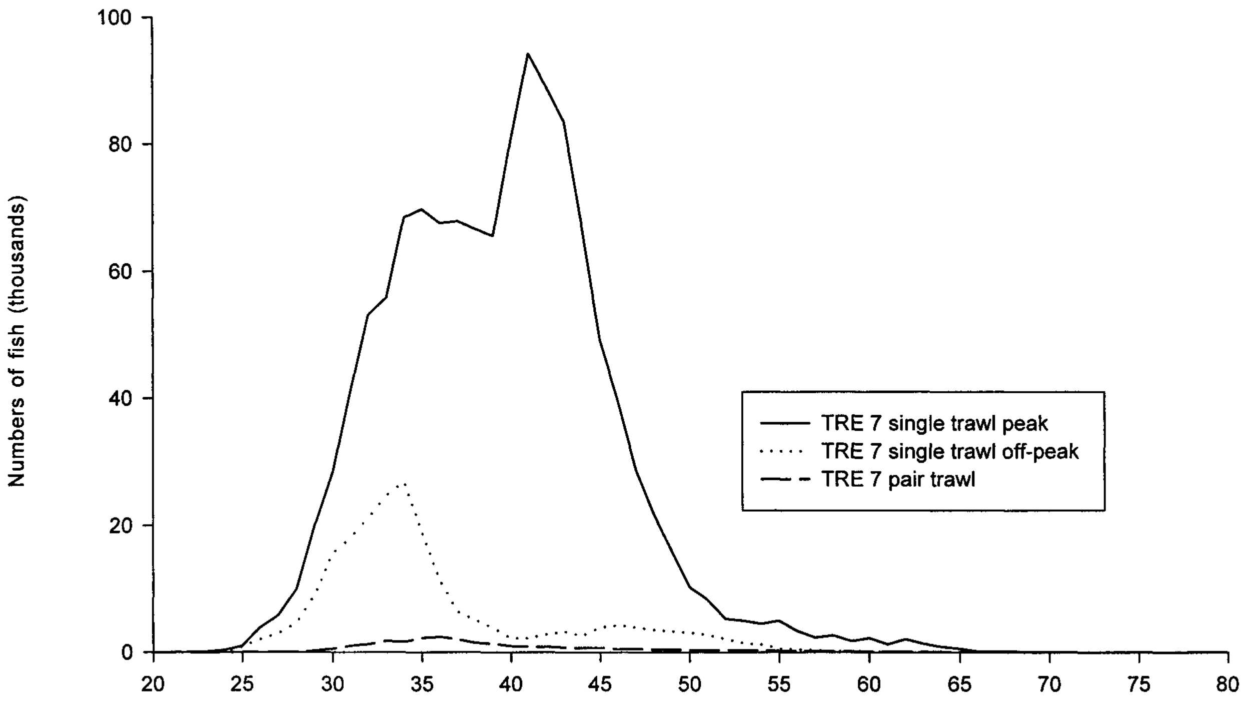


***Figure 11*: Scaled total numbers of trevally caught at length for the main methods in the TRE 7 fishery during 1997–98.**

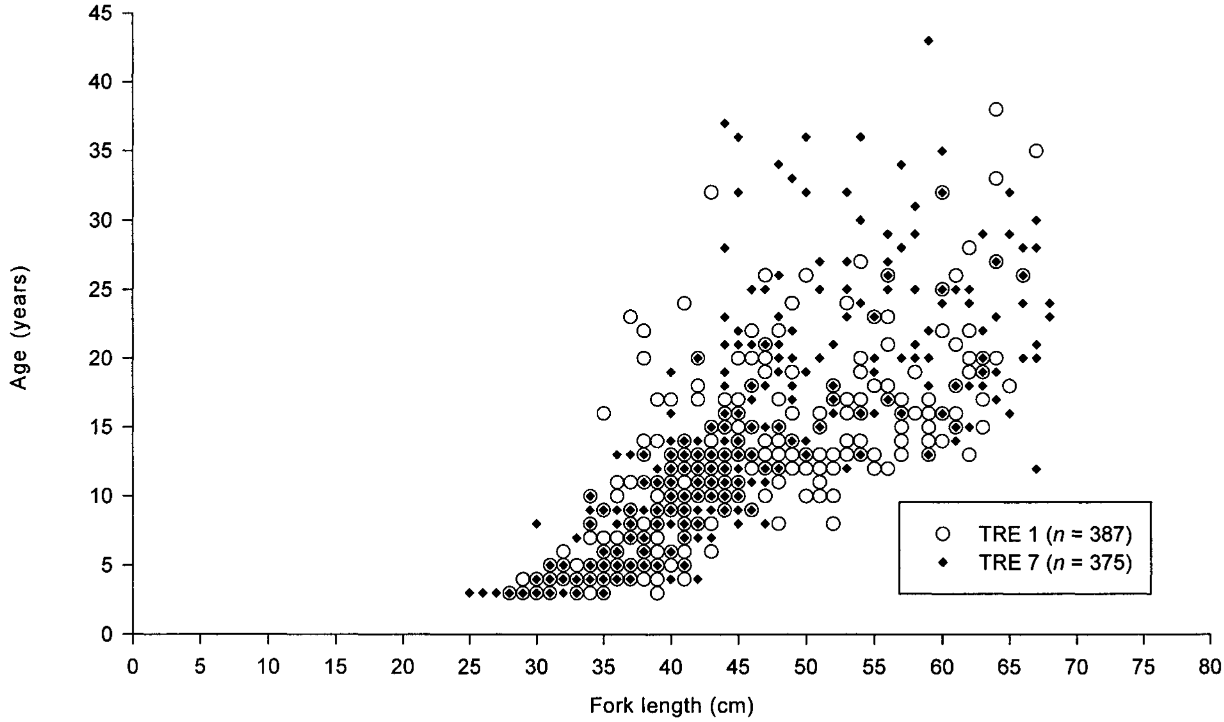


***Figure 12*: Scatterplot of trevally age-at-length data collected from the TRE 1 and TRE 7 fisheries during 1997–98 (*n* denotes sample size).**

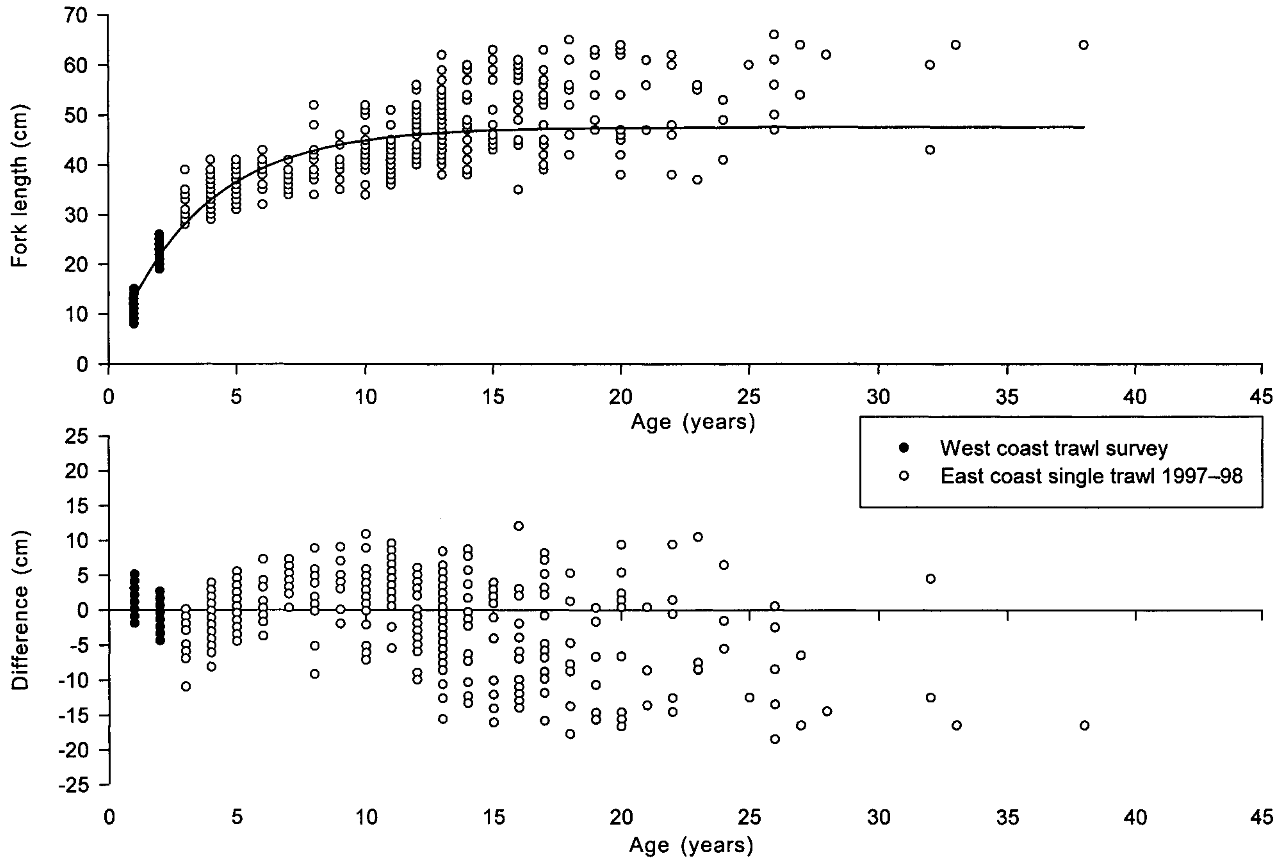


***Figure 13*: Von Bertalanffy growth curve and scatterplot of trevally age data collected from the TRE 1 fishery during 1997–98 and modified with single trawl length frequency data. Associated plot of residuals below.**

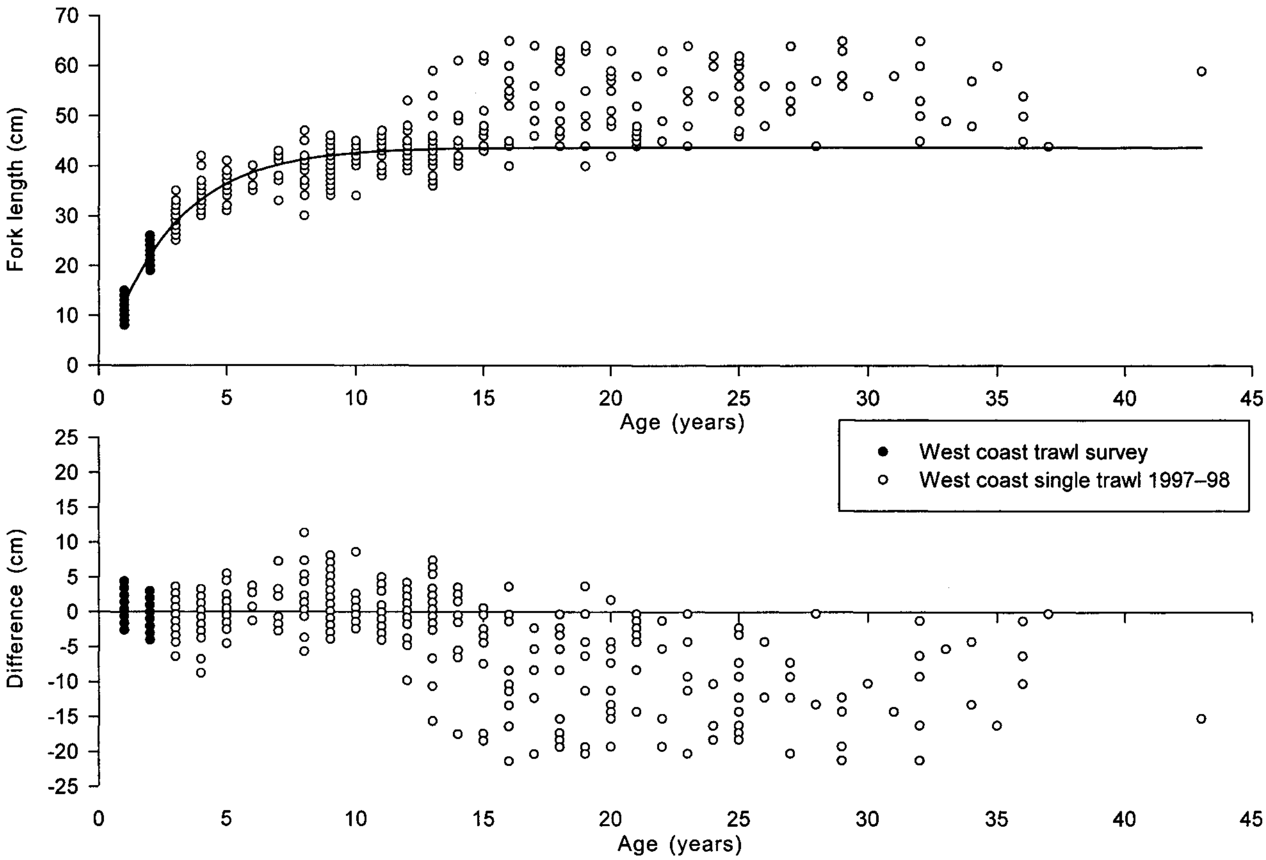


***Figure 14*: Von Bertalanffy growth curve and scatterplot of trevally age data collected from the TRE 7 fishery during 1997–98 and modified with single trawl length frequency data. Associated plot of residuals below.**

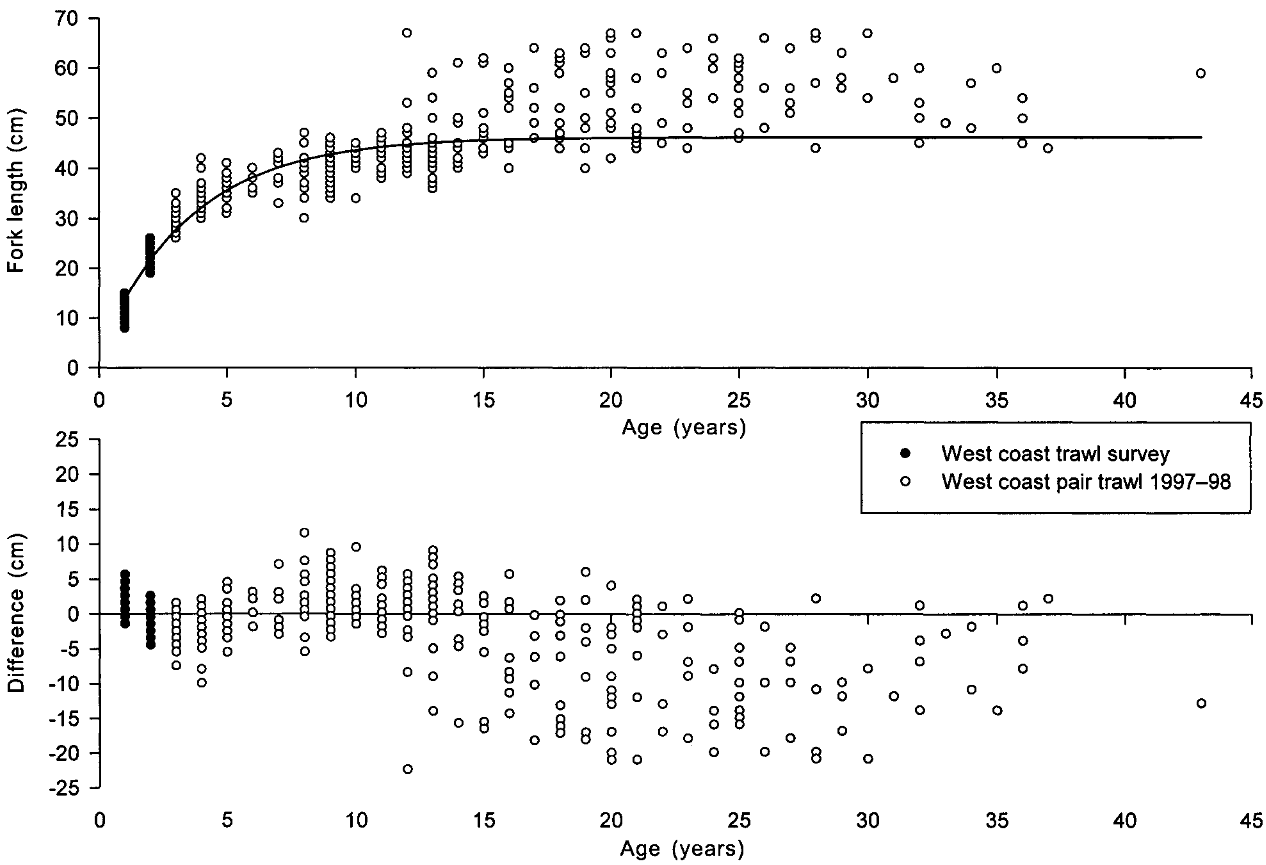


***Figure 15*: Von Bertalanffy growth curve and scatterplot of trevally age data collected from the TRE 7 fishery during 1997–98 and modified with pair trawl length frequency data. Associated plot of residuals below.**

Appendix 1: Comparing length frequency distributions by bootstrapping the Kolmogorov-Smirnov d-statistic

Descriptions of the Kolmogorov-Smirnov test for comparing two frequency distributions can be found in most good statistical texts, e.g., Sokal & Rohlf (1995). In order to derive the KS test statistic (d-statistic) the two frequency distributions have to be first expressed as cumulative proportional curves (curves ranging from 0–1). The maximum proportional difference between the two curves is the KS d-statistic. The d-statistic random variable is described by the KS probability density function and this function underlies the classical KS parametric test. This test is typically too sensitive for fisheries data which generally have very large sample sizes and hence the test is prone to Type II error (falsely rejecting the null hypothesis). To overcome these problems a bootstrap procedure was used to derive expected distributions of the d-statistic against which the observed d-statistic could be compared. Two length frequency distributions were sampled from a combined distribution and a d-statistic derived. Data were combined using the methods described by Davies & Walsh (1995) and the bootstrap distributions were derived from the individual length class *c.v.*s assuming random normal deviates. The bootstrap process was repeated 1000 times to generate an expected distribution for the d-statistic. The original d-statistic was then compared to generated distribution. The proportion of bootstrap d-statistic values less than the observed value was considered to represent the rejection probability of the null hypothesis (Type I rejection probability). The test is by nature only one-tailed in that very small d-statistic values, although unlikely, represent almost perfect correspondence between the two compared distributions. We are therefore interested only in the rejection tail corresponding to large d-statistic values (i.e., the right hand tail).

Appendix 2: Estimates of proportional length-at-age for 1 and 2 year old trevally derived from west coast North Island trawl surveys (1986, 1987, 1989, 1991, 1994, 1996)

1 year old trevally			2 year old trevally	
Length (cm)	Proportion		Length (cm)	Proportion
8	0.046		19	0.016
9	0.085		20	0.028
10	0.204		21	0.139
11	0.212		22	0.308
12	0.174		23	0.292
13	0.096		24	0.128
14	0.108		25	0.065
15	0.062		26	0.025

Appendix 3 : **Estimated proportion at length and *c.v.* s for trevally fisheries in TRE 1 and TRE 7 in 1997–98**

P.i. = proportion of fish in length class. *Nt* = scaled total number of fish caught.
c.v. = coefficient of variation. *n* = total number of fish sampled.

Estimates of the proportion at length of trevally from the TRE 1 purse seine and single trawl fishery in 1997–98

Length	Purse seine Combined		Single trawl Combined	
(cm)	*P.i.*	*c.v.*	*P.i.*	*c.v.*
20	0.0000	0.00	0.0000	0.00
21	0.0000	0.00	0.0000	0.00
22	0.0000	0.00	0.0000	0.00
23	0.0000	0.00	0.0014	0.60
24	0.0000	0.00	0.0000	0.00
25	0.0000	0.00	0.0000	0.00
26	0.0000	0.00	0.0000	0.00
27	0.0000	0.00	0.0014	0.60
28	0.0000	0.00	0.0075	0.51
29	0.0000	0.00	0.0118	0.42
30	0.0000	0.00	0.0181	0.44
31	0.0000	0.00	0.0298	0.31
32	0.0009	0.42	0.0672	0.35
33	0.0018	0.35	0.0804	0.34
34	0.0057	0.31	0.0669	0.32
35	0.0134	0.30	0.0759	0.28
36	0.0329	0.29	0.0565	0.19
37	0.0556	0.32	0.0558	0.19
38	0.0865	0.29	0.0508	0.18
39	0.1355	0.24	0.0434	0.28
40	0.1358	0.10	0.0360	0.14
41	0.1152	0.06	0.0341	0.15
42	0.0946	0.20	0.0350	0.21
43	0.0894	0.20	0.0243	0.30
44	0.0662	0.27	0.0191	0.39
45	0.0520	0.27	0.0216	0.38
46	0.0382	0.32	0.0297	0.36
47	0.0255	0.43	0.0289	0.53
48	0.0176	0.28	0.0209	0.52
49	0.0123	0.33	0.0196	0.62
50	0.0073	0.37	0.0228	0.48
51	0.0043	0.36	0.0287	0.43
52	0.0026	0.50	0.0197	0.52
53	0.0015	0.52	0.0143	0.57
54	0.0029	0.54	0.0160	0.69
55	0.0006	0.45	0.0099	0.70
56	0.0001	0.79	0.0105	0.76
57	0.0006	0.65	0.0072	0.88
58	0.0000	0.00	0.0070	0.71
59	0.0007	0.60	0.0079	0.74
60	0.0003	0.81	0.0051	0.72
61	0.0000	0.00	0.0044	0.77
62	0.0000	0.00	0.0029	0.76
63	0.0002	0.73	0.0038	0.85
64	0.0000	0.00	0.0023	0.69
65	0.0000	0.00	0.0005	0.88
66	0.0000	0.00	0.0003	0.86
67	0.0000	0.00	0.0000	0.00
68	0.0000	0.00	0.0003	1.13
69	0.0000	0.00	0.0000	0.00
70	0.0000	0.00	0.0000	0.00
Nt	188 791		255 305	
n	3 289		1 927	

Appendix 3 – **continued:**

Estimates of the temporal and spatial* proportion at length of trevally from the TRE 7 single trawl fishery in 1997–98

Length	Peak		Off-peak		Combined		NMB		KMH		NTB	
(cm)	*P.i.*	*c.v.*	*P.i.*	*c.v.*	*P.i.*	*c.v.*	*P.i.*	*c.v.*	*P.i.*	*c.v.*	*P.i.*	*c.v.*
20	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
21	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
22	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
23	0.0001	0.84	0.0000	0.00	0.0001	0.84	0.0000	0.00	0.0000	0.00	0.0000	0.00
24	0.0002	0.44	0.0000	0.00	0.0002	0.44	0.0000	0.00	0.0000	0.00	0.0005	0.67
25	0.0008	0.39	0.0037	0.70	0.0010	0.33	0.0006	0.60	0.0000	0.00	0.0007	0.73
26	0.0031	0.32	0.0095	0.63	0.0036	0.28	0.0011	0.60	0.0013	0.59	0.0015	0.50
27	0.0047	0.34	0.0139	0.23	0.0054	0.28	0.0017	0.60	0.0037	0.50	0.0010	0.57
28	0.0080	0.28	0.0215	0.18	0.0090	0.24	0.0039	0.58	0.0063	0.31	0.0021	0.61
29	0.0159	0.23	0.0416	0.36	0.0179	0.22	0.0080	0.52	0.0112	0.31	0.0097	0.50
30	0.0226	0.19	0.0726	0.29	0.0265	0.20	0.0104	0.60	0.0212	0.34	0.0156	0.42
31	0.0328	0.18	0.0839	0.20	0.0368	0.17	0.0210	0.51	0.0287	0.31	0.0202	0.34
32	0.0424	0.18	0.0986	0.14	0.0468	0.17	0.0302	0.57	0.0372	0.25	0.0222	0.31
33	0.0446	0.15	0.1150	0.15	0.0501	0.14	0.0406	0.35	0.0370	0.26	0.0246	0.30
34	0.0547	0.13	0.1247	0.16	0.0602	0.12	0.0437	0.40	0.0484	0.20	0.0387	0.25
35	0.0557	0.12	0.0880	0.18	0.0582	0.11	0.0459	0.42	0.0532	0.18	0.0349	0.23
36	0.0540	0.09	0.0523	0.10	0.0538	0.08	0.0497	0.33	0.0540	0.17	0.0443	0.14
37	0.0542	0.08	0.0298	0.08	0.0523	0.08	0.0516	0.30	0.0550	0.15	0.0530	0.15
38	0.0533	0.07	0.0234	0.18	0.0510	0.07	0.0485	0.29	0.0516	0.11	0.0642	0.12
39	0.0524	0.06	0.0177	0.14	0.0497	0.07	0.0546	0.24	0.0573	0.08	0.0624	0.11
40	0.0644	0.10	0.0099	0.36	0.0602	0.11	0.0613	0.22	0.0598	0.11	0.0836	0.12
41	0.0753	0.11	0.0101	0.28	0.0702	0.12	0.0512	0.19	0.0786	0.15	0.0979	0.08
42	0.0711	0.13	0.0130	0.26	0.0666	0.13	0.0457	0.30	0.0812	0.12	0.0924	0.09
43	0.0667	0.12	0.0151	0.36	0.0627	0.12	0.0467	0.32	0.0881	0.18	0.0950	0.12
44	0.0535	0.12	0.0118	0.42	0.0502	0.13	0.0351	0.18	0.0671	0.20	0.0750	0.17
45	0.0393	0.13	0.0182	0.32	0.0377	0.13	0.0379	0.27	0.0453	0.17	0.0550	0.23
46	0.0316	0.12	0.0196	0.39	0.0306	0.12	0.0378	0.39	0.0332	0.13	0.0411	0.19
47	0.0229	0.13	0.0183	0.21	0.0226	0.12	0.0312	0.43	0.0247	0.12	0.0283	0.21
48	0.0174	0.14	0.0162	0.19	0.0173	0.13	0.0323	0.34	0.0259	0.20	0.0183	0.16
49	0.0128	0.14	0.0153	0.23	0.0130	0.13	0.0221	0.33	0.0146	0.14	0.0099	0.17
50	0.0082	0.23	0.0142	0.18	0.0087	0.21	0.0283	0.47	0.0054	0.30	0.0043	0.18
51	0.0066	0.21	0.0128	0.35	0.0071	0.19	0.0176	0.47	0.0065	0.20	0.0028	0.52
52	0.0042	0.29	0.0095	0.23	0.0046	0.25	0.0186	0.46	0.0016	0.34	0.0005	0.58
53	0.0040	0.36	0.0065	0.55	0.0042	0.32	0.0186	0.51	0.0006	0.60	0.0000	0.00
54	0.0036	0.41	0.0056	0.30	0.0038	0.36	0.0135	0.57	0.0005	0.62	0.0001	0.99
55	0.0040	0.46	0.0027	0.76	0.0039	0.43	0.0160	0.71	0.0003	0.80	0.0002	1.00
56	0.0027	0.49	0.0018	0.45	0.0026	0.46	0.0121	0.84	0.0004	0.75	0.0000	0.00
57	0.0018	0.49	0.0014	0.31	0.0018	0.46	0.0075	0.72	0.0000	0.00	0.0000	0.00
58	0.0021	0.57	0.0006	0.55	0.0020	0.56	0.0110	0.93	0.0000	0.00	0.0000	0.00
59	0.0014	0.63	0.0007	0.41	0.0013	0.60	0.0077	0.97	0.0000	0.00	0.0000	0.00
60	0.0018	0.61	0.0006	0.55	0.0017	0.59	0.0088	0.91	0.0000	0.00	0.0000	0.00
61	0.0010	0.76	0.0000	0.00	0.0009	0.76	0.0066	1.03	0.0000	0.00	0.0000	0.00
62	0.0016	0.58	0.0000	0.00	0.0015	0.58	0.0068	0.99	0.0000	0.00	0.0000	0.00
63	0.0010	0.72	0.0000	0.00	0.0010	0.72	0.0068	0.99	0.0000	0.00	0.0000	0.00
64	0.0007	0.80	0.0000	0.00	0.0006	0.80	0.0046	1.03	0.0000	0.00	0.0000	0.00
65	0.0004	0.55	0.0000	0.00	0.0003	0.58	0.0013	1.03	0.0000	0.00	0.0000	0.00
66	0.0001	0.85	0.0000	0.00	0.0001	0.85	0.0007	1.03	0.0001	1.04	0.0000	0.00
67	0.0001	0.97	0.0000	0.00	0.0001	0.96	0.0000	0.00	0.0000	0.00	0.0000	0.00
68	0.0001	0.98	0.0000	0.00	0.0001	0.98	0.0007	1.03	0.0000	0.00	0.0000	0.00
69	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
70	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
Nt	1 251 184		214 838		1 442 219		140 979		218 289		370 260	
n	22 576		3 206		25 782		2 720		5 882		5 258	

* NMB, Ninety Mile Beach; KMH, off the Kaipara and Manukau Harbours; NTB, North Taranaki Bight.

Appendix 3 **– continued:**
Estimates of the proportion at length of trevally from the TRE 7 pair trawl fishery in 1997–98

Length (cm)	Combined *P.i.*	*c.v.*
20	0.0000	0.00
21	0.0000	0.00
22	0.0000	0.00
23	0.0000	0.00
24	0.0000	0.00
25	0.0000	0.00
26	0.0003	1.02
27	0.0007	0.55
28	0.0007	1.02
29	0.0084	0.34
30	0.0213	0.36
31	0.0405	0.43
32	0.0501	0.40
33	0.0729	0.21
34	0.0650	0.16
35	0.0905	0.18
36	0.0990	0.17
37	0.0813	0.10
38	0.0577	0.21
39	0.0542	0.27
40	0.0370	0.31
41	0.0340	0.32
42	0.0337	0.39
43	0.0293	0.40
44	0.0247	0.31
45	0.0262	0.24
46	0.0162	0.31
47	0.0203	0.26
48	0.0151	0.23
49	0.0138	0.29
50	0.0131	0.25
51	0.0109	0.30
52	0.0145	0.37
53	0.0116	0.45
54	0.0122	0.36
55	0.0071	0.59
56	0.0071	0.48
57	0.0079	0.46
58	0.0039	0.78
59	0.0054	0.51
60	0.0013	0.50
61	0.0045	0.55
62	0.0027	0.51
63	0.0032	0.54
64	0.0010	0.78
65	0.0000	0.00
66	0.0005	0.78
67	0.0005	0.78
68	0.0000	0.00
69	0.0000	0.00
70	0.0000	0.00
Nt	24 337	
n	2 329	

Appendix 4 : **Estimated proportion at age and *c.v.* s for trevally fisheries in TRE 1 and TRE 7 in 1997–98**

P.j. = proportion of fish in age class. *c.v.* = coefficient of variation.

Estimates of proportion at age of trevally from the TRE 1 purse seine and single trawl fishery in 1997–98

Otolith sample size = 387

Age	Purse seine		Single trawl	
	Combined		Combined	
(years)	*P.j.*	*c.v.*	*P.j.*	*c.v.*
1	0.0000	0.00	0.0000	0.00
2	0.0000	0.00	0.0000	0.00
3	0.0089	0.70	0.0825	0.19
4	0.0641	0.25	0.2131	0.11
5	0.0760	0.24	0.1092	0.19
6	0.0544	0.32	0.0435	0.30
7	0.0472	0.32	0.0347	0.33
8	0.0337	0.39	0.0232	0.36
9	0.0579	0.29	0.0289	0.30
10	0.0913	0.23	0.0506	0.24
11	0.1294	0.19	0.0572	0.21
12	0.0885	0.22	0.0544	0.20
13	0.1459	0.16	0.0918	0.14
14	0.0470	0.30	0.0351	0.24
15	0.0310	0.35	0.0223	0.29
16	0.0123	0.44	0.0301	0.28
17	0.0386	0.33	0.0285	0.25
18	0.0087	0.68	0.0127	0.42
19	0.0057	0.56	0.0144	0.37
>19	0.0593	0.26	0.0647	0.18

Estimates of proportion at age of trevally from the TRE 7 single trawl and pair trawl fishery in 1997–98

Otolith sample size = 375

Age					Single trawl		Pair trawl	
	Peak		Off-peak		Combined		Combined	
(years)	*P.j.*	*c.v.*	*P.j.*	*c.v.*	*P.j.*	*c.v.*	*P.j.*	*c.v.*
1	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
2	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
3	0.0822	0.14	0.2213	0.13	0.0931	0.14	0.0719	0.23
4	0.1584	0.13	0.3114	0.13	0.1704	0.13	0.2165	0.14
5	0.0882	0.22	0.1034	0.26	0.0893	0.22	0.1135	0.23
6	0.0242	0.44	0.0188	0.57	0.0238	0.45	0.0315	0.49
7	0.0269	0.42	0.0193	0.64	0.0263	0.42	0.0276	0.50
8	0.0828	0.22	0.0536	0.34	0.0806	0.22	0.0866	0.26
9	0.0995	0.20	0.0595	0.32	0.0964	0.20	0.0934	0.25
10	0.0495	0.26	0.0204	0.62	0.0472	0.26	0.0275	0.31
11	0.0696	0.21	0.0211	0.24	0.0658	0.21	0.0443	0.25
12	0.0702	0.21	0.0219	0.22	0.0664	0.21	0.0444	0.22
13	0.0738	0.22	0.0289	0.28	0.0703	0.22	0.0585	0.29
14	0.0180	0.41	0.0064	0.42	0.0171	0.40	0.0118	0.36
15	0.0211	0.35	0.0119	0.39	0.0204	0.35	0.0146	0.33
16	0.0139	0.40	0.0072	0.40	0.0134	0.39	0.0154	0.37
17	0.0095	0.41	0.0107	0.37	0.0096	0.40	0.0134	0.36
18	0.0178	0.34	0.0119	0.36	0.0173	0.34	0.0180	0.30
19	0.0165	0.36	0.0104	0.34	0.0160	0.35	0.0145	0.31
>19	0.0775	0.13	0.0620	0.12	0.0763	0.13	0.0967	0.10

Appendix 5 : **Age-length keys derived from otolith samples collected from trevally fisheries in TRE 1 and TRE 7 in 1997–98**

Estimates of proportion of length at age for trevally sampled from TRE 1 during 1997–98
(Note: Aged to 01/01/98)

Length	Age (years)																			No.
(cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Aged
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
29	0	0	0.40	0.60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
30	0	0	0.70	0.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
31	0	0	0.27	0.55	0.18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
32	0	0	0	0.75	0.17	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
33	0	0	0.42	0.42	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
34	0	0	0.07	0.47	0.27	0	0.07	0.07	0	0.07	0	0	0	0	0	0	0	0	0	0	15
35	0	0	0.13	0.38	0.13	0.19	0.06	0	0.06	0	0	0	0	0	0	0.06	0	0	0	0	16
36	0	0	0	0.22	0.33	0.11	0.11	0	0	0.11	0.11	0	0	0	0	0	0	0	0	0	9
37	0	0	0	0.22	0.33	0	0.11	0.06	0.11	0	0.11	0	0	0	0	0	0	0	0	0.06	18
38	0	0	0	0.20	0.07	0.13	0.07	0.07	0	0	0.13	0	0.07	0.07	0	0	0	0	0	0.20	15
39	0	0	0.05	0.09	0.14	0.09	0.18	0.05	0.09	0.18	0.05	0	0	0.05	0	0	0.05	0	0	0	22
40	0	0	0	0	0.10	0.10	0	0	0.10	0.14	0.19	0.14	0.19	0	0	0	0.05	0	0	0	21
41	0	0	0	0.05	0.05	0.05	0.05	0.05	0.10	0.05	0.15	0.05	0.30	0.05	0	0	0	0	0	0.05	20
42	0	0	0	0	0	0	0	0.05	0	0.05	0.21	0.21	0.32	0	0	0	0.05	0.05	0	0.05	19
43	0	0	0	0	0	0.06	0	0.06	0	0.19	0.19	0.13	0.06	0.13	0.13	0	0	0	0	0.06	16
44	0	0	0	0	0	0	0	0	0.12	0.12	0.12	0.12	0.18	0	0.12	0.06	0.18	0	0	0	17
45	0	0	0	0	0	0	0	0	0	0.06	0.24	0	0.24	0.12	0.12	0.06	0.12	0	0	0.06	17
46	0	0	0	0	0	0	0	0	0.17	0	0	0.33	0.17	0	0.08	0	0	0.08	0	0.17	12
47	0	0	0	0	0	0	0	0	0	0.10	0	0.20	0.10	0.20	0	0	0	0	0.10	0.30	10
48	0	0	0	0	0	0	0	0.09	0	0	0.09	0.18	0.18	0.18	0.09	0	0.09	0	0	0.09	11
49	0	0	0	0	0	0	0	0	0	0	0	0.11	0.11	0.22	0	0.22	0	0	0.22	0.11	9
50	0	0	0	0	0	0	0	0	0	0.14	0	0.14	0.57	0	0	0	0	0	0	0.14	7
51	0	0	0	0	0	0	0	0	0	0.20	0.10	0.10	0.20	0	0.20	0.20	0	0	0	0	10
52	0	0	0	0	0	0	0	0.17	0	0.17	0	0.17	0.17	0	0	0	0.17	0.17	0	0	6
53	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0.17	0	0.17	0.17	0	0	0.17	6
54	0	0	0	0	0	0	0	0	0	0	0	0	0.14	0.14	0	0.14	0.14	0	0.14	0.29	7
55	0	0	0	0	0	0	0	0	0	0	0	0.20	0.40	0	0	0	0	0.20	0	0.20	5
56	0	0	0	0	0	0	0	0	0	0	0	0.17	0	0	0	0	0.17	0.17	0	0.50	6
57	0	0	0	0	0	0	0	0	0	0	0	0	0.17	0.17	0.17	0.17	0.33	0	0	0	6
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.50	0	0	0.50	0	4
59	0	0	0	0	0	0	0	0	0	0	0	0	0.20	0.20	0.20	0.20	0.20	0	0	0	5
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0.20	0	0.20	0	0	0	0.60	5
61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.20	0.20	0	0.20	0	0.40	5
62	0	0	0	0	0	0	0	0	0	0	0	0	0.20	0	0	0	0	0	0.20	0.60	5
63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.20	0	0.40	0	0.20	0.20	5
64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	4
65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	0	0	1
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	1
67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	1
68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total																					387

Appendix 5 **– continued:**

Estimates of proportion of length at age for trevally sampled from TRE 7 during 1997–98
(Note: Aged to 01/01/98)

Length	Age (years)																			No.
(cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Aged
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
26	0	0	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
27	0	0	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
28	0	0	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
29	0	0	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
30	0	0	0.75	0.13	0	0	0	0.13	0	0	0	0	0	0	0	0	0	0	0	0	8
31	0	0	0.30	0.60	0.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
32	0	0	0.20	0.50	0.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
33	0	0	0.20	0.70	0	0	0.10	0	0	0	0	0	0	0	0	0	0	0	0	0	10
34	0	0	0	0.50	0.20	0	0	0.10	0.10	0.10	0	0	0	0	0	0	0	0	0	0	10
35	0	0	0.10	0.50	0.10	0.10	0	0	0.20	0	0	0	0	0	0	0	0	0	0	0	10
36	0	0	0	0.20	0.30	0.10	0	0.20	0.10	0	0	0	0.10	0	0	0	0	0	0	0	10
37	0	0	0	0.13	0.13	0	0.13	0.38	0.13	0	0	0	0.13	0	0	0	0	0	0	0	8
38	0	0	0	0	0.36	0.18	0.09	0	0.09	0	0.18	0	0.09	0	0	0	0	0	0	0	11
39	0	0	0	0	0.18	0	0	0.18	0.36	0	0.09	0.18	0	0	0	0	0	0	0	0	11
40	0	0	0	0.11	0	0.06	0	0.06	0.22	0.06	0.17	0.11	0.06	0.06	0	0.06	0	0	0.06	0	18
41	0	0	0	0	0.05	0	0.05	0.25	0.05	0.25	0	0.10	0.20	0.05	0	0	0	0	0	0	20
42	0	0	0	0.05	0	0	0.05	0.10	0.10	0.15	0.15	0.20	0.10	0.05	0	0	0	0	0	0.05	20
43	0	0	0	0	0	0	0.05	0	0.16	0.05	0.21	0.26	0.21	0	0.05	0	0	0	0	0	19
44	0	0	0	0	0	0	0	0	0.05	0.10	0.15	0.05	0.05	0.05	0.10	0.05	0	0.10	0.10	0.20	20
45	0	0	0	0	0	0	0	0.05	0.05	0.05	0.16	0.05	0.21	0.05	0	0.11	0	0	0	0.26	19
46	0	0	0	0	0	0	0	0	0.20	0	0.10	0	0.10	0	0.20	0	0.10	0.10	0	0.20	10
47	0	0	0	0	0	0	0	0.10	0	0	0.10	0.30	0	0	0.10	0	0	0.20	0	0.20	10
48	0	0	0	0	0	0	0	0	0	0	0	0.10	0	0	0.10	0	0	0	0.20	0.60	10
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0.10	0	0	0.30	0.20	0	0.40	10
50	0	0	0	0	0	0	0	0	0	0	0	0	0.22	0.11	0	0	0	0	0.33	0.33	9
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.20	0	0	0	0	0.80	5
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.20	0.40	0.20	0	0.20	5
53	0	0	0	0	0	0	0	0	0	0	0	0.20	0	0	0	0	0	0	0	0.80	5
54	0	0	0	0	0	0	0	0	0	0	0	0	0.20	0	0	0.20	0	0	0	0.60	5
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0	0.25	0.50	4
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.20	0	0	0.80	5
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0	0	0.75	4
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	6
59	0	0	0	0	0	0	0	0	0	0	0	0	0.20	0	0	0	0	0.20	0	0.60	5
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.20	0	0	0	0.80	5
61	0	0	0	0	0	0	0	0	0	0	0	0	0	0.20	0.20	0	0	0.40	0	0.20	5
62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0	0.25	0	0.50	4
63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.20	0.20	0.60	5
64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.40	0	0.20	0.40	5
65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.40	0	0	0	0.60	5
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	4
67	0	0	0	0	0	0	0	0	0	0	0	0.20	0	0	0	0	0	0	0	0.80	5
68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	2
69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total																					375

Appendix 6: **Table of bootstrapped mean weighted coefficients of variation based on landings sampled and otoliths collected from the TRE 7 single trawl fishery in 1997–98**

	Number of otoliths										
Landings	200	300	400	500	600	700	800	900	1000	1100	1200
10	0.357	0.306	0.285	0.275	0.258	0.245	0.239	0.240	0.236	0.232	0.223
20	0.323	0.265	0.245	0.227	0.213	0.213	0.202	0.190	0.191	0.186	0.179
30	0.299	0.248	0.229	0.207	0.197	0.188	0.179	0.172	0.167	0.165	0.158
40	0.296	0.245	0.219	0.204	0.189	0.179	0.172	0.165	0.158	0.156	0.149
50	0.288	0.243	0.219	0.196	0.182	0.170	0.165	0.157	0.154	0.148	0.144
60	0.289	0.238	0.213	0.190	0.179	0.171	0.160	0.151	0.148	0.144	0.138