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Length and age composition of commercial trevally landings in TRE 1, 2012–13

New Zealand Fisheries Assessment Report 2014/65

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This report presents the results of Objective 1 of the Ministry for Primary Industries project "Estimation of year class strength in TRE 1" (TRE201201). The general objective was to determine the length frequency and age structure of commercial landings of trevally from TRE 1 in 2012–13 (by market sampling), for use in stock assessment models.

The length frequency and age-length key sampling approach was employed during the 2012–13 fishing year to estimate catch-at-age for trevally for the main fishing methods in TRE 1. Length frequency samples were collected from the TRE 1 bottom trawl and purse-seine fisheries, and otoliths were collected randomly from bottom trawl to form a fixed allocation age-length key, to ensure that fish in all length intervals were adequately represented. Landings were stratified by subarea (East Northland/Hauraki Gulf and Bay of Plenty) but no seasonal stratification was imposed on the sampling design.

A total of 21 bottom trawl landings (target of 20) were successfully sampled from TRE 1, with 12 784 fish measured for length and 804 otoliths aged to construct age-length keys. For purse-seine, seven landings were sampled (target of eight landings of over 10 t) with 5 175 fish measured. Estimates of proportion at length and age for the TRE 1 method fisheries were calculated according to stratified subarea specific collections, using identifiable subarea data to weight proportions of length and age for each stratum according to the estimated number of fish landed in each stratum.

The stratified length and age distributions sampled from the TRE 1 bottom trawl fishery in 2012–13 mainly comprised trevally of small and young to moderate size and age, with two-thirds of the landed catch by number less than nine years, and with moderate estimates of mean length (38.4 cm, about 1.1 kg) and mean age (8.2 years). There was reasonable representation across most recruited age classes in the fishery, the 2006 year class (7-year-olds) singularly the most dominant, accounting for almost one-fifth (18%) of the catch, with the proportion of fish occupying the aggregate (over 19 years) age group, moderate at 4%. In the purse-seine catch, stratified length and age distributions were mainly comprised of moderate to large sized trevally with good representation across most recruited age classes up to and over 20 years, particularly those between 3 and 15 years of age. This resulted in higher estimates of mean length (42.4 cm, about 1.5 kg) and mean age (9.7 years) than in the bottom trawl catch, reflective of selectivity differences between the methods. Similar to bottom trawl, the 2006 year class (7-year-olds) was also the most dominant in the purse-seine fishery and made up almost one-fifth (18%) of the catch in 2012–13.

For the third year, spatial differences in the length and age structure of bottom trawl landings in TRE 1 were examined, with independent sample collections made from the East Northland/Hauraki Gulf (combined together in 2012–13) and Bay of Plenty subareas. The bottom trawl catch from East Northland/Hauraki Gulf in 2012–13 comprised proportionally more large and very young trevally, compared to the Bay of Plenty, and displayed high variability in the recruitment strength for young age classes. The purse-seine catch from East Northland/Hauraki Gulf comprised more large and old trevally than the Bay of Plenty. Differences in relative year class strengths between the subareas were apparent.

A comparison of relative year class strengths in a time series summary between 2006–07 and 2012–13 showed that more consistency exists within subareas than between subareas and further confirms that

heterogeneous patterns exist within TRE 1 on a moderate spatial scale from north to south. The age composition of landings from the Bay of Plenty were more consistent than those from East Northland, with strong and weak year classes more easily tracked across years; reflective of comprehensive sampling, consistency in the fishery operation over the same spatial scale, and the rigorous and accurate ageing approach in place. This further demonstrates that trevally movement between subareas is relatively limited.

Estimates of mean weight- and mean length-at-age for the two fishing methods in 2012–13 were consistently higher for the East Northland/Hauraki Gulf stratum, indicative of spatial growth differences within TRE 1, and further indicating the existence of multiple biological stocks.

It is expected that the derived proportional length and age estimates presented here provide representative descriptions of the temporal and spatial spread of bottom trawl and purse-seine landings from the TRE 1 fishery for 2012–13. Precision on the combined TRE 1 length and age distributions for both methods can be considered acceptable, with mean weighted coefficient of variation (MWCV) estimates ranging from 0.17 to 0.27, thus falling below the target goal of the project of 0.30. Precision on subarea length and age distributions was more variable, with MWCVs ranging from 0.18 to 0.41, reflective of lower sample sizes and heterogeneity between sample collections.

1. INTRODUCTION

Trevally (*Pseudocaranx dentex*) is one of New Zealand's most important commercial inshore fish species. Almost 40% of the national Total Allowable Commercial Catch (TACC) of 3933 t is apportioned to TRE 1 (1507 t) encompassing the northeast coast of the North Island (Figure 1). In most recent years the greatest proportion of the TRE 1 catch has been taken by both the bottom trawl and purse-seine methods, mainly from the eastern Bay of Plenty and northern East Northland. Most trevally is caught as the target species (over 80% in 2012–13), but it is also taken as a bycatch when targeting other species, usually snapper (*Pagrus auratus*) in the trawl fisheries. The annual TRE 1 catch in recent years has increased from just over half the Total Allowable Commercial Catch (TACC) taken between 2007–08 and 2009–10, to an average of 83% of the TACC between 2010–11 and 2012–13 (Figure 2, Ministry for Primary Industries 2014).

Catch sampling of the TRE 1 commercial landings for length and age composition took place intermittently from 1972 to 1978 (James 1984, unpublished data) and was resumed in the 1997–98 fishing year (Walsh et al. 1999) as part of a new stock monitoring programme instigated by the Ministry of Fisheries. Annual sampling from the main fishing methods continued in the TRE 1 fisheries until 2002–03 and the data summarised in a series of subsequent reports (Walsh et al. 2000, Langley 2001, 2002, 2003, 2004) and in reviews by Langley (unpublished) and Walsh & McKenzie (2009). The programme was reinstated in 2005–06 (Langley 2009) and continued to 2008–09 (Walsh et al. 2010a, 2010b, 2012b) with sampling conducted on the TRE 1 purse-seine fishery with additional collections being directed to the TRE 1 bottom trawl fisheries. This programme had a secondary aim of investigating patterns of spatial heterogeneity within the stock. A summary of the various method and subarea strata that have been sampled from TRE 1 since 1997–98 is presented in Appendix 1.

This report presents the results of market sampling from the TRE 1 stock for both bottom trawl and purse-seine between October 2012 and September 2013 and thus continues the time series. Funding for this project, TRE2012/01, was provided by the Ministry for Primary Industries (MPI).

The specific objectives of this project for 2012–13 were:

1. To characterise the TRE 1 fishery by analysing existing commercial catch and effort data to the end of 2012/13 fishing year.

2. To conduct representative sampling to determine the length, sex and age composition of the commercial catch of trevally in TRE 1 during the 2012/13 fishing year.

3. To explore the time series of catch sampling data, in particular, for any significant changes in the length and age composition of commercial catches.

2. METHODS

2.1 Characterisation of recent fishery profile data for TRE 1, 2007–08 to 2012–13

A characterisation of patterns in the TRE 1 fishery over the period October 2007 through to September 2013 was undertaken using data extracted from the MPI commercial catch reporting system. All effort details and associated catch weights (all species including trevally) from all trips landing TRE 1 were requested.

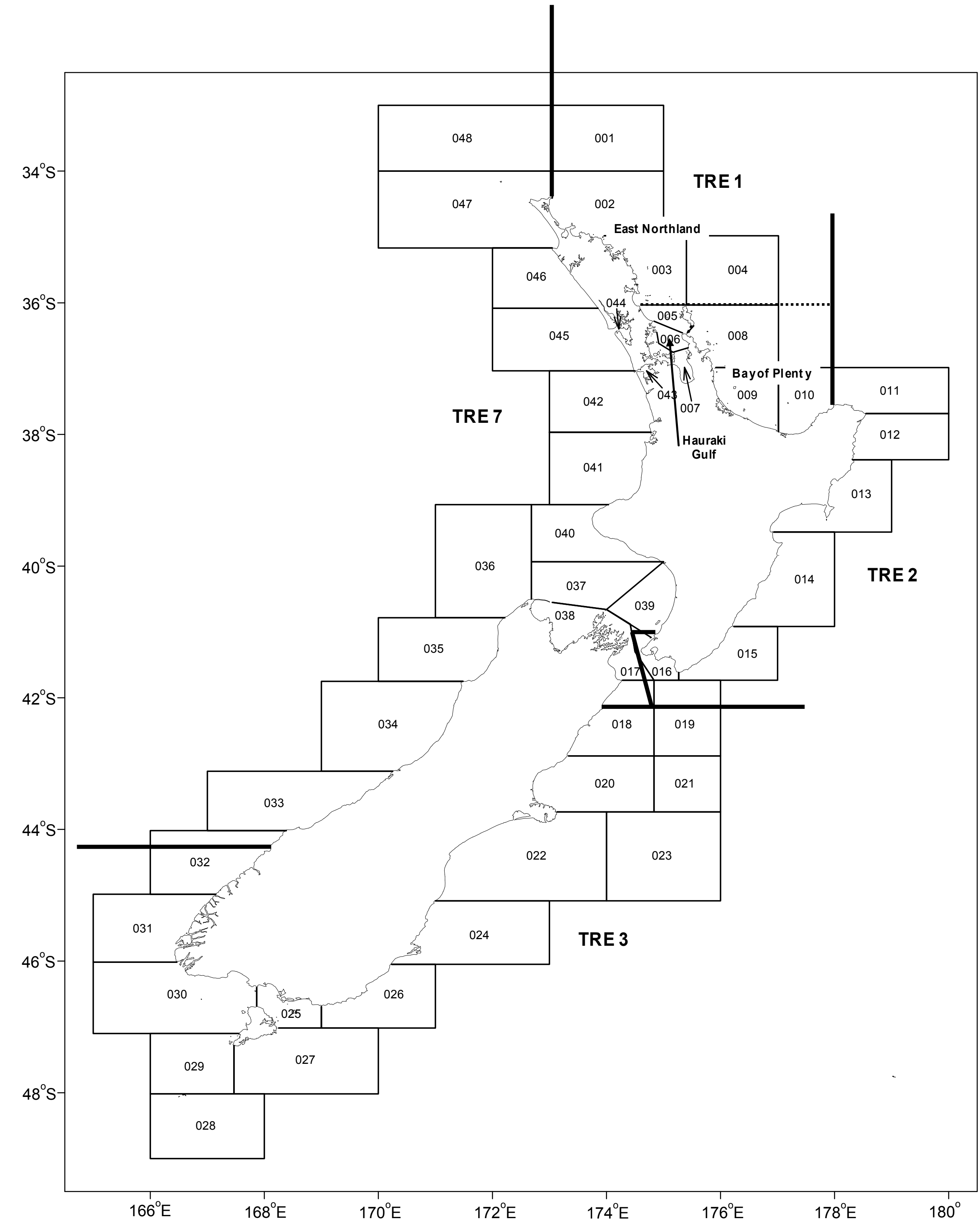

Figure 1: Trevally quota management areas, statistical areas, and locations referred to in the text. Dashed lines represent the boundaries separating the subareas that make up the TRE 1 stock.

Data obtained from MPI was groomed and checked for typical reporting errors. Information to perform the characterisation was compiled in two tables:

1. Landed catch weight: A file containing the verified green (unprocessed) landed weight of all TRE 1 trips.
2. Trip specific data: A file containing demographic information (location, method, target species, estimated catch etc).

Although the trip effort data table has information on catch, these are only fisher estimates. The process followed was to prorate the actual trip landed weight totals across the effort information (location, method, target species) on the basis of the estimated catch ratios. The link between the two data tables was the common trip number field (trip_key).

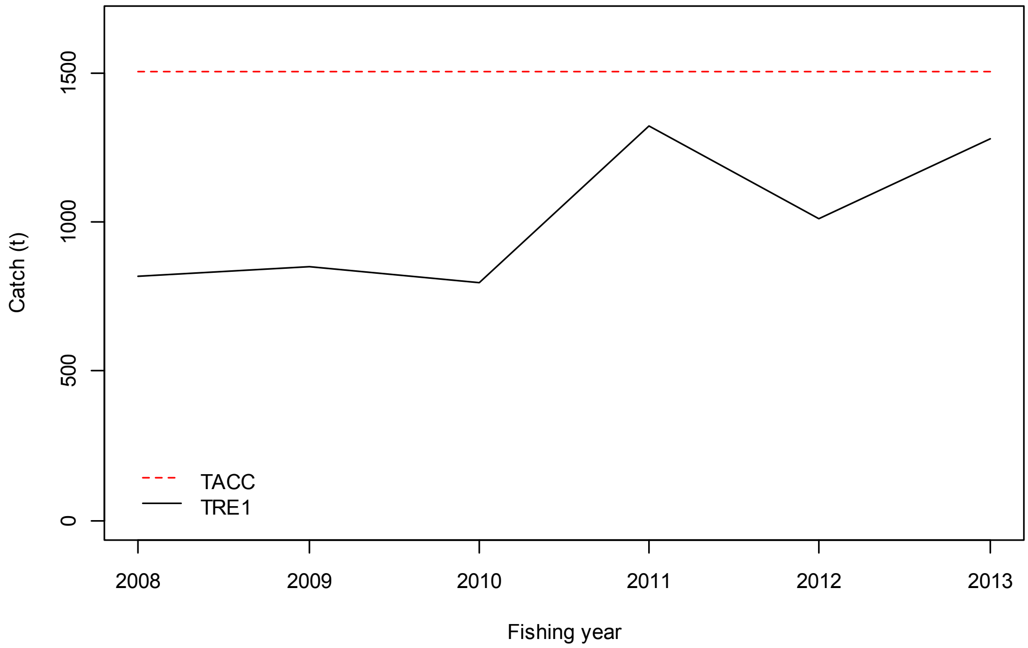

Figure 2: Reported landings of trevally in TRE 1 and TACCs for 2007–08 to 2012–13.

2.2 Design of TRE 1 sampling in 2012–13

Landings were stratified by subarea (East Northland/Hauraki Gulf and Bay of Plenty) and sample collections made from the main commercial methods that operate in TRE 1: bottom trawl and purse-seine. There was no seasonal stratification imposed on the sampling other than it be conducted over the "peak" period when trevally is landed by these methods. The subarea for each of the bottom trawl landings was identified by communication with the skipper during the fishing trip and before sampling. The stratum sample collections were confirmed some months after sampling based on data received from the MPI catch and effort returns.

Subarea stratification of the TRE 1 fishery was first used by James (1984) who investigated the age, biology and fisheries of trevally during the 1970s. The same stratification was used by Walsh et al. (2010a, 2010b, 2012b) who found consistent heterogeneous patterns in catch-at-age over consecutive years between the East Northland and Bay of Plenty subareas of TRE 1. For sampling in 2012–13, a concerted effort was made to ensure that only clean subarea samples were collected from landings identified as coming from two subareas: East Northland/Hauraki Gulf and Bay of Plenty (see Figure 1). A very small proportion of the TRE 1 annual catch is taken from the Hauraki Gulf, hence it has not been practicable to collect age data specifically from this area. The Hauraki Gulf subarea was combined with East Northland in 2012–13 because bottom trawl vessels operating from the port of

Auckland regularly fish in both subareas during a single trip, and no "at-sea" sampling was able to be instigated to sample them separately (unlike in TRE 7, Walsh et al. 2014c). It is not known whether the age composition and growth rates of Hauraki Gulf trevally are more similar to East Northland or the Bay of Plenty.

Sampling TRE 1 bottom trawl and purse-seine landings

The length frequency and age-length key sampling design implemented in the TRE 1 bottom trawl and purse-seine fisheries in 2012–13 to estimate catch-at-age, has been the preferred sampling method since 1997–98. This design allows for a single age-length key sample to be collected from the bottom trawl fishery in each subarea and length frequency samples to be collected from both fishing methods, therefore eliminating the cost of ageing additional otolith samples from the purse-seine fishery. Bottom trawl samples comprise a wide range of fish sizes and are assumed to provide a roughly random sample of the length composition of the portion of the population fully recruited to the fishery, as opposed to samples from purse-seine which tend to have highly variable size-selectivity due to the size structure of the targeted schools (Walsh et al. 1999).

As part of the trevally catch sampling review, Walsh & McKenzie (2009) undertook an optimisation analysis for various catch sampling designs. The optimisation results for the length frequency and age-length key approach indicated that a mean weighted coefficient of variation (MWCV) of 0.20 for TRE 1 bottom trawl catch-at-age estimates could be achieved by sampling about 20 landings and through the application of a 900 otolith age-length key. A MWCV of 0.20 could be achieved for TRE 1 purse-seine if a similar size age-length key was applied to length data from 10 sampled landings, however, in the past decade the greatest number of purse-seine landings in the fishery was typically less than this, so a MWCV of 0.20 would most likely be unachievable. This design was implemented in 2006–07, 2007–08 and 2008–09, but with targets of 10 landings and about 450 otoliths for each subarea bottom trawl fishery. In 2012–13, the goal of the programme was slightly modified to achieve a MWCV of 0.30 (for each method) in the TRE 1 stock after stratum amalgamation using the target sample sizes (length frequency samples and age-length key) outlined above and in Table 1. The sampling design for TRE 1 specified that bottom trawl landings were to be of a minimum catch weight of at least 750 kg for the East Northland/Hauraki Gulf subarea and 1 t for the Bay of Plenty subarea, and that all purse-seine landings over 10 t of trevally were to be selected for sampling.

Table 1: Level of sampling proposed to describe the TRE 1 subarea-method fisheries in 2012–13.

Stock	Subarea	Method	Minimum landing size	Number of landings*	Number of otoliths in age-length-key
TRE 1	East Northland/Hauraki Gulf	Bottom trawl	0.75 t	10	~450
		Purse-seine	>10 t	1–10	
	Bay of Plenty	Bottom trawl	1 t	10	~450
		Purse-seine	>10 t	1–10	

*Although the total number of TRE 1 purse-seine landings is 1–10, the number to be sampled in each stratum cannot not be specified *a priori*

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. For bottom trawl landings, a random sample of about 20–30 bins (dependent on bin capacity) was selected. Sampling of purse-seine catches as described by Walsh et al. (1999) was slightly modified in that each hold (from a total of four) was treated as a separate stratum. A random sample of four bins of trevally was collected from the top, middle, and bottom of each hold as the fish were unloaded. 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 adopted for trevally.

Otolith collections and ageing of TRE 1 samples in 2012–13

Otoliths were collected as a subsample of all landings sampled for length frequency to create age-length keys (refer Davies & Walsh 1995). Samples taken from TRE 1 bottom trawl landings encompassed the period January–August. The purpose of the keys was to convert catch length frequency information to age frequency. It was assumed that age was distributed randomly within each sampled centimetre length class (Southward 1976). A fixed allocation sample for each length class was determined from the proportion of fish in each length class in bottom trawl length frequency samples in TRE 1 from 1999–2000, but was broadened to ensure that fish in all length intervals were well represented (Appendix 2). Otolith sample sizes were capped at 20 for the common length class intervals (35–40 cm), and a step-wise sample size of about fifteen fish for length intervals greater than 40 cm, ten fish over 46 cm, five fish over 55 cm, three fish over 60 cm, and one fish for all length classes 65 cm and above was specified for collection. This resulted in about 450 otolith samples targeted for collection from each subarea, East Northland/Hauraki Gulf and Bay of Plenty, and the overall target allocation for TRE 1 would therefore sum to about 900 (Table 1). To ensure spatial and temporal representativeness in the sample collections, a target of about 45 otoliths was collected from all bottom trawl landings sampled for length frequency within a subarea until the target sample sizes for each length class within the age-length key were achieved. Those size classes that were uncommon in landings (i.e., very small or large fish) were often targeted for otoliths when available to samplers in order to fulfil the age-length key requirements as best as possible. The collection of otoliths from large and small fish was therefore opportunistic and roughly random throughout the year.

All trevally otoliths were prepared using the thin section technique as described by Stevens & Kalish (1998) and Tracey & Horn (1999) and a standardised procedure for reading otoliths was documented in an age determination protocol for trevally (Walsh et al. 2014a). In a review of trevally catch sampling, Walsh & McKenzie (2009) determined that inconsistencies observed in the relative year class strengths of trevally catch-at-age data from collections prior to 2006–07 were most likely a result of ageing error caused by two main factors: the misinterpretation of growth zones in difficult otolith sections, and the inaccurate determination of the margin relative to the sample collection and birth dates. A more rigorous approach to ageing trevally was adopted in 2006–07 to improve reader accuracy and increase the level of between-reader agreements (now documented in a trevally age determination protocol by Walsh et al. (2014a)), and this approach was followed for 2012–13. In summary, this approach focused on a few main aspects: the interpretation and location of the first annulus; forcing an expected margin on the reader relative to the otolith collection date; and allowing the readers access to a variety of otolith images from previous collections. The forced margin method was implemented to anticipate the otolith margin type (wide, line, narrow) *a priori* in the month in which the fish was sampled to provide guidance in determining age, and was found to be essential for ageing trevally sampled throughout the fishing year (October to September). To determine the "fishing year age class" of fish using the forced margin, 'wide' readings are increased by 1 year (e.g., 3W is aged as a 4 year old) and 'line' and 'narrow' readings remain the same as the zone count (e.g., 4L or 4N are aged as a 4 year old), meaning that regardless of whether the fish was caught before or after the nominal birth date of 1 January, age remains the same throughout, unlike that which would be used for age groups/age classes or in growth rate estimation (see Walsh et al. 2014a). As a result, there has been considerable improvement in recent years in reader accuracy and precision in ageing trevally (Walsh et al. 2010a, 2010b, 2012a, 2012b, 2014c).

As part of the development of the age determination protocol for trevally, a reference collection numbering approximately 500 preparations was compiled and documented from previously prepared archived samples (Walsh et al. 2014a). Reference collections are used to ensure consistent ageing between readers and across time. To assess reader competency in ageing trevally otoliths in 2012–13, each of the two selected readers aged a subsample of 50 reference otolith preparations with an aim of achieving a pass mark score for Index of Average Percentage Error, IAPE (Beamish & Fournier 1981), and mean coefficient of variation (CV) (Chang 1982), of 2.50% and 3.54% respectively (see Walsh et al. 2014a).

Once reader competency was established, both readers read the entire TRE 1 otolith collection from 2012–13 independently to determine an unbiased reading estimate. Counts that agreed were accepted as the final reading. If counts disagreed, then the otolith was reviewed again by both readers with an experienced third reader present to reach agreement, or discarded if deemed to be unreadable; but only if it was of an age less than 20 years, as samples over 19 years were combined into an aggregate age group for the analysis. It was envisaged that discarding a few unreadable otoliths from the age-length key should have minimal effect on the sample collections and was likely to improve the precision in estimates of catch-at-age. Reading precision for the TRE 1 otolith collections from 2012–13 was quantified by carrying out between-reader comparison tests after Campana et al. (1995), including those between each reader and the agreed age, with IAPE and CV calculated for each test.

Catch-at-age analysis

The National Institute of Water and Atmospheric Research (NIWA) catch-at-length and -age analysis software tool CALA (catch-at-length and -age, Francis & Bian 2011) was used in the calculation of proportions at length and age, and variances for length frequency samples and the age frequencies of aged fish used for age-length keys. For sample collections from the TRE 1 bottom trawl and purse-seine fisheries in 2012–13, estimates of proportion at length and age (and coefficient of variation) were calculated for each stratum, and then combined to calculate weighted mean estimates. CALA scales up the numbers of fish in the samples to numbers of fish in landings and finally the numbers of fish in each subarea stratum, based on the weights of both samples and landings. Bootstrap variances were determined for the combined and subarea proportion at length and proportion at age estimates of TRE 1.

The calculation of mean weight-at-age and variances followed Quinn II et al. (1983), with a length-weight relationship: w (g) = 0.016 $l^{3.064}$ (cm) from James (1984). Proportions at age, mean length-at-age and mean weight-at-age (with estimates of coefficient of variation, CV) were calculated for the range of recruited fishing year age classes (herein referred to as “age classes” encompassing October 2012 to September 2013), with the maximum age being an aggregate of all age classes over 19 years. Estimates of mean age determined from year-round catch-at-age estimates were calculated such that all fish comprising the aggregate (over 19 years) age group were assigned an age of 20.

Trevally length and age data are stored on the MPI *market* and *age* databases respectively, administered by NIWA.

3. RESULTS

3.1 Characterisation of TRE 1, 2007–08 to 2012–13

Annual TRE 1 catch by subarea

Between 2007–08 and 2012–13 the annual TRE 1 catch has been disproportionate between subareas, the largest proportion consistently taken from the Bay of Plenty (Figure 3). The catch from the East Northland/Hauraki Gulf subarea increased substantially in 2012–13 to be the largest in six years (Figure 3).

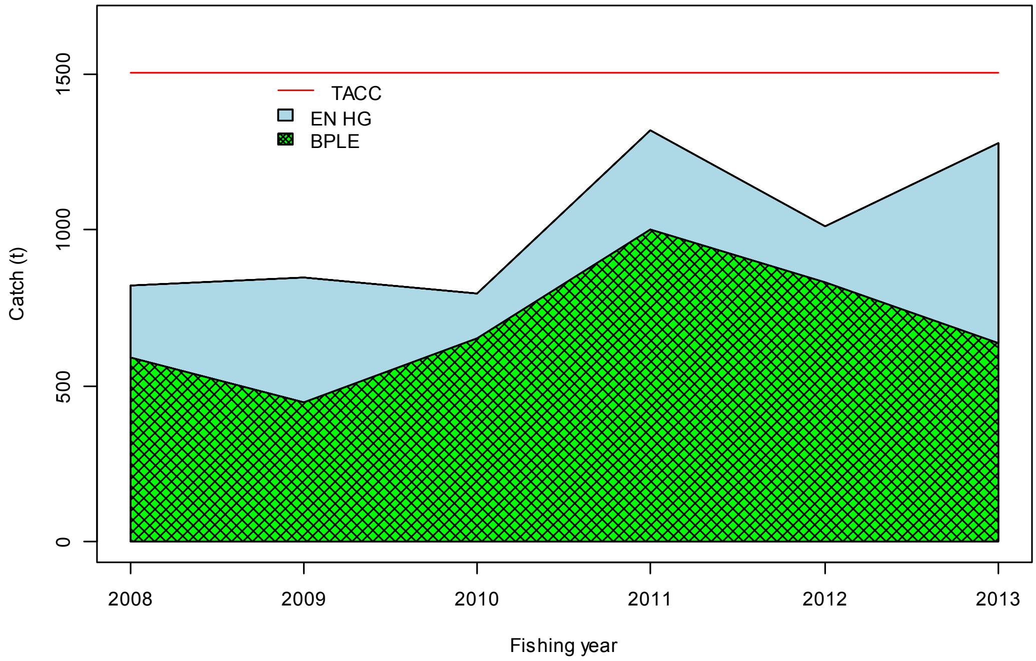

Figure 3: Annual TRE 1 catch by subarea for 2007–08 to 2012–13. ENHG, East Northland/Hauraki Gulf; BPLE, Bay of Plenty.

Relative catch by method for the subareas of TRE 1

Overall, bottom trawl and purse-seine were the dominant fishing methods in both subareas of TRE 1, with the catch from bottom trawl largely consistent through time (Figure 4, Appendix 3). A recent shift in purse-seine effort for trevally away from the Bay of Plenty to the East Northland/Hauraki Gulf subarea is evident. In 2012–13, bottom trawl and purse-seine accounted for 34% and 56% of the total TRE 1 catch (1301 t) respectively.

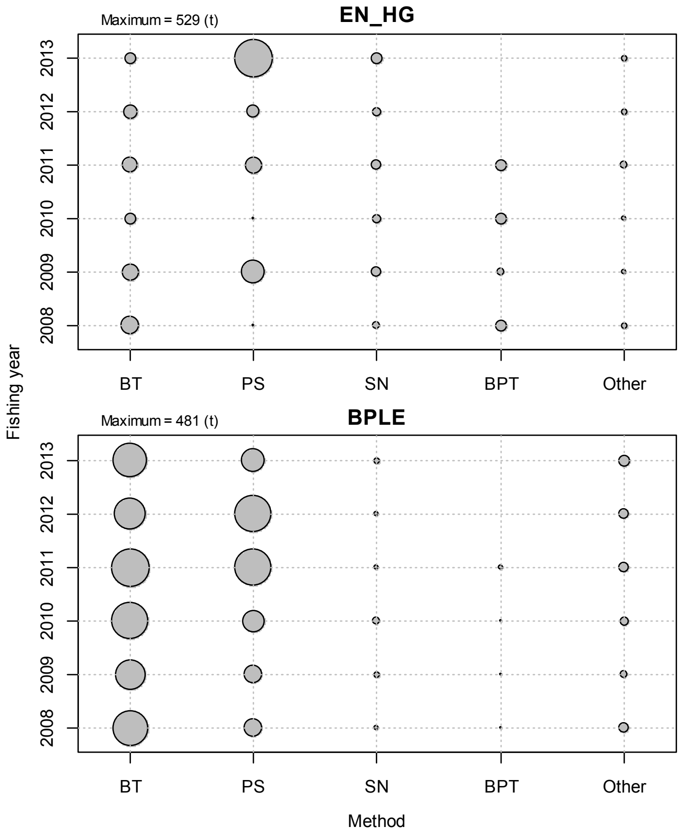

Figure 4: Relative annual trevally catch by method for the TRE 1 subareas from 2007–08 to 2012–13 (BT, bottom trawl; PS, purse-seine; SN, set net; BPT, bottom pair trawl). Scales differ between subareas.

Spatio-temporal distribution and target species of the bottom trawl and purse-seine commercial catch

The TRE 1 bottom trawl catch by statistical area for the period 2007–08 to 2012–13 shows that the most significant catches of trevally are consistently taken from the central and eastern Bay of Plenty, statistical areas 009 and 010 (Figure 5, Appendix 4a). Bottom trawl catches from the East Northland/ Hauraki Gulf subarea, principally from statistical areas 002, 003 and 005, although small in comparison, have remained relatively consistent over time. The TRE 1 purse-seine catch by statistical area over the same time period appears more variable between years than bottom trawl. Nevertheless, significant catches have been made over most years from the western and central Bay of Plenty, statistical areas 008 and 009, and in 2012–13 from East Northland, statistical area 002 (Figure 6, Appendix 4b).

Although caught year-round, most of the bottom trawl catch of trevally in recent years in the East Northland/Hauraki Gulf subarea has been taken over spring, summer and autumn, although catches in 2012–13 were highest during late autumn and winter (Figure 7). Catches from the Bay of Plenty bottom trawl fishery are typically concentrated around the summer and autumn months. For purse-seine, catches of trevally are seasonal, typically concentrated around periods when more valuable species such as skipjack tuna are absent, usually spring, early summer and winter (Figure 8). In 2012–13, purse-seine catches from East Northland were taken only in November and December, and from the Bay of Plenty, during winter.

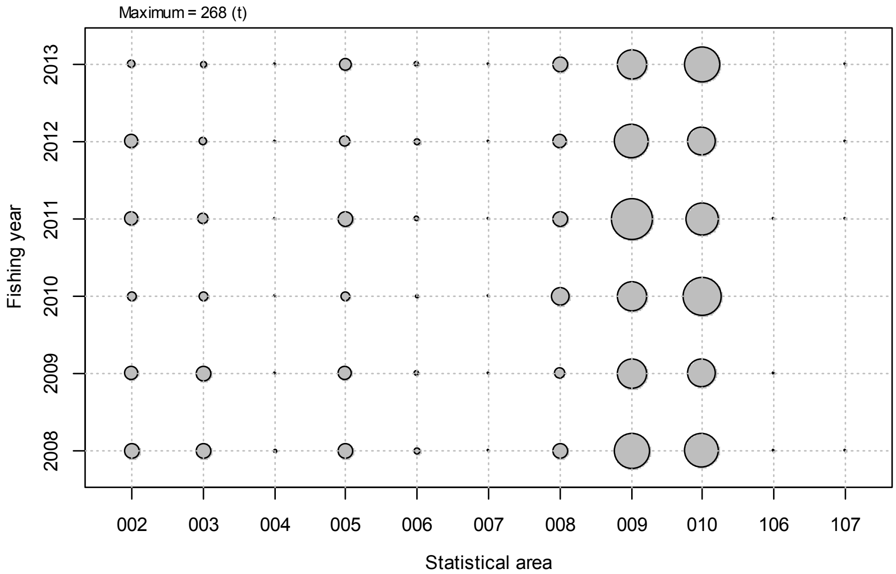

Figure 5: Relative annual bottom trawl trevally catch by statistical reporting area within the TRE 1 fishstock, 2007–08 to 2012–13.

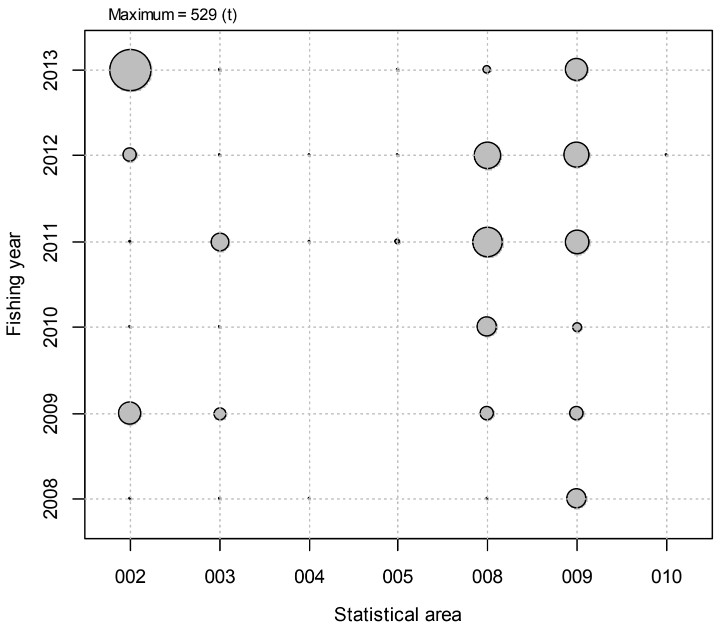

Figure 6: Relative annual purse-seine trevally catch by statistical reporting area within the TRE 1 fishstock, 2007–08 to 2012–13.

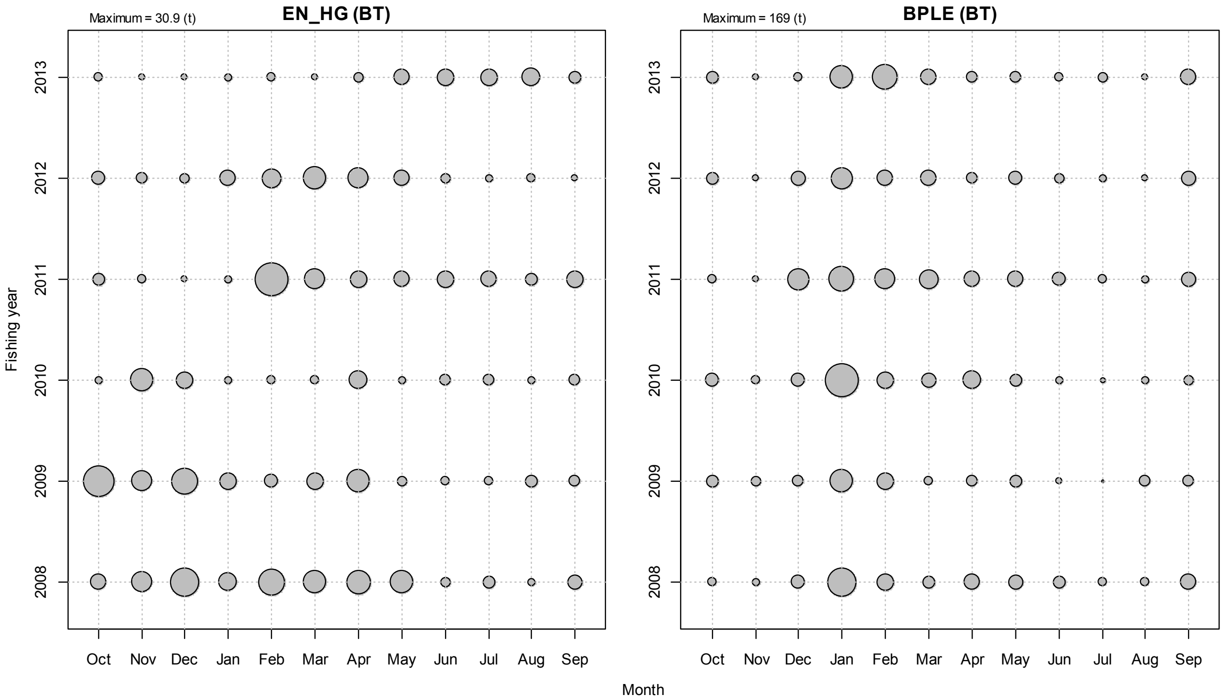

Figure 7: Relative annual bottom trawl trevally catch by month for the subareas of TRE 1, 2007–08 to 2012–13. Scales differ between subareas.

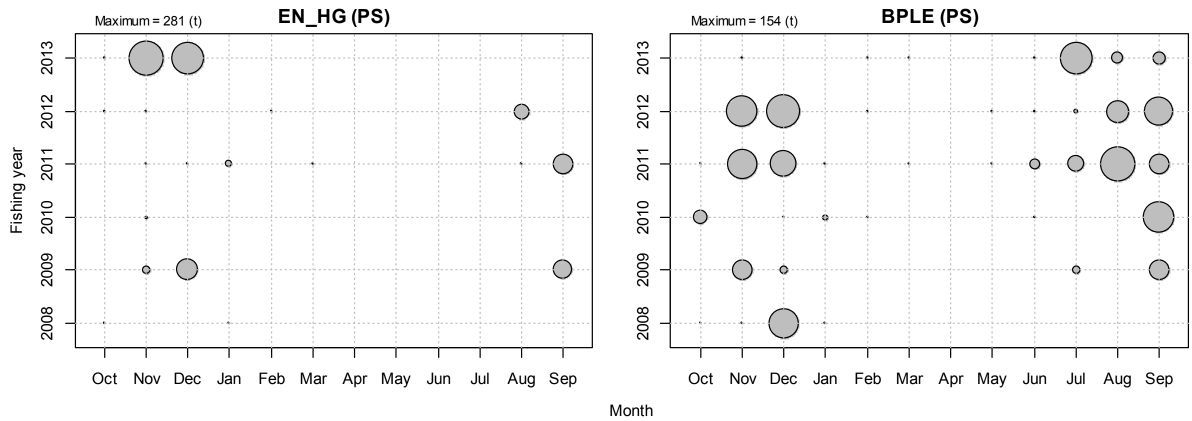

Figure 8: Relative annual purse-seine trevally catch by month for the subareas of TRE 1, 2007–08 to 2012–13. Scales differ between subareas.

In almost all years, trevally was the main target species used when trevally was caught in both TRE 1 subarea bottom trawl fisheries (Figure 9, Appendix 5a) although significant catches of trevally were also made while targeting snapper in both subareas and John dory (*Zeus faber*) in East Northland/Hauraki Gulf. In recent years, trevally has been the main target species in both TRE 1 subarea purse-seine fisheries (Figure 10, Appendix 5b).

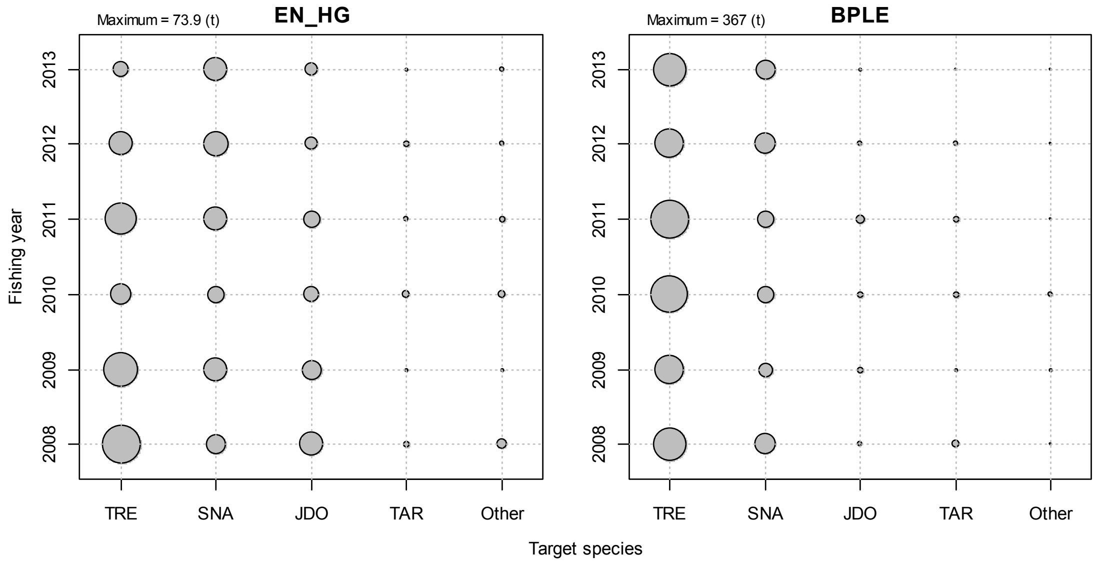

Figure 9: Relative annual bottom trawl trevally catch by target species for the subareas of TRE 1, 2007–08 to 2012–13 (TRE, trevally; SNA, snapper; JDO, John dory; TAR, tarakihi). Scales differ between subareas.

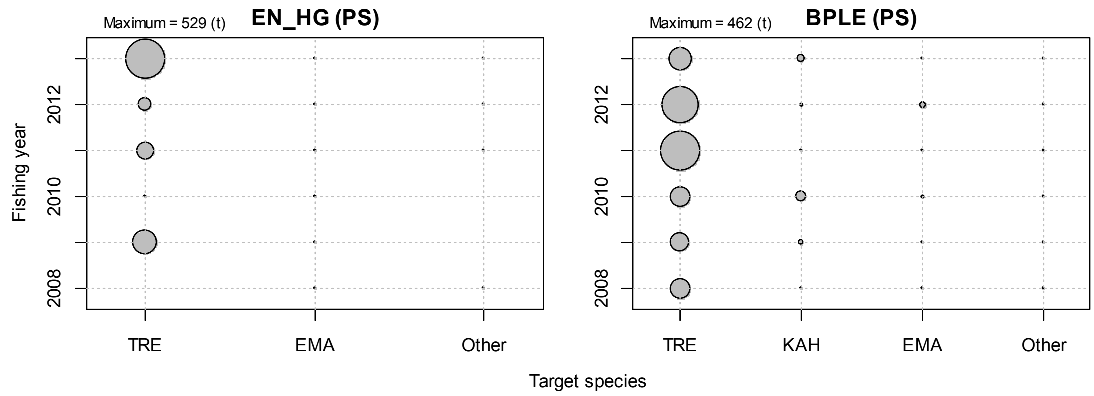

Figure 10: Relative annual purse-seine trevally catch by target species for the subareas of TRE 1, 2007–08 to 2012–13 (TRE, trevally; KAH, kahawai; EMA, blue mackerel). Scales differ between subareas.

3.2 Sampling of the TRE 1 bottom trawl and purse-seine fisheries in 2012–13

Sample collections

Summaries of the length frequency sample sizes for bottom trawl and purse-seine taken from each subarea stratum within TRE 1 in 2012–13 are given in Table 2. A total of 21 bottom trawl landings were successfully sampled, with four landings omitted from the collection, either due to inadequate sample size or because they were caught by a fishing method other than bottom trawl. In all, ten bottom trawl landings were sampled from East Northland/Hauraki Gulf and eleven landings from the Bay of Plenty, meeting the proposed subarea sampling targets of ten (Tables 1 and 2). For purse-seine, with the exception of one 20 t landing of trevally from September 2013, all other landings of over 10 t (n = 7) were successfully sampled from the TRE 1 fishery in 2012–13 (Table 2). A total of 12 784 fish were measured for length frequency from the bottom trawl fishery and 5 175 fish from the purse-seine fishery.

Table 2: Summary of the trevally catch (total number and weight of landings) and samples (number of landings and weight sampled, and number of fish measured) in method–subarea strata for the TRE 1 bottom trawl and purse-seine fisheries in 2012–13.

		Number of landings			No. of fish	Weight of landings (t)		
Method	Subarea*	Total	Sampled	% of total	measured	Total	Sampled	% of total
Bottom trawl	ENHG	285	10	3.5	5 733	53	15	28.3
	BPLE	343	11	3.2	7 051	386	70	18.1
	TRE 1†	547	21	3.8	12 784	439	85	19.4
Purse-seine	ENHG	9	5	55.6	4 046	529	529	100.0
	BPLE	14	2	14.3	1 129	182	150	82.4
	TRE 1	23	7	30.4	5 175	711	679	95.5

* BPLE = Bay of Plenty; ENHG = East Northland and Hauraki Gulf combined.
† The TRE 1 bottom trawl total number of landings does not equal the combined subareas total as a vessel may fish over more than one subarea per trip.
The number and weight of landings is for all bottom trawl and purse-seine landings containing trevally (target and bycatch) caught from TRE 1.

The average weight of the sampled landings from the TRE 1 bottom trawl fishery in 2012–13 was 4.060 t, with a relatively broad range spanning 0.539 to 18.772 t, and for purse-seine, the average weight of sampled landings was 97.053 t, and the range spanned 12.491 to 142.040 t. The sampled component accounted for 19% by weight and 4% by number of the total bottom trawl catch and 96% by weight and 30% by number of the total purse-seine catch in TRE 1.

A total of 827 otolith pairs were subsampled from the TRE 1 subarea bottom trawl length frequency samples in 2012–13, with 804 (97%) of these successfully aged (Table 3). Length distributions of otolith sample collections as a comparison to that targeted for TRE 1 subarea bottom trawl strata are presented in Appendix 2.

Table 3: Details of trevally otolith samples collected in 2012–13 from TRE 1.

Method	Subarea*	Sampling period	Sampling method	Length range	Number collected	Number aged
Bottom trawl	ENHG	Apr–Aug 2013	Stratified random	26–69	402	389
	BPLE	Jan–May 2013	Stratified random	27–61	425	415
	TRE 1	Jan–Aug 2013	Stratified random	26–69	827	804

* BPLE = Bay of Plenty; ENHG = East Northland and Hauraki Gulf combined.

3.3 Sampling representativeness

Monthly catch comparisons for bottom trawl

A temporal comparison of the monthly catch of trevally and of that sampled (weight and number of landings) for the bottom trawl method (all landings and those greater than 750 kg for East Northland/Hauraki Gulf and 1 t for Bay of Plenty (i.e., candidate landings)) is presented in Figure 11 to display the seasonal patterns in the fisheries and the representativeness of the sample collections. Although trevally may be caught year-round, the greatest proportion of the bottom trawl catch in East Northland/Hauraki Gulf was over the autumn and winter months, and in the Bay of Plenty, over the summer months. Although temporal sampling coverage was restricted by the availability of candidate landings, particularly in East Northland/Hauraki Gulf, overall, it was generally well aligned to the operation of the respective fisheries, more so in East Northland/Hauraki Gulf than in the Bay of Plenty (Figure 11). Furthermore, more large landings were sampled from the Bay of Plenty during January and February than other months, and it is likely that this reflects the peak spawning period for trevally.

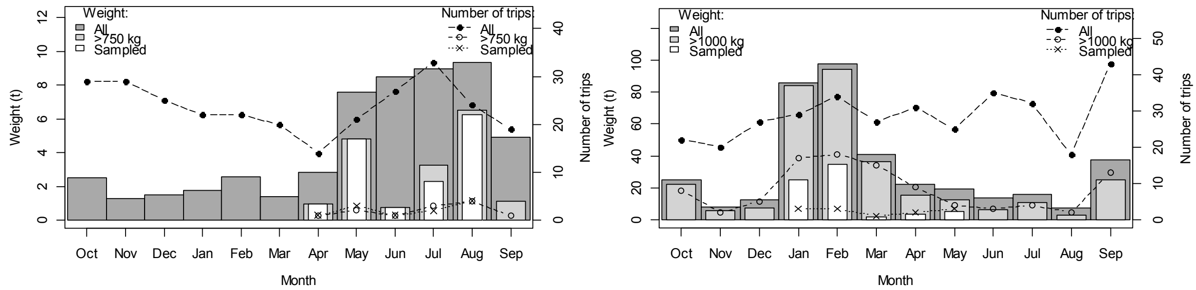

Figure 11: Comparison of the monthly distributions of landed weight and number of landings of trevally in the TRE 1 bottom trawl subarea fisheries (East Northland/Hauraki Gulf left, Bay of Plenty right) for all landings where trevally was caught in 2012–13. Also provided are monthly weight and number of landings to qualifying trips, and the weight and number of landings sampled. Note: bars and lines are overlaid.

The sampling performance relative to the cumulative proportion of the total number and catch weight of bottom trawl landings throughout the sampling period illustrates that sampling was marginally more temporally consistent with the fishery operation for the East Northland/Hauraki Gulf subarea relative to the availability of candidate landings, than for the Bay of Plenty subarea (Figure 12).

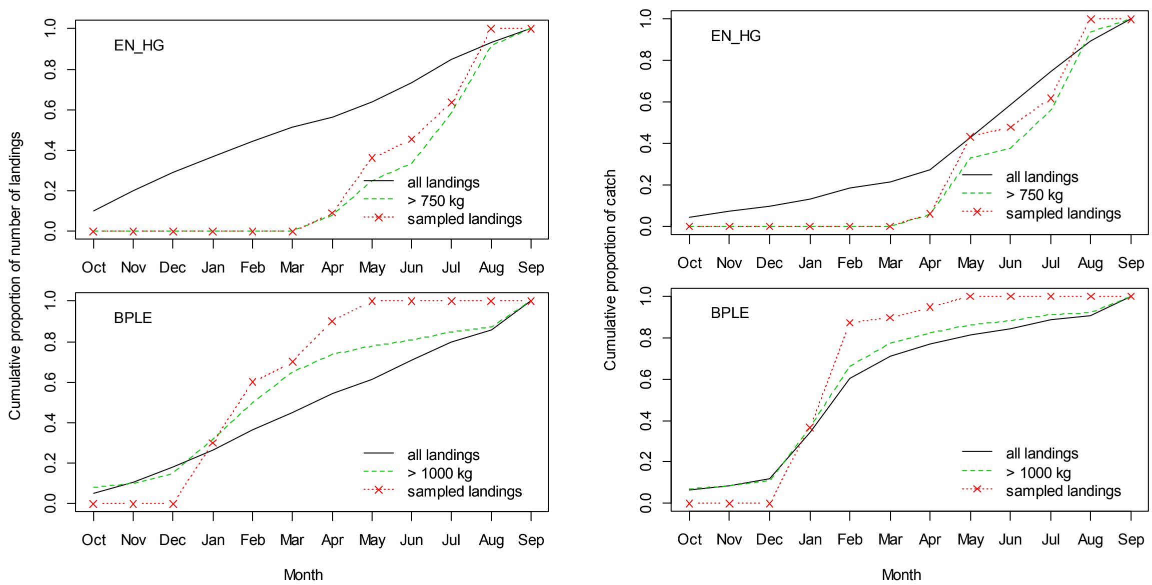

Figure 12: Comparison of the cumulative proportion of the number of landings (left) and catch weight of landings (right) with samples taken from the TRE 1 bottom trawl subarea fisheries in 2012–13. ENHG, East Northland/Hauraki Gulf; BPLE, Bay of Plenty.

Monthly catch comparisons for purse-seine

A temporal comparison of the monthly catch of trevally and of that sampled (weight and number of landings) for the purse-seine method (all landings and those greater than 10 t) is presented in Figure 13 to display the seasonal patterns in the TRE 1 fishery and the representativeness of the sample collections. As seven of the eight candidate purse-seine landings were sampled in 2012–13, the temporal spread of landings and the sampling performance relative to the cumulative proportion of the total number and catch weight of landings was well aligned and consistent with the operation of the fishery (Figures 13 and 14).

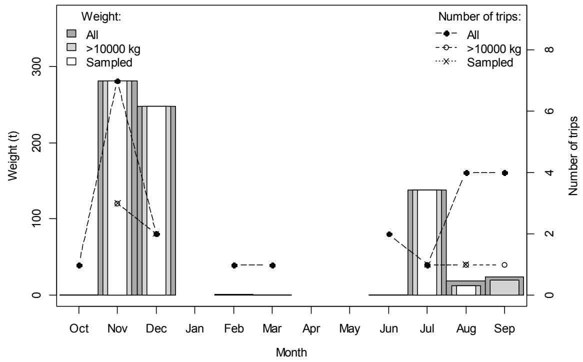

Figure 13: Comparison of the monthly distributions of landed weight and number of landings of trevally in the TRE 1 purse-seine fishery for all landings where trevally was caught in 2012–13. Included are corresponding estimates for all sampled landings to show representativeness of collections. Note: bars and lines are overlaid.

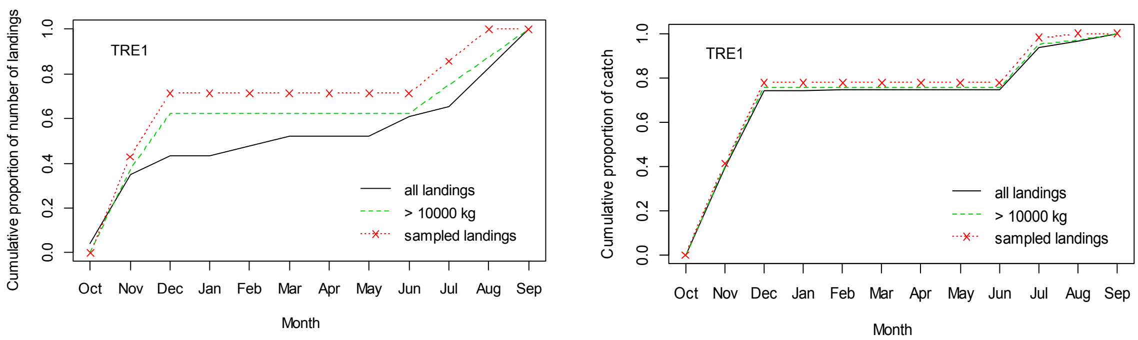

Figure 14: Comparison of the cumulative proportion of the number of landings (left) and catch weight of landings (right) with samples taken from the TRE 1 purse-seine fishery in 2012–13.

Spatial catch, statistical area, target species and depth distribution comparisons for bottom trawl

Fine scale spatial comparisons (0.1 degree blocks) of the proportional distribution of the estimated TRE 1 bottom trawl commercial catch and sampled catch for 2012–13 shows that the majority (95%) of the catch, as well as the sampled component, was taken from coastal regions between Bream Tail and Cape Runaway, statistical areas 005, 008–010 (Figure 15). Samples from the bottom trawl fishery predominantly came from the far north of East Northland, the outer Hauraki Gulf and western and eastern Bay of Plenty, the latter area comprising the largest catches in 2012–13. With the exception of the central Bay of Plenty region (principally statistical area 009), the sampled component was generally spread throughout areas where the commercial bottom trawl fishery operated in 2012–13, suggesting that sampled landings, overall, are likely to be spatially representative of the TRE 1 fishery (Figure 15).

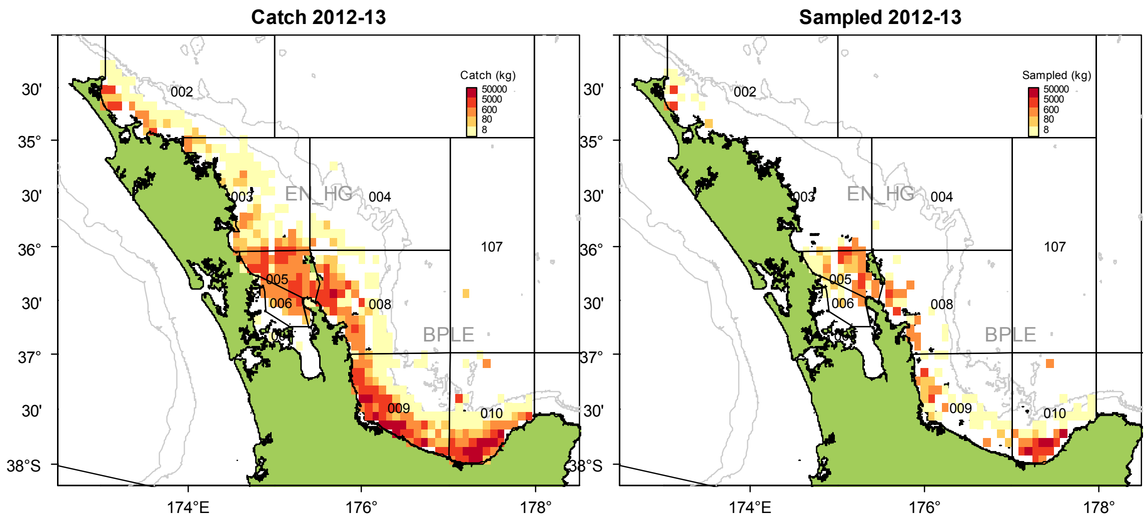

Figure 15: Comparison of the spatial distribution of the bottom trawl trevally catch and the sampled component for the TRE 1 stock in 2012–13.

A comparison of the proportional distribution of the estimated bottom trawl catch of trevally with that sampled in 2012–13 for the statistical areas that make up TRE 1 indicates that sampling appears spatially consistent to the fishery operation with the exception of the samples from vessels fishing in the central and eastern Bay of Plenty, statistical areas 009 and 010 (Figure 16). Furthermore, it was from both these statistical areas that by far the greatest proportion (approximately 80%) of the TRE 1 bottom trawl catch was taken (see Figures 15 and 16).

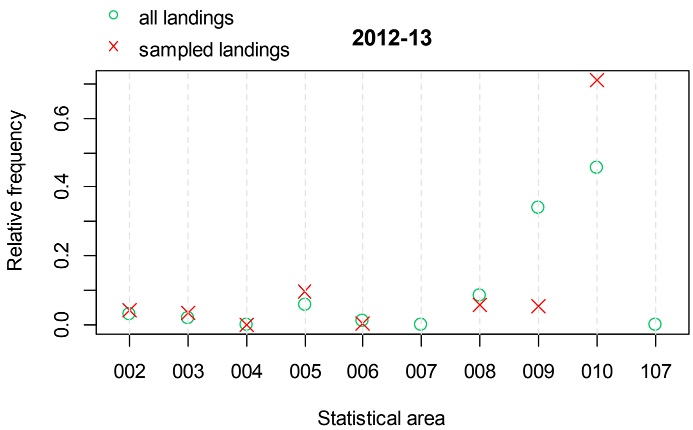

Figure 16: Comparison of the proportional distribution of the estimated bottom trawl trevally catch and the sampled component by statistical area over the sampling period for the TRE 1 stock in 2012–13.

A similar comparison based on the bottom trawl catch by target species is given in Figure 17, and shows that approximately 20% and 70% of the 2012–13 landed catch of trevally for East Northland/Hauraki Gulf and Bay of Plenty subareas, respectively, was taken by trevally targeted tows. Snapper was the other significant target species used in TRE 1 and accounted for approximately 60% and 30% of the respective subarea trevally catches.

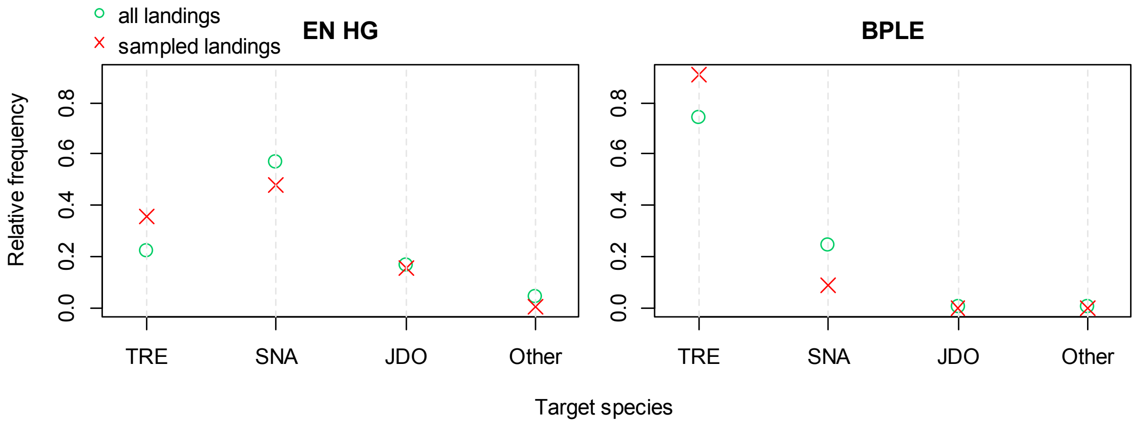

Figure 17: Comparison of the proportional distribution of the estimated bottom trawl catch and the sampled component by target species over the sampling period for the TRE 1 bottom trawl subarea fisheries in 2012–13. ENHG, East Northland/Hauraki Gulf; BPLE, Bay of Plenty.

A comparison of the proportional distribution of the number of tows and the estimated catch of trevally by depth for bottom trawl indicates that sampled landings were generally aligned to the distribution of depths fished by the entire fleet in 2012–13, more so for East Northland/Hauraki Gulf than for the Bay of Plenty subarea (Figure 18).

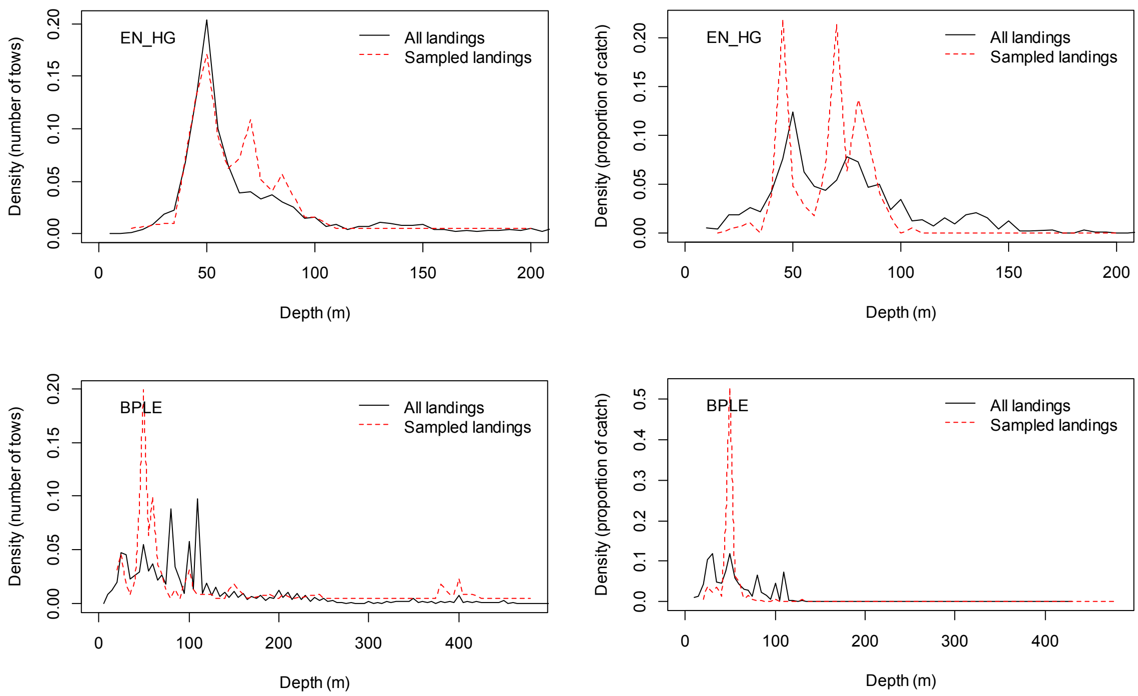

Figure 18: Comparison of the proportional distribution of the estimated bottom trawl trevally catch and the sampled component by number (left) of tows and catch (right) by tows over the sampling period for the TRE 1 bottom trawl subarea fisheries in 2012–13. Depth scale differs between subareas.

Temporal and spatial comparisons of the total and sampled landings suggest that sampled landings were generally representative of the TRE 1 bottom trawl catch.

Spatial catch, statistical area and target species comparisons for purse-seine

Fine scale spatial comparisons (0.1 degree blocks) of the proportional distribution of the estimated TRE 1 purse-seine commercial catch and sampled catch for 2012–13 shows that all candidate landings (over 10 t) originated from a handful of isolated coastal regions associated with surface schooling trevally in northern East Northland and western and central Bay of Plenty (Figure 19). Negligible catch and no samples were taken from the southern East Northland, Hauraki Gulf or eastern Bay of Plenty regions. As the sampled component was spread throughout areas where the commercial purse-seine fishery operated in 2012–13, sampled landings are spatially representative of the TRE 1 fishery (Figure 19).

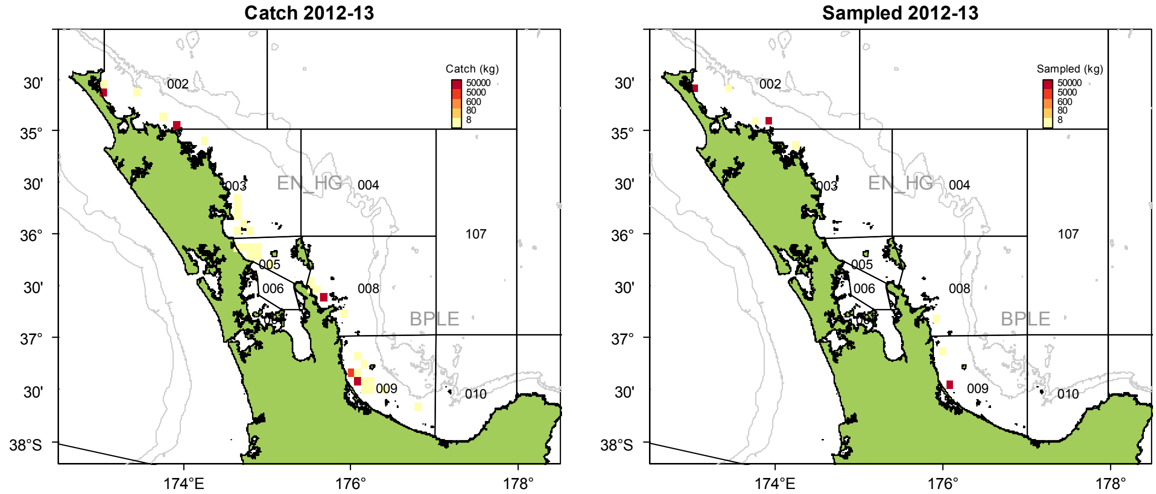

Figure 19: Comparison of the spatial distribution of the purse-seine trevally catch and the sampled component for the TRE 1 stock in 2012–13.

A comparison of the proportional distribution of the estimated purse-seine catch of trevally with that sampled in 2012–13 indicates that sampling was spatially consistent to the fishery operation across all statistical areas that make up TRE 1 (Figure 20).

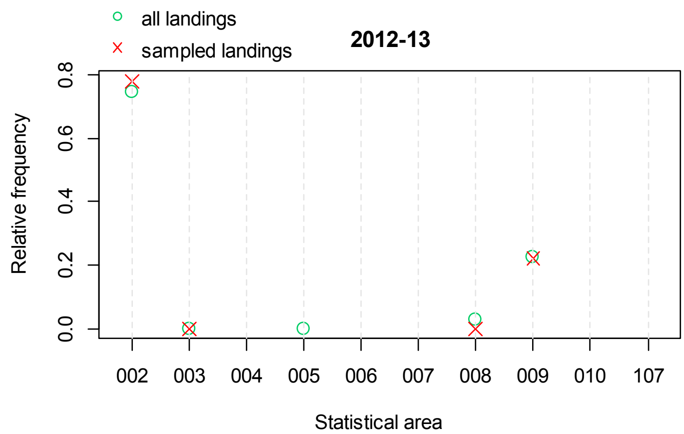

Figure 20: Comparison of the proportional distribution of the estimated purse-seine trevally catch and the sampled component by statistical area over the sampling period for the TRE 1 stock in 2012–13.

A similar comparison based on the purse-seine catch by target species shows that almost the entire TRE 1 catch (97%) in 2012–13 was taken when trevally was the target species (Figure 21).

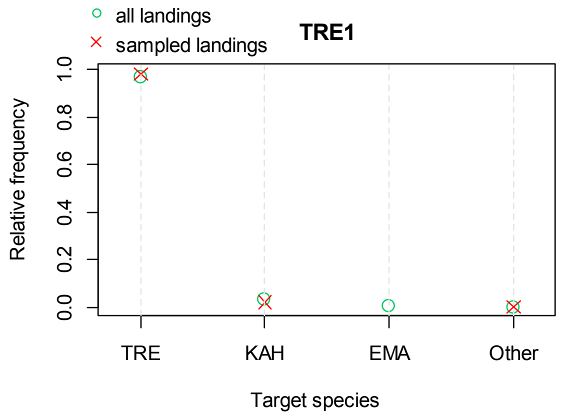

Figure 21: Comparison of the proportional distribution of the estimated purse-seine trevally catch and the sampled component by target species over the sampling period for the TRE 1 stock in 2012–13.

3.4 Otolith readings

Reader comparison tests for reference readings

For the 50 reference otoliths used to assess reader competency, both readers 1 and 2 achieved CV and IAPE pass mark scores below the targets set at 3.54% (CV) and 2.50% (IAPE) respectively, meaning that both readers could proceed to age the TRE 1 otolith collection from 2012–13 to independently determine an unbiased reading estimate (Table 4).

Table 4: Reader comparison scores determined from ageing 50 randomly selected trevally reference otolith samples ranging in age from 3 to 42 years.

	CV	IAPE	Agreed age	Pass/Fail
Target	3.54%	2.50%	–	–
Reader 1	2.41%	1.71%	76%	Pass
Reader 2	2.82%	2.00%	61%	Pass

Reader comparison tests for TRE 1 2012–13 readings

Between-reader tests with graphical comparisons for the 804 otoliths successfully aged from TRE 1 in 2012–13 are given in Figure 22 and show a reasonable level of consistency between readers. There appeared to be relatively minor systematic differences (bias) in first counts of trevally otoliths between the readers. The slight negative weighting of the histogram in Figure 22(a), the relative clustering of plotted points about the zero line in Figure 22(b), and the deviation from the one-to-one line on the age-bias plot for older age classes (Figures 22(c)) indicate that the second reader slightly over-counted zones relative to the first reader. The overall percentage agreement between readers was 71.3%, with 40 of the 804 readings (5.0%) resulting in reader disagreement of more than 1 year. The between reader CV and IAPE were 2.58% and 1.82% respectively (Figure 22(c)) and the profiles show that precision was lowest for very young age classes and moderate across most other age classes (Figure 22(d)). Comparisons of the age-bias plots for reader 1 and 2 with the agreed age show that overall agreement was reasonable (77.5 and 89.9%) and precision highest for reader 2 with CV and IAPE estimates less than 1% (Figures 22(e) and (f)).

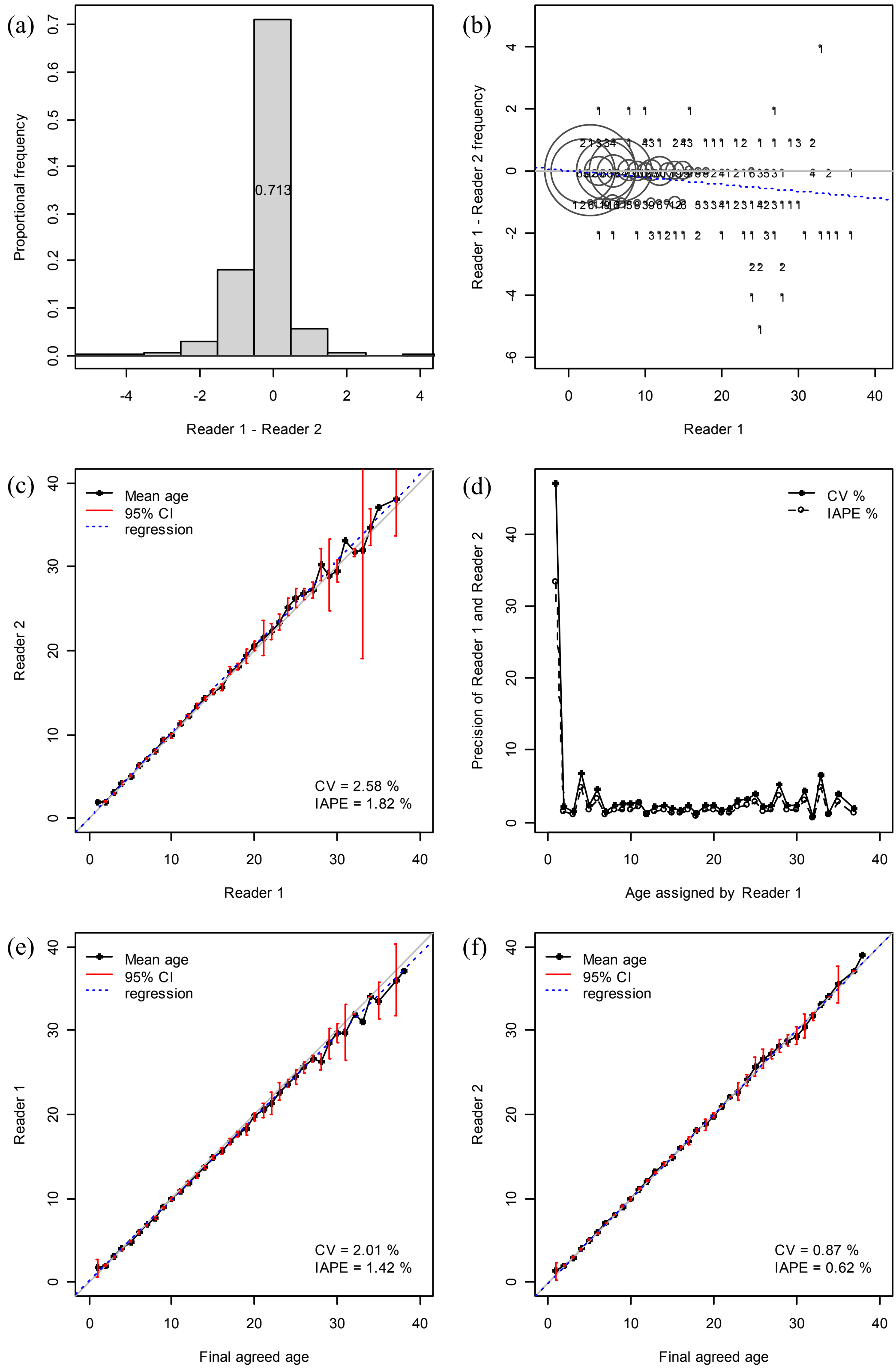

Figure 22: Results of between-reader comparison test (reader 1 and 2) for TRE 1 otoliths collected in 2012–13 (*n* = 804): (a) histogram of differences between readings for the same otolith; (b) differences between readers for a given age assigned by reader 1; (c) bias plot between readers; (d) CV and IAPE profiles (precision) relative to the age assigned by reader 1; (e) bias plot between reader 1 ((f) reader 2) and agreed age. The expected one-to-one (solid line) and actual relationship (dashed line) between readers are overlaid on (b) and (c), and between reader 1 and 2 and the agreed age on (e) and (f).

3.5 Length and age distributions

For the TRE 1 fisheries in 2012–13, catch-at-age compositions (using the length frequency and age-length key approach) were derived from the combined length distributions of subarea strata, and used to identify year class strengths. Otolith collections may not have been consistent across the entire sampling period, especially from landings sampled toward the end of the season when the age-length key collection was nearly complete or when specific subarea collections were difficult to obtain. This is unlikely to bias the age characterisations because the growth of recruited trevally (i.e., those over 25 cm long) would have been relatively low over the period when length frequency only collections were made. This assumption has been accepted for other species with growth rates comparable to those of trevally (Westrheim & Ricker 1978, Davies & Walsh 1995).

The TRE 1 and subarea age-length keys are presented in Appendix 6 and age-at-length scatterplots (using decimalised ages and not fishing year ages) are given in Appendix 7.

3.6 TRE 1 subarea and method catch-at-length and catch-at-age estimates

Length and age distributions and coefficients of variation, and cumulative proportions of length and age for the TRE 1 stock and subarea bottom trawl and purse-seine fisheries in 2012–13 are presented in Figures 23–26 (Appendices 8 and 9). Variation in length and age was apparent between subareas and methods. Cumulative plots indicate that the bottom trawl catch from East Northland/Hauraki Gulf comprised proportionally more large, and appreciably more very young trevally, relative to the Bay of Plenty, whereas the purse-seine catch from East Northland/Hauraki Gulf comprised proportionally more large and old trevally relative to the Bay of Plenty (Figures 24 and 26).

TRE 1 bottom trawl

The stratified length distribution for the TRE 1 bottom trawl fishery was mainly comprised of small to moderate sized trevally, characterised by one main mode centred around 38 cm, with a narrow tail extending out to over 60 cm (Figure 23, see Appendix 8). The mean length sampled from the fishery was 38.4 cm (about 1.1 kg) and the proportion at length MWCV was low at 0.17. The stratified age distribution for the TRE 1 bottom trawl fishery was broad with a reasonable level of representation across most recruited age classes up to and over 20 years (Figure 23, see Appendices 7 and 9). Young trevally between 3 and 8 years of age (2005 to 2010 year classes) dominate the fishery and collectively made up around two in every three fish landed in 2012–13. The mean age of the TRE 1 distribution in 2012–13 was 8.2 years and the proportion at age MWCV was 0.23, indicative of a moderate level of precision (Figure 23). The oldest trevally sampled from the TRE 1 fishery in 2012–13 was 38 years old.

East Northland/Hauraki Gulf bottom trawl

Landings from the East Northland/Hauraki Gulf subarea comprised a high proportion of small to moderate sized trevally between 34 and 45 cm, characterised by one main mode centred around 37 cm, with a significant tail extending out to 60 cm (Figure 23, see Appendix 8). The mean length sampled from the fishery was the highest of the TRE 1 subareas at 40.0 cm (about 1.3 kg), and the proportion at length MWCV was 0.36, indicative of high between-landing variability, given a sample size of ten landings and 5733 fish measured. East Northland/Hauraki Gulf bottom trawl catches were overwhelmingly dominated by young trevally occupying 3-, 5- and 7-year-old age classes (2010, 2008 and 2006 year classes) which collectively made up more than half (55%) the landed catch by number in 2012–13, suggesting that recent recruitment has been highly variable (Figure 23, see Appendix 9). The 2010 year class (3-year-olds) was by far the most dominant of these making up just under one-third (29%) of the annual catch, twofold that of any other year class in the fishery. There were moderate proportions of fish occupying the older age classes, the combined total 10 years and older amounting to more than one-quarter (28%) of the catch, inclusive of the aggregate (over 19 years) age group, which stands at 4% (Figure 23, Appendix 9). The mean age of trevally sampled from East Northland/Hauraki Gulf subarea was 7.0 years and the proportion at age MWCV was 0.32.

Bay of Plenty bottom trawl

The Bay of Plenty length distribution was mainly comprised of small to moderate sized trevally between 33 and 43 cm, characterised by one main mode centred around 38 cm and had a short tail extending to 50 cm (Figure 23, see Appendix 8). The mean length for the total sample of eleven landings was 38.2 cm (about 1.1 kg), and the proportion at length MWCV was 0.18, indicative of low between-landing variability. The Bay of Plenty age distribution was relatively broad with a good level of representation across most recruited age classes up to 15 years, and for fish 20 years and older (Figure 23, see Appendices 7 and 9). Young trevally dominate the Bay of Plenty fishery in 2012–13, those 3 to 8 years of age (2005 to 2010 year classes) and collectively made up almost two in every three (62%) fish landed, the 2006 year (7-year-olds) class the strongest of these, individually almost twofold that of any other year class. The mean age of the Bay of Plenty age distribution was 8.3 years and the proportion at age MWCV was 0.25.

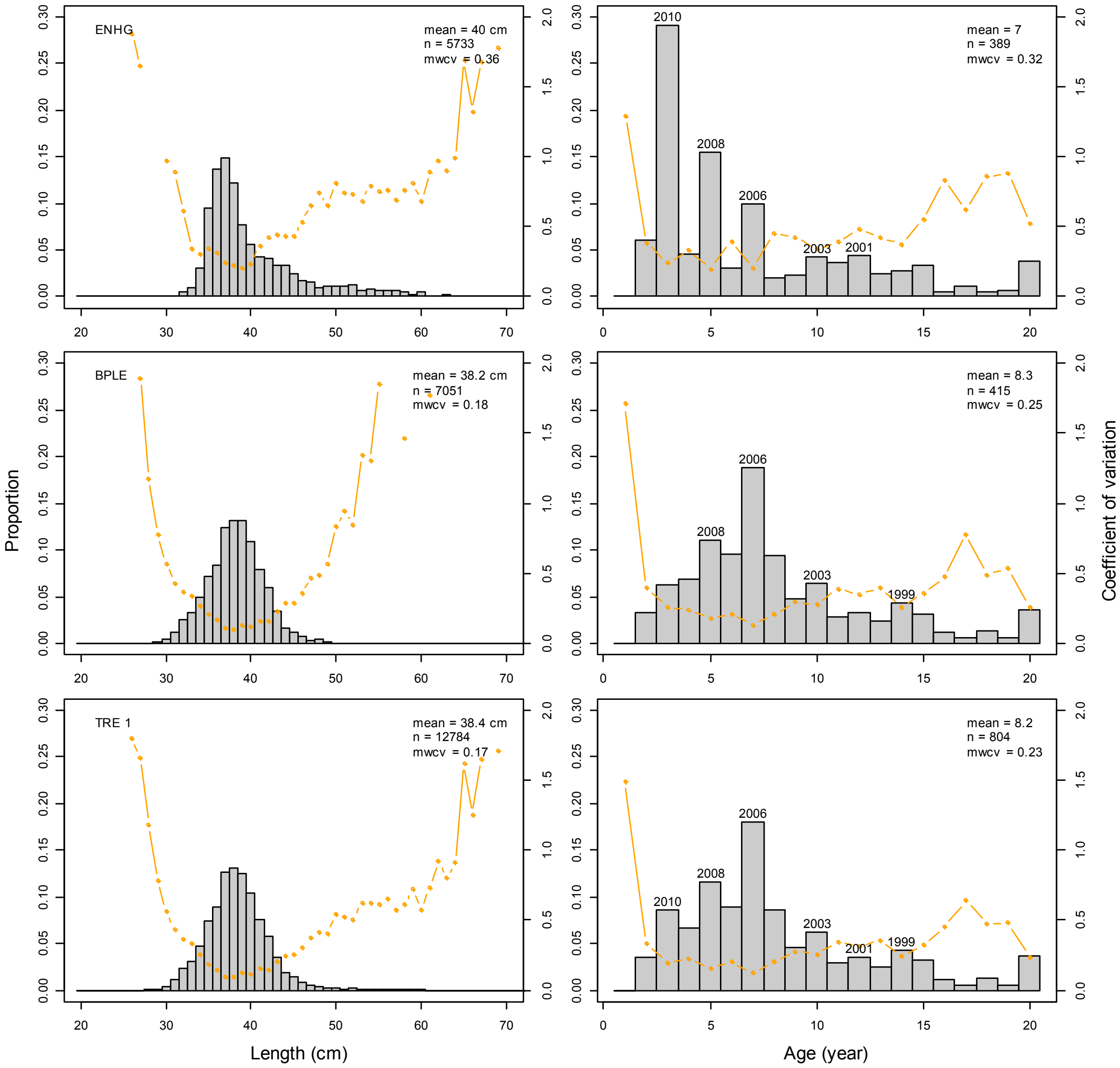

Figure 23: Proportion at length and age distributions (histograms) and bootstrap CVs (lines) determined from trevally landings sampled from the TRE 1 and subarea bottom trawl fisheries in 2012–13 using the length frequency and age-length key approach (n, sample size; MWCV, mean weighted CV). ENHG, East Northland/Hauraki Gulf; BPLE, Bay of Plenty. Selected age classes are shown above the proportions at age.

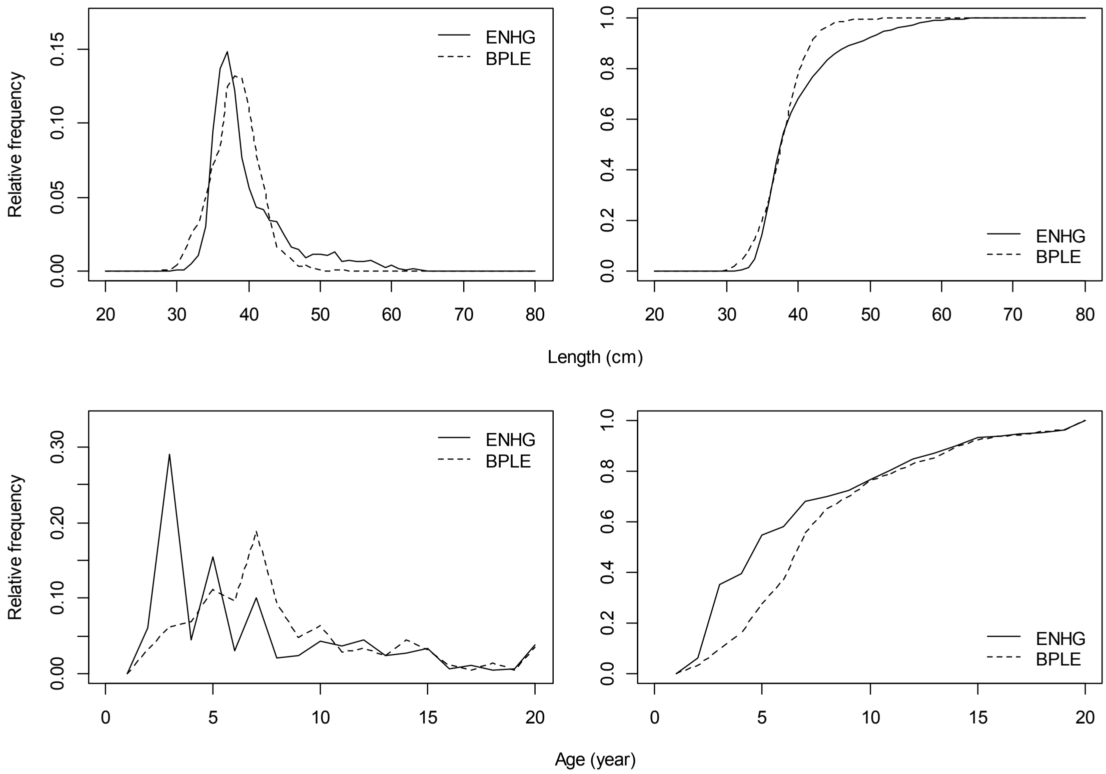

Figure 24: Comparison of the proportion and cumulative proportion at length (top) and age (bottom) distributions determined from trevally landings sampled from the TRE 1 subarea bottom trawl fisheries in 2012–13. ENHG, East Northland/Hauraki Gulf; BPLE, Bay of Plenty.

TRE 1 purse-seine

The stratified length distribution for the TRE 1 purse-seine fishery was relatively broad and mainly comprised of moderate to large trevally between 37 and 48 cm, although some fish were as small as 31 cm or as large as 59 cm (Figure 25, see Appendix 8). The mean length sampled from the fishery was 42.4 cm (about 1.5 kg) and the proportion at length MWCV was moderate at 0.23. The stratified age distribution for the TRE 1 purse-seine fishery was broad and had good representation across most recruited age classes, particularly those between 3 and 15 years of age (Figure 25, see Appendices 7 and 9). A number of year classes appear strong, the 2006 year class (7-year-olds), the most dominant in the fishery, made up almost one-fifth (18%) of the catch by number in 2012–13. The mean age of the TRE 1 purse-seine distribution in 2012–13 was high at 9.7 years and the proportion at age MWCV was 0.27, indicative of a moderate level of precision (Figure 25).

East Northland/Hauraki Gulf purse-seine

Landings from the East Northland/Hauraki Gulf subarea comprised the largest trevally and broadest length distribution caught by purse-seine in TRE 1 (Figure 25). The distribution was mainly comprised of fish between 39 and 50 cm, characterised by one main mode centred around 43 cm, with a small tail extending out to 55 cm (Figure 25, see Appendix 8). A total of over 4000 fish were sampled from five landings in the fishery and the mean length was the highest of the TRE 1 subareas at 43.9 cm (about 1.7 kg), and the proportion at length MWCV was 0.26, indicative of moderate between-landing variability. The age distribution of East Northland/Hauraki Gulf purse-seine catch was broad and comprised a number of strong and weak year classes, the most prominent of these being from 2001, 2002, 2003, 2006 and 2008, which collectively make up over half (55%) the landed catch by number in 2012–13 (Figure 25, Appendix 9). The mean age of trevally sampled from East

Northland/Hauraki Gulf was the highest of the TRE 1 subareas at 10.1 years and the proportion at age MWCV was 0.34.

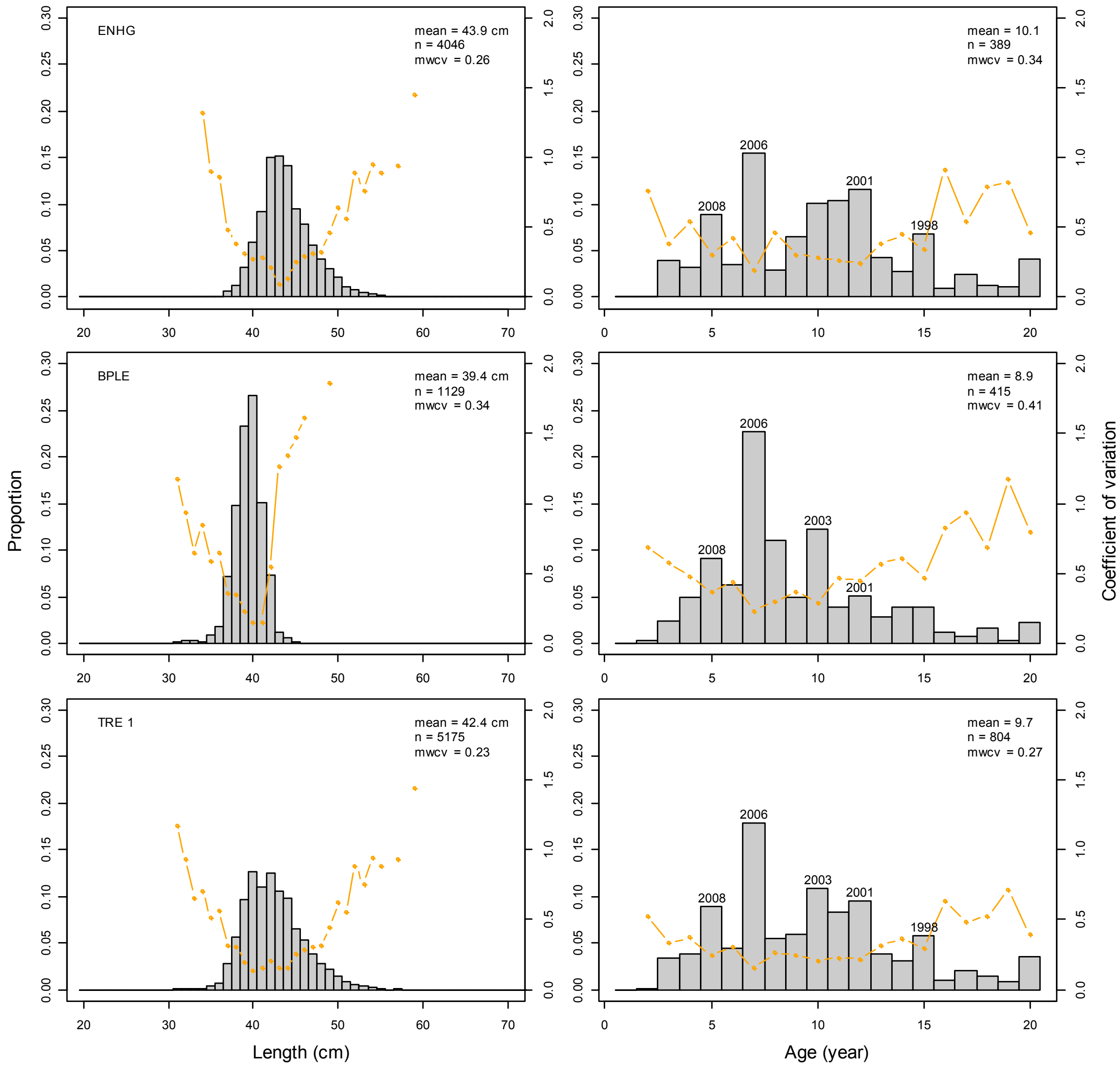

Figure 25: Proportion at length and age distributions (histograms) and bootstrap CVs (lines) determined from trevally landings sampled from the TRE 1 and subarea purse-seine fisheries in 2012–13 using the length frequency and age-length key approach (n, sample size; MWCV, mean weighted CV). ENHG, East Northland/Hauraki Gulf; BPLE, Bay of Plenty.

Bay of Plenty purse-seine

The Bay of Plenty length distribution was narrow, characterised by one main mode centred around 40 cm and comprised of only a few moderate size classes from 37 to 42 cm contributing 94% of the catch by number in 2012–13 (Figure 25, see Appendix 8). The mean length was 39.4 cm (about 1.2 kg), and the proportion at length MWCV was 0.34, indicative of high between-landing variability for the two sampled landings. The Bay of Plenty age distribution was relatively broad with a good level of representation across most recruited age classes up to 15 years (Figure 25, see Appendices 7 and 9). Young trevally predominated in the Bay of Plenty fishery in 2012–13, where those fish 10 years and younger collectively made up almost three-quarters (74%) of the landed catch, the 2006 year (7-year-olds) class overwhelmingly the strongest of these, individually almost twofold that of any other age year class. The mean age of the Bay of Plenty age distribution was 8.9 years and the proportion at age MWCV was high at 0.41, reflective of heterogeneity in age between purse-seine landings in the subarea in 2012–13.

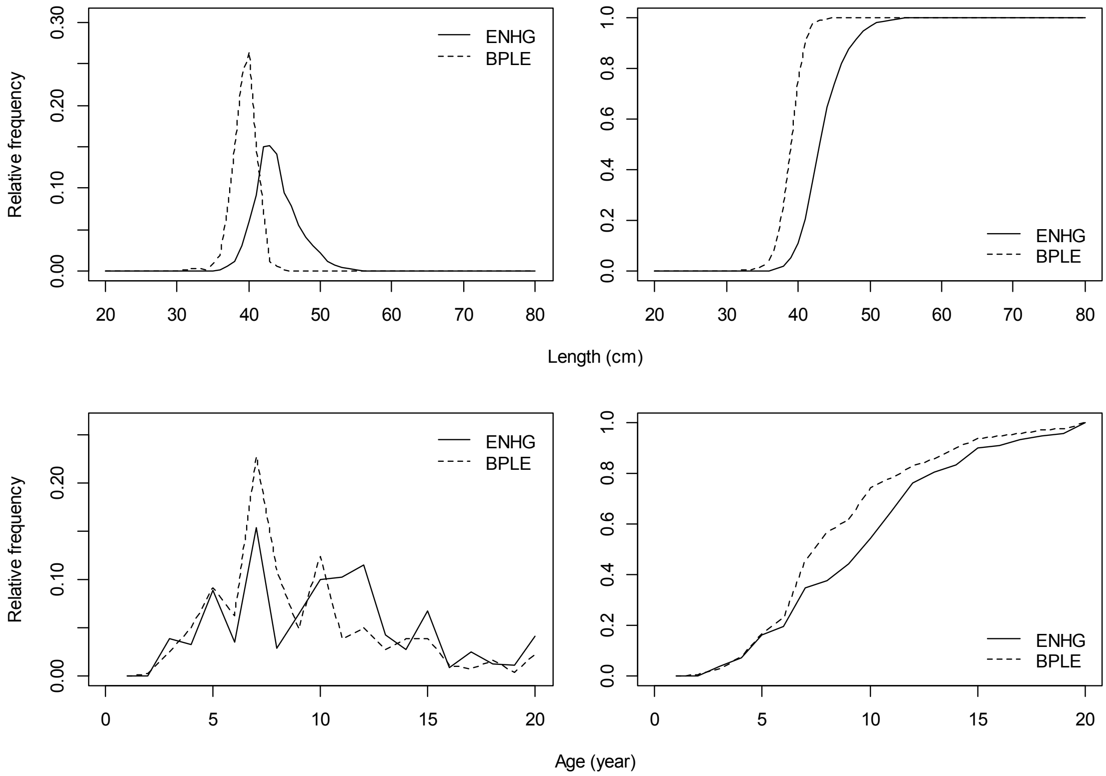

Figure 26: Comparison of the proportion and cumulative proportion at length (top) and age (bottom) distributions determined from trevally landings sampled from the TRE 1 subarea purse-seine fisheries in 2012–13. ENHG, East Northland/Hauraki Gulf; BPLE, Bay of Plenty.

3.7 Mean weight-at-age and mean length-at-age

A trend of increasing mean weight-at-age over successive age classes up to 20 years of age was generally evident in data collected from the TRE 1 bottom trawl and purse-seine fisheries in 2012–13, although estimates of mean weight-at-age for purse-seine were consistently higher than bottom trawl (Figure 27, Appendix 10). The highest mean weight-at-age estimates for both methods were exclusively from East Northland/Hauraki Gulf and indicative of considerable spatial growth differences within TRE 1 (Figure 28, Appendix 10). Comparisons made between methods within a subarea indicate that, in general, mean weight-at-age for young fish up to about 11 years of age was higher for purse-seine, but those above 11 years were higher for bottom trawl (Figure 28, Appendix 10). Mean weight-at-age for some of the young age classes (1- to 3-year-olds) may be positively biased because of the minimum legal size (MLS) restriction of 25 cm in commercial catches, and also because fish of this age range may not yet be fully recruited to the fishery (Davies et al. 2003). Observed mean length-at-age estimates closely resemble those patterns seen in mean weight-at-age estimates (Figures 27 and 29, Appendix 11).

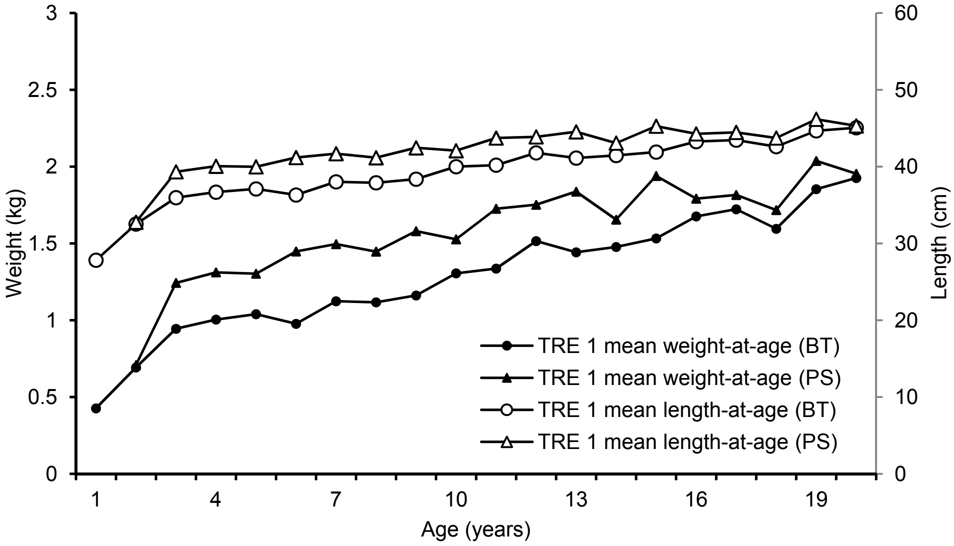

Figure 27: Observed mean weight-at-age and mean length-at-age estimates from trevally landings sampled from the TRE 1 bottom trawl (BT) and purse-seine (PS) fisheries in 2012–13.

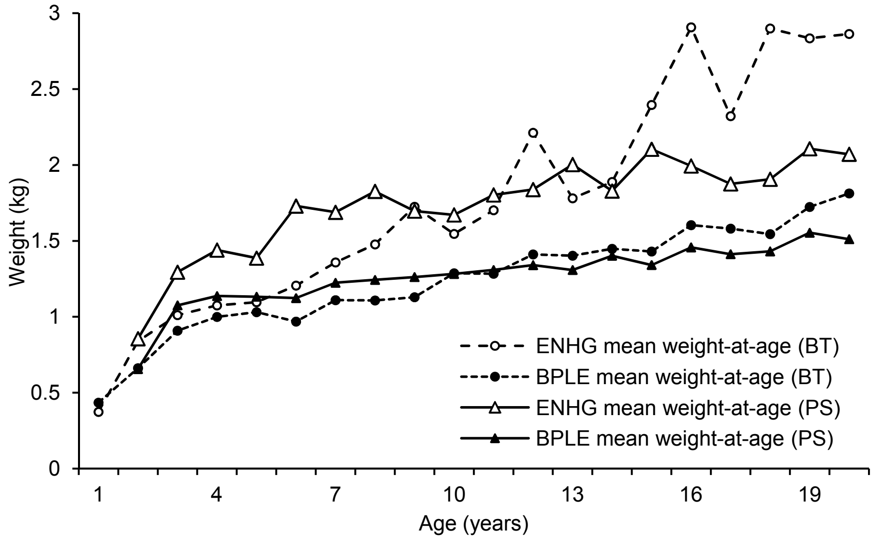

Figure 28: Observed mean weight-at-age estimates from trevally landings sampled from the TRE 1 subarea bottom trawl (BT) and purse-seine (PS) fisheries in 2012–13. ENHG, East Northland/Hauraki Gulf; BPLE, Bay of Plenty.

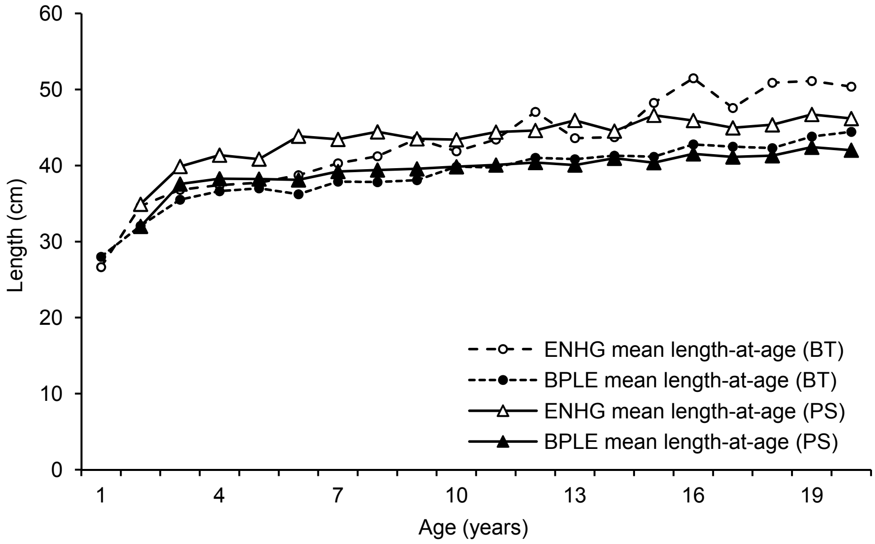

Figure 29: Observed mean length-at-age estimates from trevally landings sampled from the TRE 1 subarea bottom trawl (BT) and purse-seine (PS) fisheries in 2012–13. ENHG, East Northland/Hauraki Gulf; BPLE, Bay of Plenty.

3.8 TRE 1 and subarea-method length and age distribution time series comparisons (2006–07, 2007–08, 2008–09, 2012–13)

Although a time series of length and age information from catch sampling the TRE 1 fishery spans the period 1997–98 to 2012–13 (see Appendices 1, 12a and 12b), investigation into patterns of spatial heterogeneity within the stock for two subareas (East Northland and Bay of Plenty) only began in 2006–07 (Walsh et al. 2010a), the same time a rigorous approach to ageing trevally was adopted (see Section 2.2). A four year non-sequential time series (2006–07, 2007–08, 2008–09 and 2012–13) of these distributions for TRE 1 and the respective subarea fisheries is presented in Figures 30–32 for bottom trawl and Figures 33–35 for purse-seine, with the Hauraki Gulf and East Northland subareas combined in 2012–13. As samples from 2012–13 are non-sequential, specific age classes within each time series age distribution have been annotated white for easier interpretation of cohort progression between sampling years.

TRE 1 bottom trawl

Length and age distributions sampled from TRE 1 bottom trawl landings have broadened slightly between 2006–07 and 2012–13 with estimates of mean length and age increasing from 36.8 to 38.4 cm and 6.9 to 8.2 years respectively, over the seven year period (Figure 30). Despite some variability in length and age structure between years, there is reasonable continuity in year class strength evident in the progression of many year classes over successive years, particularly those occupying the common age classes. Sample sizes for both length and age collections in the 2006–07 were low compared to other years and only comprise samples from the East Northland subarea, and may explain some of the variability apparent in length and age structure comparisons to other years.

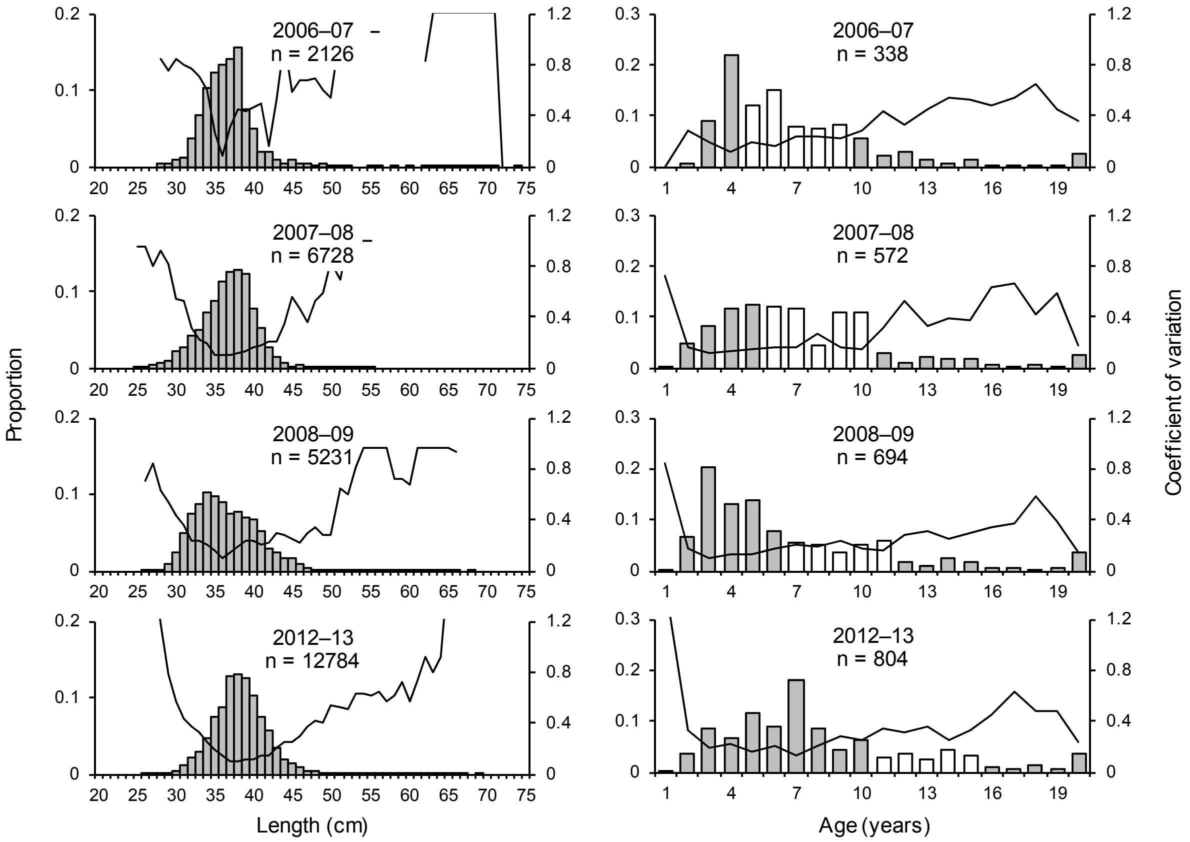

Figure 30: Recent time series of proportion at length and age distributions (histograms) and CVs (lines) determined from trevally landings sampled from the TRE 1 bottom trawl fishery in 2006–07, 2007–08, 2008–09 and 2012–13 (*n*, sample size). White bars in the age distribution represent the 1998 to 2002 year classes.

East Northland bottom trawl

The length and age distributions sampled from bottom trawl landings from the East Northland subarea between 2006–07 and 2012–13 although variable, consistently comprised a high proportion of small and young trevally, with fish 10 years and younger accounting for 77–91% of the catch (Figure 31). Estimates of mean length ranged from 36.7 to 40.0 cm, and mean age, 6.1 to 8.1 years. Some continuity of year class progression over successive years was evident, although sample sizes for both length and age collections in the 2006–07 and 2007–08 fishing years were well below targets and this may explain some of the variability apparent in length and age structure comparisons.

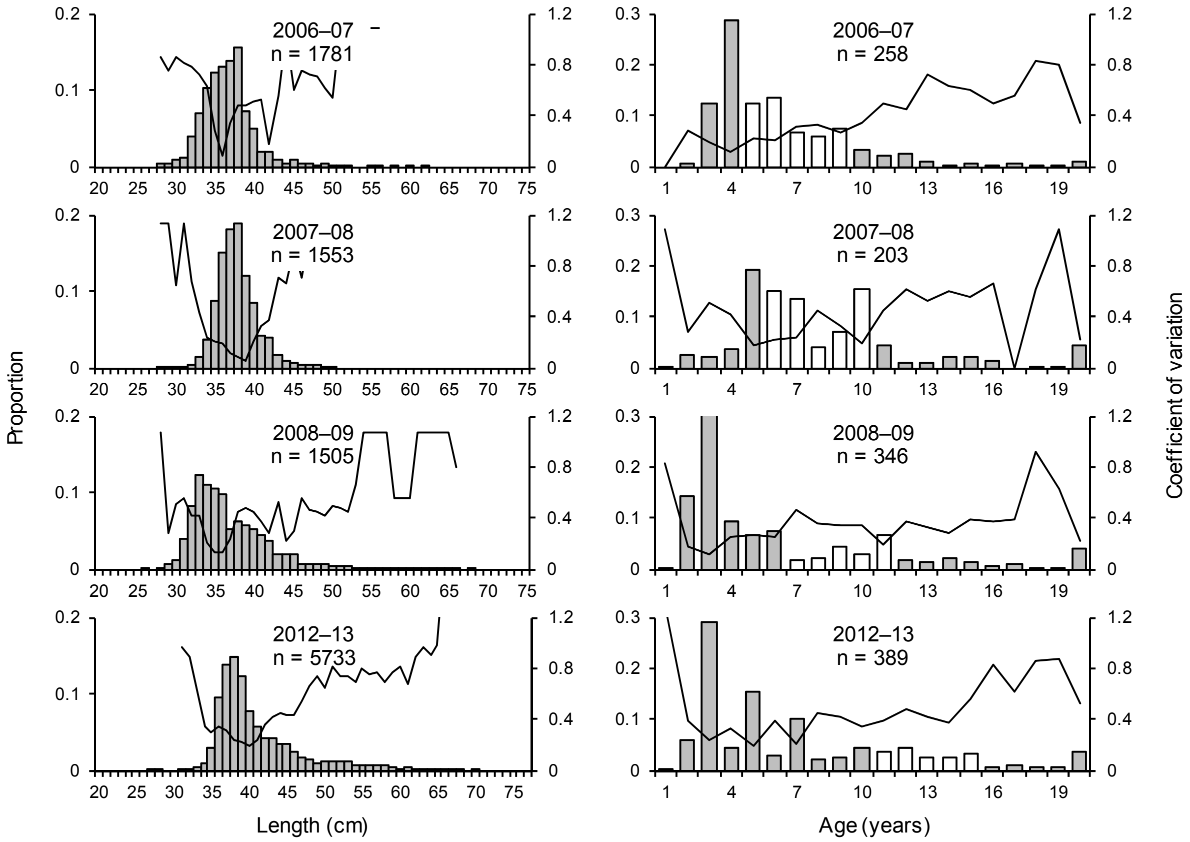

Figure 31: Recent time series of proportion at length and age distributions (histograms) and CVs (lines) determined from trevally landings sampled from the East Northland/Hauraki Gulf subarea bottom trawl fishery in 2006–07, 2007–08, 2008–09 and 2012–13 (*n*, sample size). White bars in the age distribution represent the 1998 to 2002 year classes.

Bay of Plenty bottom trawl

Sampled bottom trawl length and age distributions from the Bay of Plenty have broadened slightly between 2007–08 and 2012–13 with estimates of mean length increasing from 36.7 to 38.2 cm, and mean age, 7.4 to 8.3 years (Figure 32). Despite some variability in length and age structure between years, particularly the most recent in 2012–13, there is reasonable continuity in year class strength evident in the progression of many year classes over successive years, with sample sizes for both length and age collections over the three fishing years being the most comprehensive in TRE 1, despite no sampling being undertaken in 2006–07.

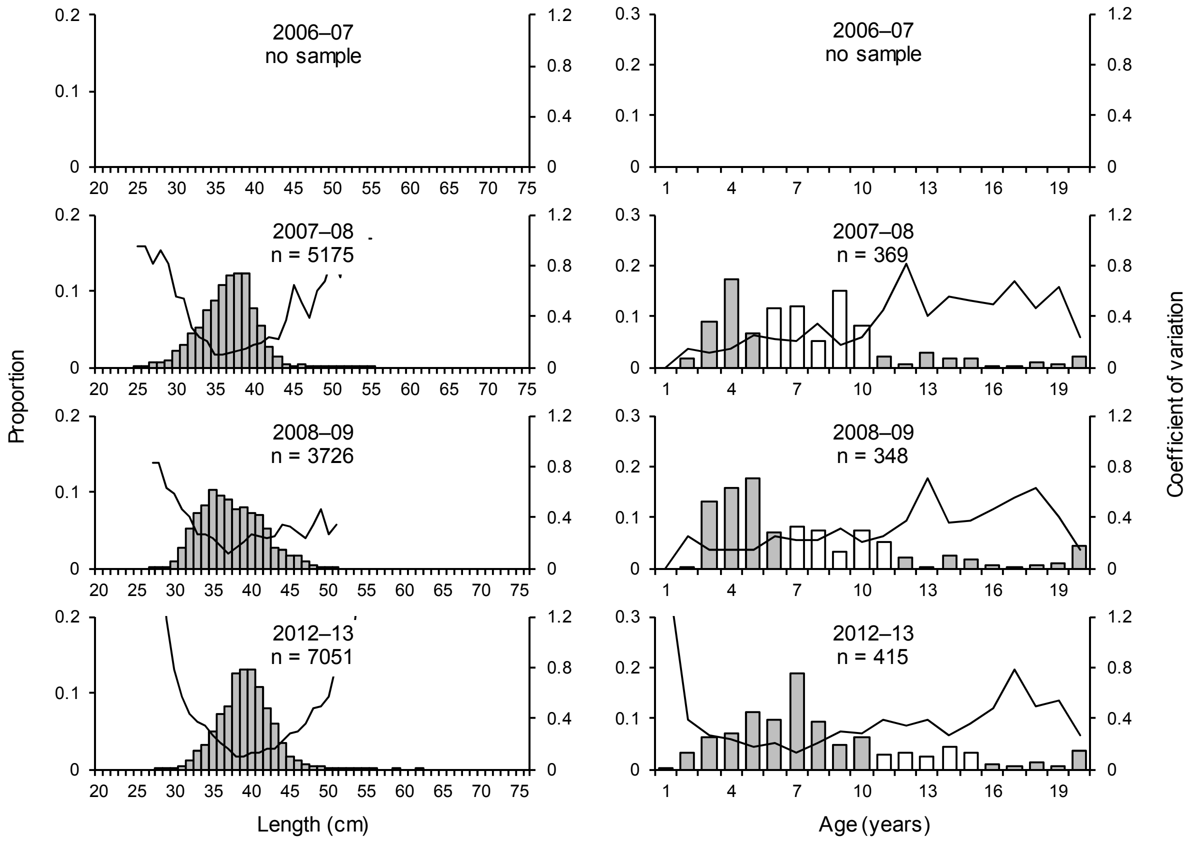

Figure 32: Recent time series of proportion at length and age distributions (histograms) and CVs (lines) determined from trevally landings sampled from the Bay of Plenty subarea bottom trawl fishery in 2006–07, 2007–08, 2008–09 and 2012–13 (*n*, sample size). White bars in the age distribution represent the 1998 to 2002 year classes.

TRE 1 purse-seine

Length distributions for TRE 1 purse-seine landings between 2006–07 and 2012–13 showed considerably less variation between years in comparison to that evident in age distributions (Figure 33). Length compositions were mostly dome shaped, predominantly comprised of moderate to large trevally occupying fewer than 15–20 size classes, with estimates of mean length relatively stable, ranging from 40.9 to 43.8 cm. Age compositions were highly variable between years, most often broad and comprising a high proportion of fish 20 years and older, with mean age ranging from 9.7 to 15.4 years respectively, over the seven year period (Figure 33). As a result, consistent patterns in relative year class strengths between years were less evident than those determined for bottom trawl. Length frequency sample sizes for TRE 1 purse-seine were low for collections made in 2006–07, 2007–08 and 2008–09. Furthermore, the first and second fishing year samples only comprised length and age samples from single subarea strata, East Northland and Bay of Plenty respectively, which may, in part, explain some of the variability in age structure evident between years.

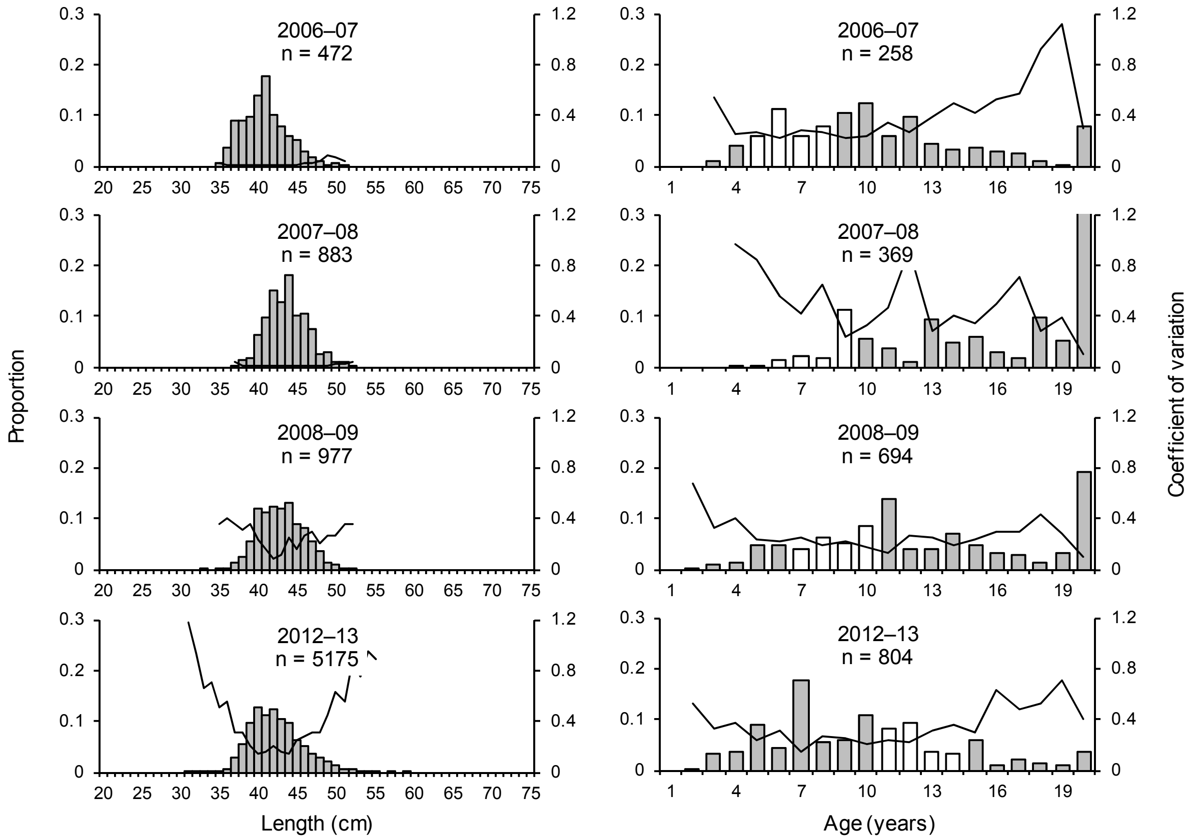

Figure 33: Recent time series of proportion at length and age distributions (histograms) and CVs (lines) determined from trevally landings sampled from the TRE 1 purse-seine fishery in 2006–07, 2007–08, 2008–09 and 2012–13 (*n*, sample size). White bars in the age distribution represent the 1999 to 2002 year classes.

East Northland purse-seine

Length distributions for East Northland purse-seine landings between 2006–07 and 2012–13 indicate a slight increase in the size of trevally caught from the subarea over the seven year period, with mean length increasing from 40.9 to 43.9 cm (Figure 34). The East Northland age distributions were broad with good representation across most recruited age classes, including the aggregate (over 19 years) age group, although this decreased in 2012–13 to less than half that seen in the previous two years of sampling. Sample sizes for either length or age collections in some years were low, no samples were collected in 2007–08, and there is inconsistency in relative year class strengths between years (Figure 34). Mean age ranged from 10.1 to 11.3 years.

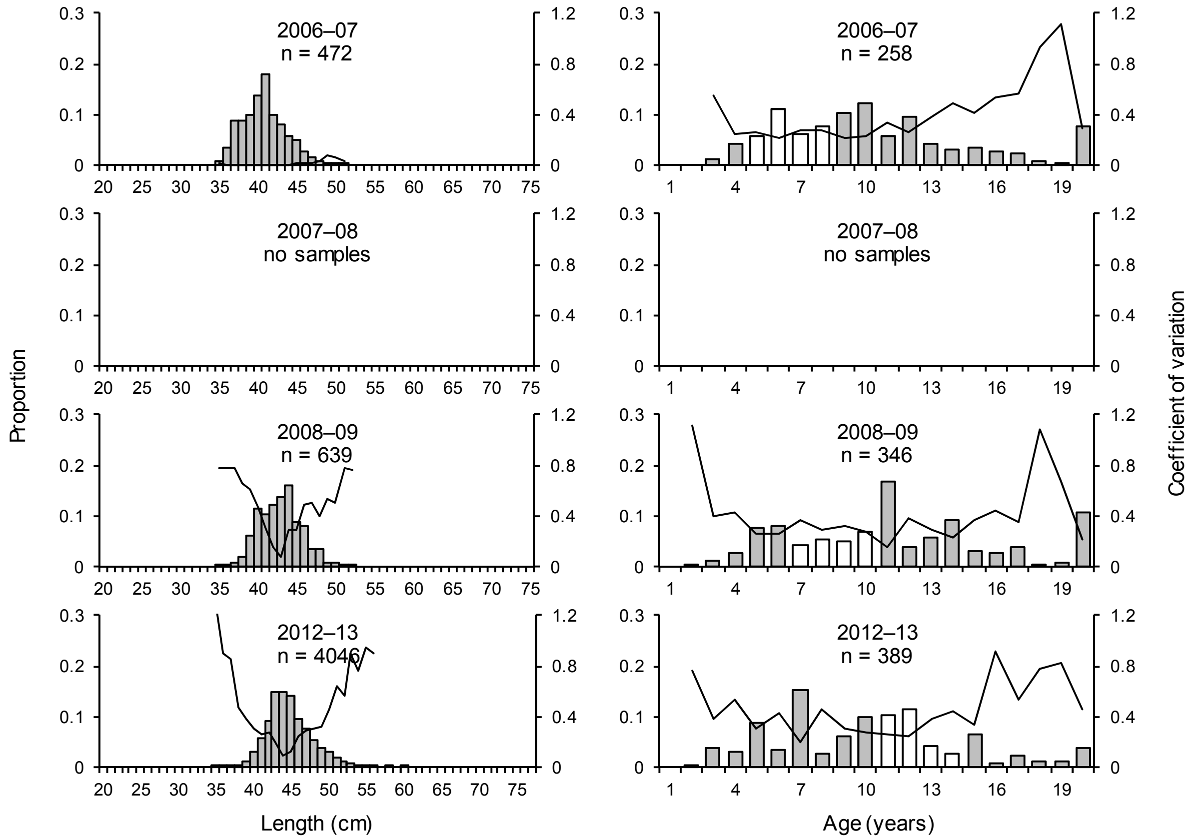

Figure 34: Recent time series of proportion at length and age distributions (histograms) and CVs (lines) determined from trevally landings sampled from the East Northland/Hauraki Gulf subarea purse-seine fishery in 2006–07, 2007–08, 2008–09 and 2012–13 (*n*, sample size). White bars in the age distribution represent the 1999 to 2002 year classes.

Bay of Plenty purse-seine

Sampled length and age distributions from the Bay of Plenty purse-seine fishery over 2007–08 and 2008–09 were relatively similar, comprised few small young fish, and a moderate to high proportion of large old fish, particularly in the aggregate (over 19 years) age group (Figure 35). In contrast, samples from 2012–13 were based largely on fish of small to moderate size and age, with few 20 years of age or more, and indicative of the variable size and age structure for trevally in purse-seine landings within the fishery. Estimates of mean length ranged from 39.4 to 43.7 cm, and mean age, 8.9 to 15.4 years. Although continuity in year class strength is evident, particularly from 2007–08 to 2008–09, the progression of year classes into 2012–13 is less clear (Figure 35). No sampling was undertaken in 2006–07 and sample sizes for length frequency collections were poor.

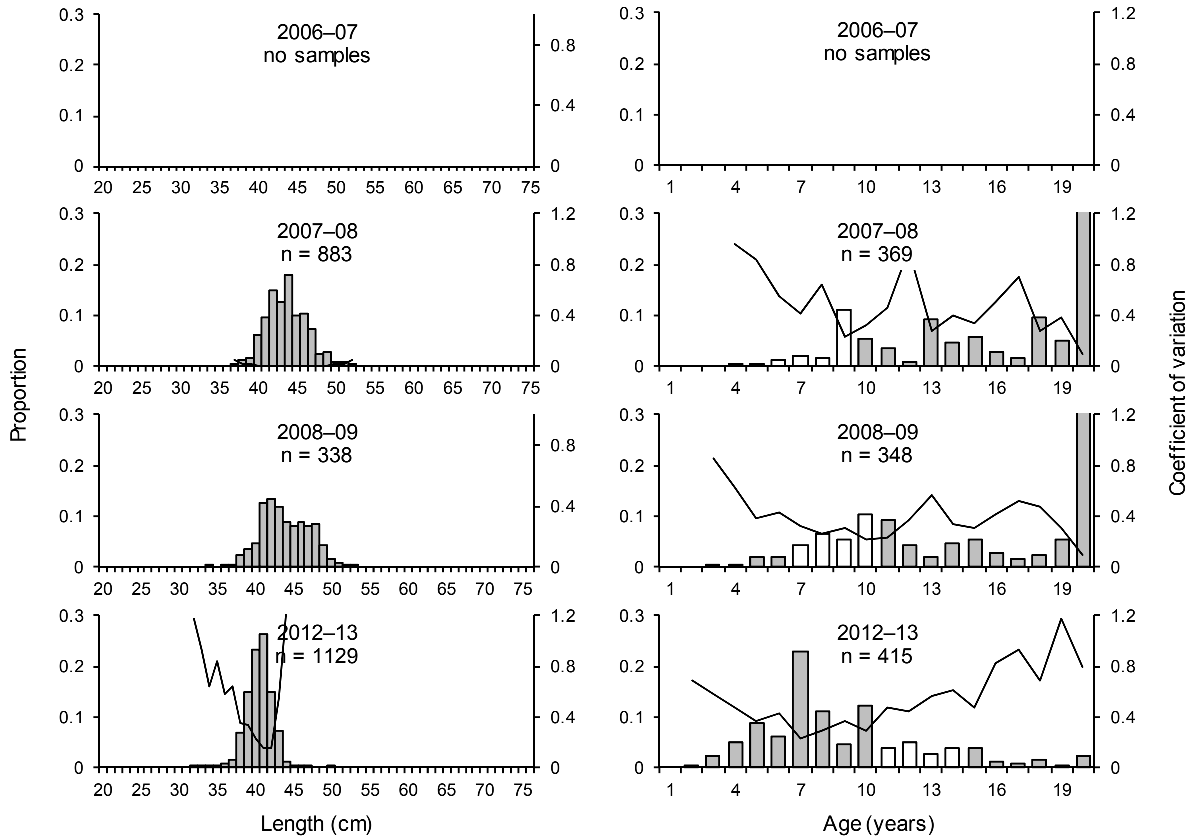

Figure 35: Recent time series of proportion at length and age distributions (histograms) and CVs (lines) determined from trevally landings sampled from the Bay of Plenty subarea purse-seine fishery in 2006–07, 2007–08, 2008–09 and 2012–13 (*n*, sample size). White bars in the age distribution represent the 1999 to 2002 year classes.

4. DISCUSSION

This is the eleventh report to summarise the length and age compositions of trevally landings from the main fishing methods operating in TRE 1 since 1997–98, and the fourth report since 2006–07 where patterns of spatial heterogeneity within the stock have been investigated. The implementation of a revised ageing protocol to improve reader accuracy and precision in age estimation was also undertaken in 2006–07 (documented in a trevally age determination protocol by Walsh et al. (2014a)), and now means that relative year class strengths inferred from the age distributions sampled from the TRE 1 and subarea-method fisheries since this time can be treated with a considerable level of confidence. Nevertheless, trevally otoliths can be inherently difficult to age, and as such, some level of ageing error is always likely to be present in catch-at-age results, particularly when ageing older fish.

Sampling landings

In the most recent years of sampling, Walsh et al. (2010a, 2010b, 2012b) reported difficulties associated with meeting the sample size target requirements to adequately describe the length and age compositions of the main TRE 1 fisheries. It was suggested that inadequate sample sizes may have adversely affected results, warning that in order to fully determine whether spatial variability in length and age composition exists for trevally, future sampling would require full industry (company managers and fishers) cooperation to improve on previous results, and to minimise bias in sample estimates (spatial, temporal, and size/age selective). In 2012–13, a concerted effort in fulfilling sample requirements was undertaken to ensure that only subarea samples were collected and targets achieved, and resulted in the most successful and comprehensive sampling programme instigated in TRE 1 since sampling first began in 1997–98. In total, twenty-one bottom trawl landings were sampled, ten from East Northland/Hauraki Gulf and eleven from the Bay of Plenty, meeting the proposed subarea sampling targets of ten. For purse-seine, with the exception of one 20 t landing in September 2013, all other landings over 10 t in the fishery were successfully sampled. Furthermore, the number of fish measured for length frequency from the respective methods (12 784 from bottom trawl and 5175 from purse-seine) and the number of otolith samples aged (804) in 2012–13 was also comprehensive, and likely to be the best catch sampling description of the TRE 1 fishery to date.

Although not yet tested for sampling in TRE 1, and primarily advocated because of growth differences between the East Northland/Hauraki Gulf and Bay of Plenty subarea strata, the MPI Northern Inshore Working Group (NINSWG) in May 2014 recommended that a random age frequency sampling design replace the current length frequency and age-length key approach with the intention of increasing spatial resolution (i.e., to statistical area rather than the current subarea strata) to determine where the TRE 1 biological stock boundaries occur. In a concurrent TRE 7 catch sampling report, Walsh et al. (2014c) outlined the limitations of both sampling methods, and the implications of catch sampling for trevally "at-sea", based on the TRE 7 2012–13 results, where a total of 19 samples were omitted from the collection, mainly due to inadequate sample size. The relative benefit of the two sampling approaches should be compared, in terms of resources required and the information needed to address the objectives of the sampling programme, before implementing either approach (Davies et al. 2003). Nevertheless, the continuation of a spatially stratified trawl-based sampling programme with some regularity should continue to provide better information on the mortality and recruitment variation of the TRE 1 stock required for stock assessments. This is contingent on maintaining adequate sampling strategies and robust collections to meet the target requirements, and relies on industry participation and cooperation. The NINSWG also recommended that future TRE 1 catch-at-age sampling programmes be expanded from two to three spatial strata with separation of East Northland and Hauraki Gulf.

Length and age distributions

As only subarea specific data (i.e., East Northland/Hauraki Gulf and Bay of Plenty) was collected from the TRE 1 bottom trawl and purse-seine fisheries in 2012–13, a stratified design was used in analysing the length and age distributions, as opposed to an unstratified design where data are pooled across spatial strata and used in analyses prior to 2007–08. The stratified design weights proportions of length and age for each stratum according to the estimated number of fish landed in that stratum, when calculating TRE 1 proportions at length and age. The total tonnage (and the estimated number of trevally) landed by bottom trawl from the Bay of Plenty subarea in 2012–13 was far greater (about nine times by number) than for East Northland/Hauraki Gulf, resulting in the stratified length and age distributions for the TRE 1 bottom trawl fishery closely resembling the Bay of Plenty subarea stratum estimates (see Figure 23). Similarly, the total tonnage landed by purse-seine in the respective subarea strata in 2012–13 was greater for the East Northland subarea (about twice by number), resulting in the stratified length and age distributions for the TRE 1 purse-seine fishery closely resembling the East Northland subarea stratum estimates (see Figure 25).

The results determined for length and age collections in TRE 1 in 2012–13 show that variability in trevally catch-at-length and catch-at-age estimates exists between the bottom trawl and purse-seine method fisheries, similar to findings in previous years (Walsh et al. 1999, 2000, Langley 2001, Walsh & McKenzie 2009, Walsh et al. 2010a, 2010b, 2012b). The TRE 1 bottom trawl length distribution in 2012–13 was similar to those in recent years, being relatively narrow and dominated by small to moderate sized trevally, with a mean size of 38.4 cm (about 1.1 kg). In comparison, the length distribution of the TRE 1 purse-seine catch in 2012–13, although of a similar dome shape to bottom trawl, comprised mainly moderate to large trevally, with a mean size of 42.4 cm (about 1.5 kg), reflecting method-specific differences in selectivity. For proportion at age comparisons, bottom trawl comprised slightly more young fish below 7 years of age and purse-seine proportionally more between 10 and 12 years of age, with marginal differences for fish older than this. The purse-seine method is highly selective, catching surface schools of similar sized fish with little variation, while bottom trawl is thought to be more representative of the recruited population, capturing a wider range of sizes and ages, and therefore having better stock monitoring utility (Walsh & McKenzie 2009).

James (1980) found that although length and age compositions of surface and bottom caught trevally were different, tagging evidence had shown that both the pelagic and demersal phases in the Bay of Plenty belonged to the same stock, with trevally tagged and released from purse-seine subsequently recaptured in significant numbers by purse-seine and a variety of bottom fishing methods. Nevertheless, Langley (unpublished results) raised concern over the use of a single age-length key to describe catch-at-age for trevally caught by bottom trawl and purse-seine methods, and suggested that any future monitoring of the TRE 1 stock should include method-specific age collections to fully determine age-specific selectivity differences.

Spatial patterns in length and age

Similar to findings since 2006–07 (Walsh et al. 2010a, 2010b, 2012b), the length and age distributions for the TRE 1 subarea fisheries in 2012–13 further confirm that heterogeneous patterns exist within TRE 1 on a moderate spatial scale from north to south. Like previous years, this fourth year addition to the time series of proportion at age data for the two subarea fisheries (East Northland and Bay of Plenty) has further reinforced the evidence that relative year class strengths vary between subareas, and that continuity from one year to the next within each subarea is indicative of spatial heterogeneity in age within TRE 1, particularly in bottom trawl collections. This persistent feature implies that more than one biological stock is present, although it is unclear where the boundaries of these occur, and is consistent with what is known from tagging studies; which showed that trevally movement between areas is limited with most fish (88%) captured within 30 nautical miles of release sites (James 1980). Given the consistency of heterogeneous patterns in age structure in TRE 1, it is highly likely that the vast majority of fish probably reside within the same spatial strata from year to year, indicative of low levels of stock and subarea mixing, similar to that determined from tagging studies of snapper (Paul 1967, Crossland 1976, 1982, Tong 1978, Walsh et al. 2006c).

Despite the persistent spatial differences in proportion at age that exist across time in TRE 1, there has always been some level of consistency in relative year strengths between the two subareas, which may relate to the positioning of subarea boundaries and internal spatial patterns of fishing effort. Furthermore, as biological boundaries have not yet been fully determined in TRE 1, the combining of the Hauraki Gulf subarea with East Northland in 2012–13 may have also influenced recent results. Even so, any variability in relative year class proportions between the TRE 1 subareas may also be due to the variable recruitment specific to a stock (a reflection of unique environmental conditions), growth differences, and fishing mortality differences. Only a tagging programme would clarify the level of connectivity between the subareas of TRE 1, as has been done for SNA 8 (Gilbert et al. 2005).

Despite shortfalls in length and age sample sizes for some years, the East Northland bottom trawl subarea catch-at-age time series (2006–07 to 2012–13) demonstrated reasonable continuity of year class strength progression between years. East Northland catches comprised a consistently high proportion of small young trevally (77–91% less than 11 years), and often displayed highly variable recruitment for young age classes, most evident in samples from 2012–13. In comparison, bottom trawl catch samples from the Bay of Plenty subarea were usually more comprehensive, displayed better continuity in year class strength progression between years, and less variability in recruitment strength, than samples from East Northland. Although not uniform in its selection of fish across both size and age, subarea-specific catch-at-age estimates from the bottom trawl fishery do provide method-specific mortality at age, reveal the relative strength of newly recruiting year classes entering the fishery, as well as variations in annual growth rates, which influence stock productivity, and are therefore a useful tool for stock monitoring.

Comparison of relative year class strengths in TRE 1 and TRE 7

In the early 1990s, only minor similarities in relative year class strengths in bottom trawl catches from the TRE 1 and TRE 7 stocks were apparent when sampling was conducted concurrently in both fisheries (Walsh et al. 1999, 2000). However, following the implementation of a revised ageing protocol to improve reader accuracy and precision in age estimation in 2006–07, some similarities in year class strength between East Northland and Ninety Mile Beach during concurrent (Walsh et al.

2010a, 2010b) and non-concurrent sampling (Walsh et al. 2012a, 2012b) of both trevally stocks were apparent. During 2012–13, sampling was undertaken concurrently in both TRE 1 and TRE 7 (Walsh et al. 2014c), and similarities in year class strengths between the stocks was again evident, more so between East Northland and the TRE 7 subareas, than the Bay of Plenty. Although trevally movement is known to be limited (James 1980), the similarities in year class strengths between the northern boundaries of TRE 1 and the subareas of TRE 7 are likely to be related to an environmental cue such as water temperature (outlined in the paragraph below), although the presence, at times, of very large fast growing fish in East Northland and Ninety Mile Beach (James 1984, Walsh et al. 1999, 2000, 2010b), may indicate some linkage between these adjacent subareas.

Comparison of relative year class strengths in TRE 1 and SNA 1

In recent years, a few speculative correlations were made between relative year class strengths in catch-at-age estimates for the TRE 1 and SNA 1 stocks and assumed to be coincidental, given the selectivity differences between the fishing methods and species, and the relative exploitation status of the respective populations (Walsh et al. 2012b). Despite this, comparisons made between the neighbouring west coast stocks TRE 7 and SNA 8, were, at times, found to correlate well (Walsh et al. 2010b, 2012a, 2014c). Visual comparisons made between TRE 1 and SNA 1 catch-at-age estimates for 2012–13 showed some similarities in relative year class strengths, particularly with the East Northland snapper substock bottom longline estimates for fish 8 years and older, and for some year classes between TRE 1 and SNA 8 (Appendix 13). Walsh et al. (2012a) reported that recruitment strength variability in TRE 7 and SNA 8 was likely to be driven by water temperature, similar to the relationship modelled for snapper in the Hauraki Gulf (Francis 1993), although this was likely to vary over the geographic range of the stocks due to the different hydrodynamic and recruitment processes between the two species.

Precision and representativeness in catch-at-age

It is expected that the derived proportional length and age distributions presented in this report are adequate and representative descriptions of commercial bottom trawl and purse-seine landings from the TRE 1 stock and subarea strata in 2012–13. These length and age distributions are also comparable with collections made since 2006–07, a time when improvements to ageing trevally were made, and heterogeneity in length and age was first investigated. The combined TRE 1 bottom trawl length and age distributions achieved acceptable levels of precision with MWCVs of 0.17 and 0.23 respectively, while those for purse-seine were slightly higher (MWCVs of 0.23 and 0.27), but still fell below the target goal of the project of 0.30. Furthermore, with the improvement in reader competency following the introduction of a revised trevally ageing protocol, and high precision for reader comparisons with the agreed age (CV and IAPE less than about 2%), ageing is now likely to be more accurate than in the past, and estimates of catch-at-age may be treated with more confidence.

The potential for differences in the subarea length and age compositions highlights the importance of ensuring that the sampling coverage is representative of the areal distribution of the entire fishery to ensure the collection of an unbiased sample of the length (Langley 2002) and age (Walsh et al. 2010b) composition of the TRE 1 stock catch. This may be dependent on changes in spatial fishing pattern and if the relative catch by subarea varies from year to year. In 2012–13, considerably more bottom trawl effort was directed toward the Bay of Plenty subarea and more purse-seine effort directed toward East Northland. It is fundamental that future sampling in TRE 1 should ensure that all length and age data are representative of the areal distribution of the entire fishery, and that the optimised targets of numbers of landings and otolith samples in the catch sampling design are firmly adhered to, as occurred for this programme.

Mean weight-at-age and mean length-at-age

Length stratification of otolith samples, such as was used in the fixed allocation for TRE 1 subarea otolith collections in 2012–13, has been known to introduce bias in estimates of mean weight- and length-at-age, and consequently in growth parameters (Goodyear 1995). To estimate catch-at-age, the otolith samples presented here have been adjusted to reflect the length composition of the fishery and are therefore unbiased. Consequently, the estimates of mean weight- and length-at-age may be suitable for gross comparisons in growth variability between the subareas of TRE 1 in 2012–13; differences possibly related to spatial and genetic factors within the TRE 1 stock.

Similar to that determined in 2008–09 (Walsh et al. 2010a), mean weight-at-age estimates for the respective methods sampled in 2012–13, were consistently higher for the East Northland/Hauraki Gulf stratum and are indicative of spatial growth differences within TRE 1, further implying the existence of multiple biological stocks. Although mean weight-at-age for TRE 1 purse-seine was consistently higher than bottom trawl, comparisons between methods within a subarea stratum indicate weight-at-age for purse-seine to generally be higher for young trevally up to about 11 years, and higher for bottom trawl above this age. Spatial and temporal variability in mean weight-at-age estimates have also been found in snapper and are thought to be due to differences in regional exploitation levels, recruitment rates, and different rates of somatic growth (Davies et al. 2003, Walsh et al. 2006a, 2006b, 2006c, 2011, 2014b). If spatial and/or temporal variation in growth exists within the TRE 1 stock or subarea strata, then it is likely that the predicted estimates presented here will not be suitable descriptions of the stock. Observed mean length-at-age estimates for the TRE 1 subarea fisheries follow the same patterns seen in mean weight-at-age estimates.

The oldest trevally sampled from the TRE 1 fishery in 2012–13 was 38 years old, and samples aged by James (1984) from collections undertaken in the 1970s determined maximum age estimates of 47 years.

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7. APPENDICES

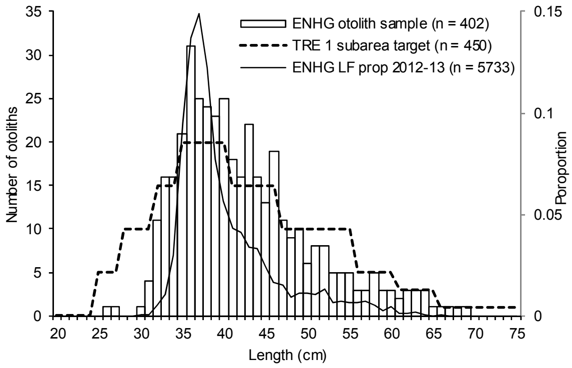
Appendix 1: TRE 1 catch sampling summary from 1997–98 to 2012–13 (Note: all collections made using the length frequency and age-length key sampling approach, and all ageing undertaken by NIWA). LF, length frequency.

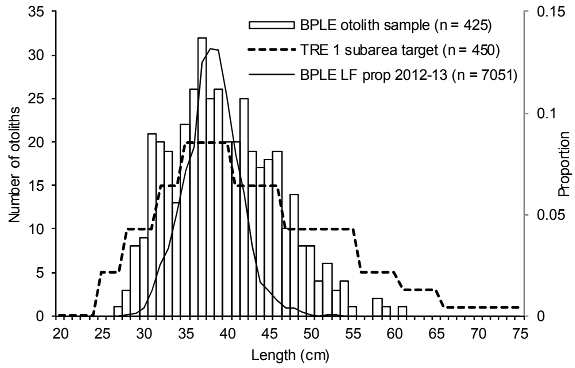
TRE 1

Catch sampling report	Research provider	Fishing year	Fishing method	No. of landings sampled for LF	Season[††]	Comments*	Otolith sample size	Otolith prep.[†]	Season[††]
Walsh et al. (1999)	NIWA	1997–98	Purse-seine	7	Spr–Sum, Win	5 BPLE, 2 ENLD			
			Bottom trawl	12	Sum–Aut	3 BPLE, 4 HAGU, 4 ENLD, 1 Mixed	387	B&E	Sum–Aut
Walsh et al. (2000)	NIWA	1998–99	Purse-seine	9	Spr–Sum, Win	5 BPLE, 4 ENLD	30	TS	Win
			Bottom trawl	12	Sum–Win	8 BPLE, 3 ENLD, 1 Mixed	280	TS	Sum–Win
Langley (2001)	Sanford Ltd	1999–2000	Purse-seine	7	Spr–Sum	4 BPLE, 3 ENLD			
			Bottom trawl	22	Spr–Win	18 BPLE, 4 Mixed	572	TS	Aut–Win
Langley (2002)	Sanford Ltd	2000–01	Purse-seine	7	Spr–Sum, Win	5 BPLE, 2 ENLD	745	TS	Spr–Sum, Win
Langley (2003)	Sanford Ltd	2001–02	Purse-seine	8	Spr–Sum, Win	7 BPLE, 1 ENLD	360	TS	Sum,Win
Langley (2004)	Sanford Ltd	2002–03	Purse-seine	8	Spr–Sum	2 BPLE, 6 ENLD	554	TS	Spr–Sum
Langley (2009)	GANZL	2005–06	Purse-seine	5	Spr, Aut, Win	2 BPLE, 3 ENLD	257	TS	Spr, Aut, Win
Walsh et al. (2010a)	NIWA	2006–07	Purse-seine	2	Spr, Sum	2 ENLD			
			Bottom trawl	5	Aut, Win	4 ENLD, 1 Mixed	338	TS	Aut, Win
Walsh et al. (2010b)	NIWA	2007–08	Purse-seine	2	Sum	2 BPLE	73	TS	Sum
			Bottom trawl	15	Spr–Aut	10 BPLE, 5 ENLD	499	TS	Spr–Aut
Walsh et al. (2012b)	NIWA	2008–09	Purse-seine	3	Win	1 BPLE, 2 ENLD	135	TS	Win
			Bottom trawl	13	Sum–Aut	9 BPLE, 4 ENLD	559	TS	Sum–Aut
This report	NIWA	2012–13	Purse-seine	7	Spr–Win	2 BPLE, 5 ENHG			
			Bottom trawl	21	Sum–Win	11 BPLE, 10 ENHG	804	TS	Sum–Win

* BPLE = Bay of Plenty; ENLD = East Northland; HAGU = Hauraki Gulf; ENHG = East Northland and Hauraki Gulf combined
[†] B&E = Bake and embed; TS = Thin section.
[††] Spr (Oct–Nov), Sum (Dec–Feb), Aut (Mar–May), Win (Jun–Sep).
NIWA, National Institute of Water and Atmospheric Research; GANZL, Golder Associates (NZ) Ltd.

Appendix 2: Length distributions of the target fixed allocation otolith samples (dashed lines) and the achieved otolith collections (histograms) from the subarea bottom trawl fisheries of TRE 1 in 2012–13. For comparison, the proportional subarea bottom trawl length distributions from 2012–13, from which the otolith subsamples were collected is also given (solid lines). ENHG, East Northland/Hauraki Gulf; BPLE, Bay of Plenty.





Appendix 3: Annual commercial trevally catch (t) by method for the subareas of TRE 1, 2007–08 to 2012–13.

	East Northland/Hauraki Gulf					Bay of Plenty				
Fishing year	BLL	BT	DS	PS	Other	BLL	BT	DS	PS	Other
2007–08	6	131	2	0	90	3	423	10	120	35
2008–09	4	112	1	214	69	1	296	6	121	26
2009–10	4	55	3	3	82	2	442	11	161	36
2010–11	12	98	1	113	94	4	481	27	464	30
2011–12	6	73	4	61	35	4	342	23	441	22
2012–13	8	53	2	529	52	4	386	28	182	36

BLL = bottom longline; BT = bottom trawl; DS = Danish seine; PS = purse-seine

Appendix 4A: Annual bottom trawl trevally catch (t) by statistical reporting areas within the TRE 1 stock, 2007–08 to 2012–13.

	Statistical area										
Fishing year	002	003	004	005	006	007	008	009	010	106	107
2007–08	43	41	2	38	7	0	42	198	183	0	0
2008–09	33	40	1	32	5	1	20	142	134	0	0
2009–10	16	18	1	17	3	0	58	147	236	0	0
2010–11	35	20	1	37	5	0	40	268	172	0	0
2011–12	34	11	0	21	7	0	29	178	135	0	0
2012–13	13	9	0	25	6	0	38	149	199	0	0

Appendix 4B: Annual purse-seine trevally catch (t) by statistical reporting areas within the TRE 1 stock, 2007–08 to 2012–13.

	Statistical area						
Fishing year	002	003	004	005	008	009	010
2007–08	0	0	0	0	0	120	0
2008–09	168	46	0	0	60	61	0
2009–10	3	0	0	0	130	30	0
2010–11	0	102	0	11	279	185	0
2011–12	61	0	0	0	234	207	0
2012–13	529	0	0	0	20	162	0

Appendix 5A: Annual bottom trawl trevally catch (t) by target species for the subareas of TRE 1, 2007–08 to 2012–13.

	East Northland/Hauraki Gulf				Bay of Plenty			
Fishing year	TRE	SNA	JDO	Other	TRE	SNA	JDO	Other
2007–08	74	21	28	8	279	119	9	16
2008–09	61	30	20	1	224	49	13	10
2009–10	23	14	13	6	343	72	9	17
2010–11	50	28	16	4	367	78	21	14
2011–12	28	34	8	4	209	116	6	11
2012–13	12	30	9	2	285	95	3	2

TRE, trevally; SNA, snapper; JDO, John dory

Appendix 5B: Annual purse-seine trevally catch (t) by target species for the subareas of TRE 1, 2007–08 to 2012–13.

	East Northland/Hauraki Gulf				Bay of Plenty			
Fishing year	TRE	KAH	EMA	Other	TRE	KAH	EMA	Other
2007–08	0	0	0	0	118	2	0	0
2008–09	214	0	0	0	111	9	0	0
2009–10	3	0	0	0	121	35	5	0
2010–11	113	0	0	0	462	2	0	0
2011–12	61	0	0	0	420	4	16	2
2012–13	529	0	0	0	158	23	1	0

Appendix 6: Age-length keys derived from otolith samples collected from trevally fisheries in TRE 1, 2012–13.

Estimates of proportion of age at length for trevally sampled from all TRE 1 subareas combined, 2012–13.

(Note: Aged to 01/01/2013)

Length (cm)	Age (years) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	No. 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	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
27	0.50	0	0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
28	0.33	0	0.33	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
29	0	0.38	0	0.38	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
30	0	0.40	0.20	0.10	0.10	0.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
31	0	0.60	0.16	0.04	0.04	0.12	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	25
32	0	0.55	0.10	0.06	0.10	0.13	0	0.03	0.03	0	0	0	0	0	0	0	0	0	0	0	31
33	0	0.31	0.23	0.11	0.06	0.09	0.11	0.06	0	0	0	0	0	0.03	0	0	0	0	0	0	35
34	0	0.24	0.34	0.03	0.14	0.10	0.10	0.03	0	0	0	0	0	0	0	0	0	0	0	0	29
35	0	0.14	0.26	0.14	0.17	0.05	0.07	0.12	0.05	0	0	0	0	0	0	0	0	0	0	0	42
36	0	0.05	0.32	0.07	0.19	0.11	0.18	0.02	0.02	0.02	0.02	0	0.02	0	0	0	0	0	0	0	57
37	0	0	0.31	0.09	0.20	0.11	0.07	0.07	0.05	0.02	0.02	0	0	0.04	0	0	0	0	0	0.02	55
38	0	0	0.25	0.08	0.17	0.10	0.25	0.02	0.02	0.04	0	0.02	0.02	0	0.02	0	0	0	0	0	48
39	0	0	0.10	0.04	0.16	0.02	0.20	0.10	0.04	0.08	0.06	0	0.06	0.08	0.04	0	0	0	0	0	49
40	0	0	0.09	0.02	0.18	0.04	0.27	0.09	0.02	0.11	0.07	0.07	0.02	0	0	0	0.02	0	0	0	45
41	0	0	0.03	0.06	0.22	0	0.11	0.08	0.11	0.08	0.03	0.03	0	0.03	0.08	0.03	0.03	0.06	0	0.03	36
42	0	0	0	0.05	0.02	0	0.12	0.02	0.05	0.07	0.10	0.17	0.02	0.12	0.05	0.02	0	0	0.02	0.15	41
43	0	0	0.03	0	0.05	0.05	0.11	0	0.11	0.08	0.08	0.05	0.05	0.19	0.11	0.03	0	0.03	0	0.03	37
44	0	0	0	0	0	0	0.12	0.03	0	0.15	0.03	0.15	0.06	0.06	0.06	0.03	0.06	0.09	0.03	0.12	33
45	0	0	0	0	0	0.03	0.03	0	0	0.10	0.07	0.10	0.07	0.03	0.03	0.07	0.03	0.07	0.10	0.24	29
46	0	0	0	0	0	0.05	0.03	0	0.05	0.03	0.11	0.08	0.14	0.14	0.03	0.08	0	0.03	0	0.24	37
47	0	0	0	0	0	0	0.05	0.05	0	0	0.10	0.05	0.14	0.05	0.10	0	0.10	0.05	0.05	0.29	21
48	0	0	0	0	0	0	0.04	0.09	0.04	0	0.09	0.13	0.04	0	0.13	0	0	0	0.04	0.39	23
49	0	0	0	0	0	0	0.13	0.06	0	0	0.06	0.06	0.06	0	0.13	0	0	0	0	0.50	16
50	0	0	0	0	0	0	0.08	0	0	0	0	0	0	0	0.15	0.15	0.08	0	0.08	0.46	13
51	0	0	0	0	0	0	0	0.09	0	0	0	0.18	0.09	0	0.18	0.09	0	0	0	0.36	11
52	0	0	0	0	0	0	0	0	0.17	0.08	0.08	0.08	0	0	0.17	0	0.08	0	0	0.33	12
53	0	0	0	0	0	0	0	0	0	0	0	0.14	0.14	0.14	0.29	0	0.14	0	0	0.14	7
54	0	0	0	0	0	0	0	0	0	0	0	0.38	0	0	0.13	0	0	0	0	0.50	8
55	0	0	0	0	0	0	0	0	0	0	0	0.17	0	0	0.17	0	0	0	0	0.67	6
56	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0.33	0.33	0	0	0	0	3
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0.33	0	0.33	0	3
58	0	0	0	0	0	0	0	0	0	0.14	0	0	0.14	0	0.14	0	0	0.14	0	0.43	7
59	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0	0	0	0.67	3
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0.50	0	0	0	0	0	0.50	2
61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0	0	0.67	3
62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0	0.67	3
63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0.67	3
64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0.67	3
65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	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	1.00	1
70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total																					804

Appendix 6 – continued:

Estimates of proportion of age at length for trevally sampled from the East Northland/Hauraki Gulf subarea of TRE 1, 2012–13. (Note: Aged to 01/01/2013)

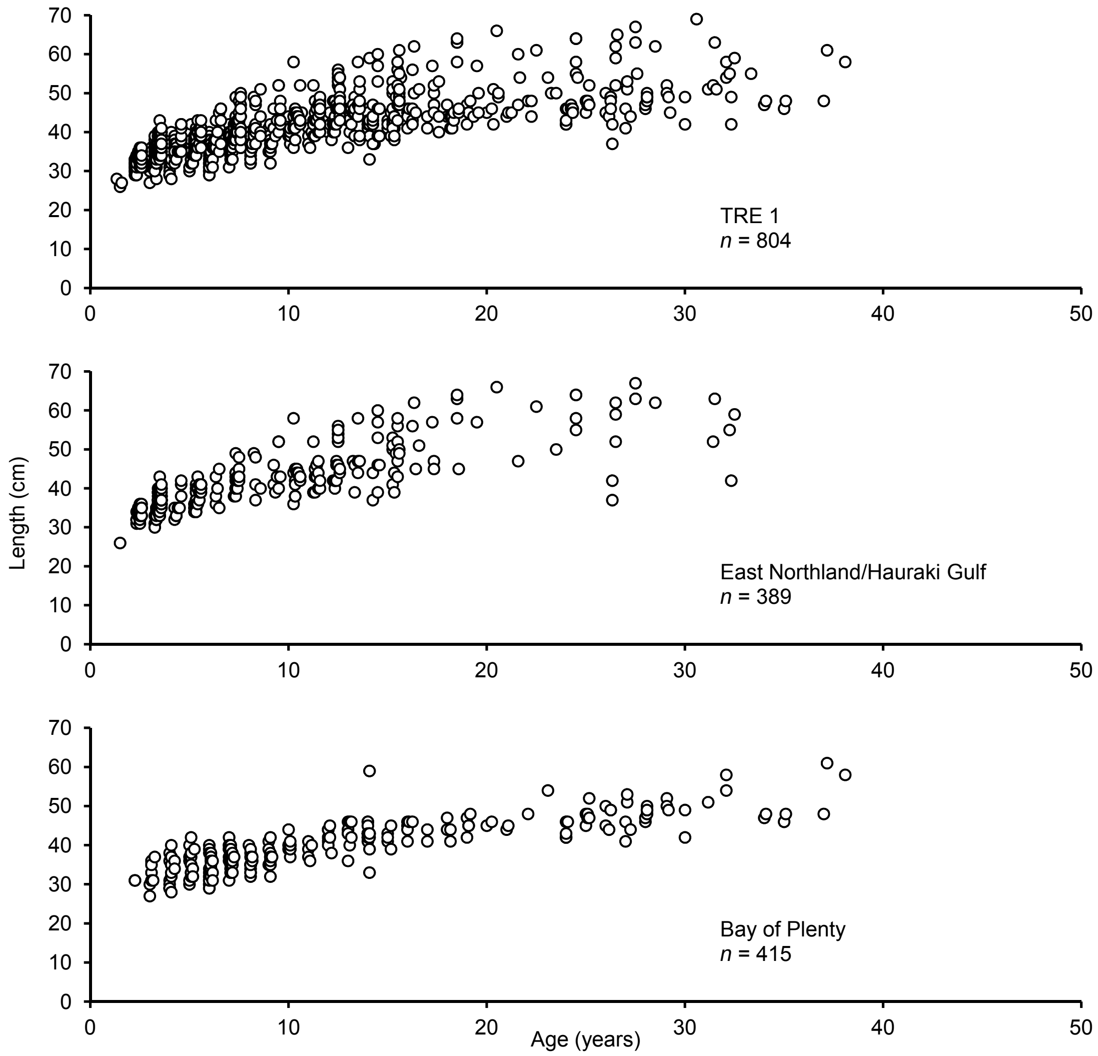
Length	Age (years)																				No.
(cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	>19	Aged
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	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	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
27	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
31	0	0.75	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
32	0	0.64	0.27	0.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
33	0	0.44	0.38	0.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16
34	0	0.38	0.44	0	0.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16
35	0	0.29	0.29	0.19	0.19	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21
36	0	0.10	0.48	0	0.26	0.03	0.10	0	0	0.03	0	0	0	0	0	0	0	0	0	0	31
37	0	0	0.63	0	0.21	0.04	0	0.04	0	0	0	0	0	0.04	0	0	0	0	0	0.04	24
38	0	0	0.48	0.09	0	0.04	0.26	0	0	0.09	0	0	0.04	0	0	0	0	0	0	0	23
39	0	0	0.17	0.04	0.30	0	0.04	0.04	0.04	0	0.09	0	0.09	0.13	0.04	0	0	0	0	0	23
40	0	0	0.16	0	0.28	0.04	0.28	0.04	0.04	0	0.08	0.04	0	0	0	0	0.04	0	0	0	25
41	0	0	0.06	0.13	0.50	0	0.06	0.06	0.06	0.06	0	0	0	0	0.06	0	0	0	0	0	16
42	0	0	0	0.13	0	0	0.19	0	0.06	0.13	0.13	0.25	0	0	0	0	0	0	0	0.13	16
43	0	0	0.05	0	0.10	0.10	0.20	0	0.20	0.15	0.10	0.05	0	0	0.05	0	0	0	0	0	20
44	0	0	0	0	0	0	0.25	0.06	0	0.25	0.06	0.13	0.06	0.06	0.06	0	0.06	0	0	0	16
45	0	0	0	0	0	0.08	0.08	0	0	0.17	0.17	0.17	0	0	0	0.08	0.08	0.08	0.08	0	12
46	0	0	0	0	0	0.11	0.06	0	0.11	0	0.22	0.17	0.11	0.17	0	0	0	0.06	0	0	18
47	0	0	0	0	0	0	0.09	0	0	0	0.18	0.09	0.27	0	0.18	0	0.09	0	0	0.09	11
48	0	0	0	0	0	0	0.11	0.11	0.11	0	0.11	0.11	0.11	0	0.33	0	0	0	0	0	9
49	0	0	0	0	0	0	0.25	0.13	0	0	0.13	0.13	0	0	0.25	0	0	0	0	0.13	8
50	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0	0.33	0	0	0	0.17	0.33	6
51	0	0	0	0	0	0	0	0.13	0	0	0	0.25	0.13	0	0.25	0.13	0	0	0	0.13	8
52	0	0	0	0	0	0	0	0	0.25	0.13	0.13	0.13	0	0	0.13	0	0	0	0	0.25	8
53	0	0	0	0	0	0	0	0	0	0	0	0.20	0.20	0.20	0.20	0	0.20	0	0	0	5
54	0	0	0	0	0	0	0	0	0	0	0	0.75	0	0	0	0	0	0	0	0.25	4
55	0	0	0	0	0	0	0	0	0	0	0	0.20	0	0	0.20	0	0	0	0	0.60	5
56	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0.33	0.33	0	0	0	0	3
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0.33	0	0.33	0	3
58	0	0	0	0	0	0	0	0	0	0.20	0	0	0.20	0	0.20	0	0	0.20	0	0.20	5
59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	2
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0.50	0	0	0	0	0	0.50	2
61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.50	0	0	0	0	0.50	2
62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0	0.67	3
63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0.67	3
64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0.67	3
65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	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	1.00	1
70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total																					389

Appendix 6 – continued:

Estimates of proportion of age at length for trevally sampled from the Bay of Plenty subarea of TRE 1, 2012–13. (Note: Aged to 01/01/2013)

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	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
28	0.33	0	0.33	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
29	0	0.38	0	0.38	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
30	0	0.44	0.11	0.11	0.11	0.22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
31	0	0.57	0.14	0.05	0.05	0.14	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	21
32	0	0.50	0	0.05	0.15	0.20	0	0.05	0.05	0	0	0	0	0	0	0	0	0	0	0	20
33	0	0.21	0.11	0.05	0.11	0.16	0.21	0.11	0	0	0	0	0	0.05	0	0	0	0	0	0	19
34	0	0.08	0.23	0.08	0.08	0.23	0.23	0.08	0	0	0	0	0	0	0	0	0	0	0	0	13
35	0	0	0.24	0.10	0.14	0.05	0.14	0.24	0.10	0	0	0	0	0	0	0	0	0	0	0	21
36	0	0	0.12	0.15	0.12	0.19	0.27	0.04	0.04	0	0.04	0	0.04	0	0	0	0	0	0	0	26
37	0	0	0.06	0.16	0.19	0.16	0.13	0.10	0.10	0.03	0.03	0	0	0.03	0	0	0	0	0	0	31
38	0	0	0.04	0.08	0.32	0.16	0.24	0.04	0.04	0	0	0.04	0	0	0.04	0	0	0	0	0	25
39	0	0	0.04	0.04	0.04	0.04	0.35	0.15	0.04	0.15	0.04	0	0.04	0.04	0.04	0	0	0	0	0	26
40	0	0	0	0.05	0.05	0.05	0.25	0.15	0	0.25	0.05	0.10	0.05	0	0	0	0	0	0	0	20
41	0	0	0	0	0	0	0.15	0.10	0.15	0.10	0.05	0.05	0	0.05	0.10	0.05	0.05	0.10	0	0.05	20
42	0	0	0	0	0.04	0	0.08	0.04	0.04	0.04	0.08	0.12	0.04	0.20	0.08	0.04	0	0	0.04	0.16	25
43	0	0	0	0	0	0	0	0	0	0	0.06	0.06	0.12	0.41	0.18	0.06	0	0.06	0	0.06	17
44	0	0	0	0	0	0	0	0	0	0.06	0	0.18	0.06	0.06	0.06	0.06	0.06	0.18	0.06	0.24	17
45	0	0	0	0	0	0	0	0	0	0.06	0	0.06	0.12	0.06	0.06	0.06	0	0.06	0.12	0.41	17
46	0	0	0	0	0	0	0	0	0	0.05	0	0	0.16	0.11	0.05	0.16	0	0	0	0.47	19
47	0	0	0	0	0	0	0	0.10	0	0	0	0	0	0.10	0	0	0.10	0.10	0.10	0.50	10
48	0	0	0	0	0	0	0	0.07	0	0	0.07	0.14	0	0	0	0	0	0	0.07	0.64	14
49	0	0	0	0	0	0	0	0	0	0	0	0	0.13	0	0	0	0	0	0	0.88	8
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.29	0.14	0	0	0.57	7
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	3
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0.25	0	0	0.50	4
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.50	0	0	0	0	0.50	2
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0	0	0	0.75	4
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	1
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	2
59	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	1
62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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
71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total																					415

Appendix 7: Scatterplot of age-at-length data for trevally sampled from the TRE 1 and subarea bottom trawl fisheries in 2012–13 (*n*, sample size). Age is decimalised as of the month of collection relative to an assumed January 1 "birthdate".



Appendix 8: Estimates of proportion at length with CVs (bootstrap estimates) for trevally from the TRE 1 and subarea bottom trawl and purse-seine fisheries in 2012–13. ENHG, East Northland/Hauraki Gulf; BPLE, Bay of Plenty.

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

Length	Bottom trawl						Purse-seine					
	TRE 1		ENHG		BPLE		TRE 1		ENHG		BPLE	
(cm)	*P.i.*	CV	*P.i.*	CV	*P.i.*	CV	*P.i.*	CV	*P.i.*	CV	*P.i.*	CV
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	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
24	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
25	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
26	0.0000	1.80	0.0001	1.87	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
27	0.0001	1.66	0.0002	1.65	0.0001	1.89	0.0000	0.00	0.0000	0.00	0.0000	0.00
28	0.0005	1.18	0.0000	0.00	0.0005	1.18	0.0000	0.00	0.0000	0.00	0.0000	0.00
29	0.0011	0.78	0.0000	0.00	0.0012	0.78	0.0000	0.00	0.0000	0.00	0.0000	0.00
30	0.0035	0.57	0.0005	0.97	0.0039	0.57	0.0000	0.00	0.0000	0.00	0.0000	0.00
31	0.0114	0.43	0.0009	0.89	0.0126	0.43	0.0005	1.18	0.0000	0.00	0.0015	1.17
32	0.0229	0.37	0.0052	0.61	0.0249	0.37	0.0010	0.93	0.0000	0.00	0.0030	0.93
33	0.0306	0.34	0.0103	0.35	0.0329	0.34	0.0009	0.66	0.0000	0.00	0.0029	0.65
34	0.0476	0.25	0.0300	0.30	0.0496	0.27	0.0008	0.70	0.0004	1.32	0.0015	0.85
35	0.0739	0.19	0.0949	0.35	0.0715	0.21	0.0035	0.51	0.0008	0.90	0.0090	0.59
36	0.0887	0.15	0.1370	0.31	0.0832	0.17	0.0068	0.56	0.0012	0.87	0.0184	0.64
37	0.1271	0.10	0.1488	0.24	0.1247	0.11	0.0275	0.32	0.0063	0.49	0.0715	0.36
38	0.1309	0.09	0.1223	0.22	0.1319	0.10	0.0563	0.31	0.0121	0.39	0.1483	0.35
39	0.1254	0.12	0.0769	0.20	0.1309	0.13	0.0970	0.20	0.0314	0.31	0.2337	0.23
40	0.1037	0.12	0.0564	0.24	0.1091	0.13	0.1265	0.14	0.0596	0.27	0.2657	0.15
41	0.0752	0.15	0.0432	0.37	0.0789	0.16	0.1107	0.16	0.0916	0.28	0.1505	0.15
42	0.0583	0.15	0.0415	0.42	0.0602	0.16	0.1253	0.21	0.1504	0.21	0.0733	0.55
43	0.0347	0.21	0.0340	0.45	0.0348	0.23	0.1061	0.16	0.1512	0.09	0.0124	1.27
44	0.0182	0.25	0.0335	0.44	0.0165	0.29	0.0974	0.15	0.1416	0.13	0.0055	1.34
45	0.0139	0.25	0.0245	0.43	0.0127	0.29	0.0648	0.26	0.0949	0.26	0.0023	1.48
46	0.0089	0.30	0.0167	0.54	0.0080	0.35	0.0530	0.28	0.0783	0.29	0.0005	1.62
47	0.0048	0.38	0.0151	0.66	0.0036	0.47	0.0379	0.31	0.0562	0.31	0.0000	0.00
48	0.0047	0.41	0.0093	0.74	0.0042	0.49	0.0273	0.31	0.0405	0.32	0.0000	0.00
49	0.0026	0.41	0.0112	0.65	0.0016	0.57	0.0212	0.45	0.0313	0.46	0.0001	1.86
50	0.0018	0.55	0.0113	0.81	0.0008	0.83	0.0148	0.63	0.0220	0.64	0.0000	0.00
51	0.0014	0.53	0.0109	0.74	0.0003	0.95	0.0077	0.55	0.0115	0.56	0.0000	0.00
52	0.0021	0.51	0.0131	0.74	0.0008	0.85	0.0054	0.89	0.0080	0.90	0.0000	0.00
53	0.0011	0.63	0.0066	0.69	0.0005	1.35	0.0033	0.75	0.0048	0.76	0.0000	0.00
54	0.0009	0.63	0.0076	0.79	0.0001	1.30	0.0025	0.94	0.0038	0.95	0.0000	0.00
55	0.0007	0.61	0.0064	0.76	0.0001	1.85	0.0011	0.89	0.0016	0.90	0.0000	0.00
56	0.0007	0.65	0.0065	0.76	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
57	0.0008	0.57	0.0074	0.69	0.0000	0.00	0.0003	0.94	0.0004	0.94	0.0000	0.00
58	0.0006	0.61	0.0050	0.76	0.0000	1.46	0.0000	0.00	0.0000	0.00	0.0000	0.00
59	0.0003	0.72	0.0026	0.81	0.0000	0.00	0.0002	1.44	0.0003	1.45	0.0000	0.00
60	0.0005	0.58	0.0046	0.68	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
61	0.0002	0.74	0.0013	0.89	0.0000	1.78	0.0000	0.00	0.0000	0.00	0.0000	0.00
62	0.0001	0.92	0.0012	0.97	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
63	0.0002	0.80	0.0017	0.90	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
64	0.0001	0.91	0.0006	0.99	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
65	0.0000	1.62	0.0003	1.69	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
66	0.0000	1.25	0.0004	1.32	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
67	0.0000	1.65	0.0001	1.68	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
68	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
69	0.0000	1.71	0.0003	1.77	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
71	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
72	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
73	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
74	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
75	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	371 888		38 240		335 369		447 102		302 314		145 474	
n	12 784		5733		7051		5 175		4 046		1 129	

Appendix 9: Estimates of proportion at age with CVs (bootstrap estimates) for trevally from the TRE 1 and subarea bottom trawl and purse-seine fisheries in 2012–13. ENHG, East Northland/Hauraki Gulf; BPLE, Bay of Plenty.

P.j. = proportion of fish in age class; CV = coefficient of variation; *n* = number of fish aged.

	Bottom trawl						Purse-seine					
Age	TRE 1		ENHG		BPLE		TRE 1		ENHG		BPLE	
(years)	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV
1	0.0002	1.49	0.0002	1.29	0.0002	1.71	0.0000	0.00	0.0000	0.00	0.0000	0.00
2	0.0354	0.33	0.0601	0.39	0.0326	0.40	0.0013	0.53	0.0005	0.76	0.0030	0.68
3	0.0858	0.20	0.2908	0.24	0.0624	0.26	0.0344	0.33	0.0390	0.38	0.0247	0.58
4	0.0667	0.23	0.0451	0.33	0.0692	0.24	0.0384	0.37	0.0328	0.54	0.0499	0.48
5	0.1155	0.16	0.1542	0.20	0.1111	0.18	0.0896	0.24	0.0890	0.31	0.0909	0.36
6	0.0890	0.21	0.0300	0.39	0.0957	0.21	0.0441	0.31	0.0350	0.43	0.0631	0.44
7	0.1795	0.12	0.1000	0.21	0.1886	0.13	0.1781	0.15	0.1542	0.20	0.2279	0.23
8	0.0861	0.20	0.0204	0.45	0.0936	0.21	0.0549	0.26	0.0284	0.46	0.1101	0.30
9	0.0454	0.28	0.0239	0.43	0.0479	0.30	0.0594	0.25	0.0643	0.31	0.0491	0.37
10	0.0617	0.26	0.0431	0.34	0.0639	0.28	0.1078	0.21	0.1005	0.28	0.1231	0.29
11	0.0296	0.34	0.0365	0.39	0.0288	0.39	0.0824	0.23	0.1031	0.26	0.0394	0.47
12	0.0347	0.31	0.0440	0.48	0.0336	0.35	0.0945	0.22	0.1156	0.24	0.0507	0.45
13	0.0242	0.36	0.0248	0.42	0.0241	0.39	0.0382	0.32	0.0430	0.38	0.0281	0.57
14	0.0423	0.25	0.0272	0.37	0.0440	0.26	0.0312	0.36	0.0274	0.45	0.0392	0.61
15	0.0319	0.32	0.0330	0.55	0.0318	0.36	0.0581	0.29	0.0675	0.35	0.0385	0.47
16	0.0110	0.45	0.0060	0.83	0.0116	0.48	0.0101	0.63	0.0093	0.91	0.0117	0.83
17	0.0062	0.64	0.0116	0.62	0.0056	0.78	0.0197	0.49	0.0254	0.54	0.0078	0.94
18	0.0130	0.47	0.0047	0.86	0.0139	0.49	0.0138	0.52	0.0123	0.79	0.0169	0.69
19	0.0056	0.48	0.0064	0.88	0.0055	0.54	0.0091	0.71	0.0117	0.82	0.0035	1.18
>19	0.0362	0.24	0.0381	0.53	0.0360	0.26	0.0350	0.40	0.0410	0.47	0.0226	0.80
n	804		389		415		804		389		415	

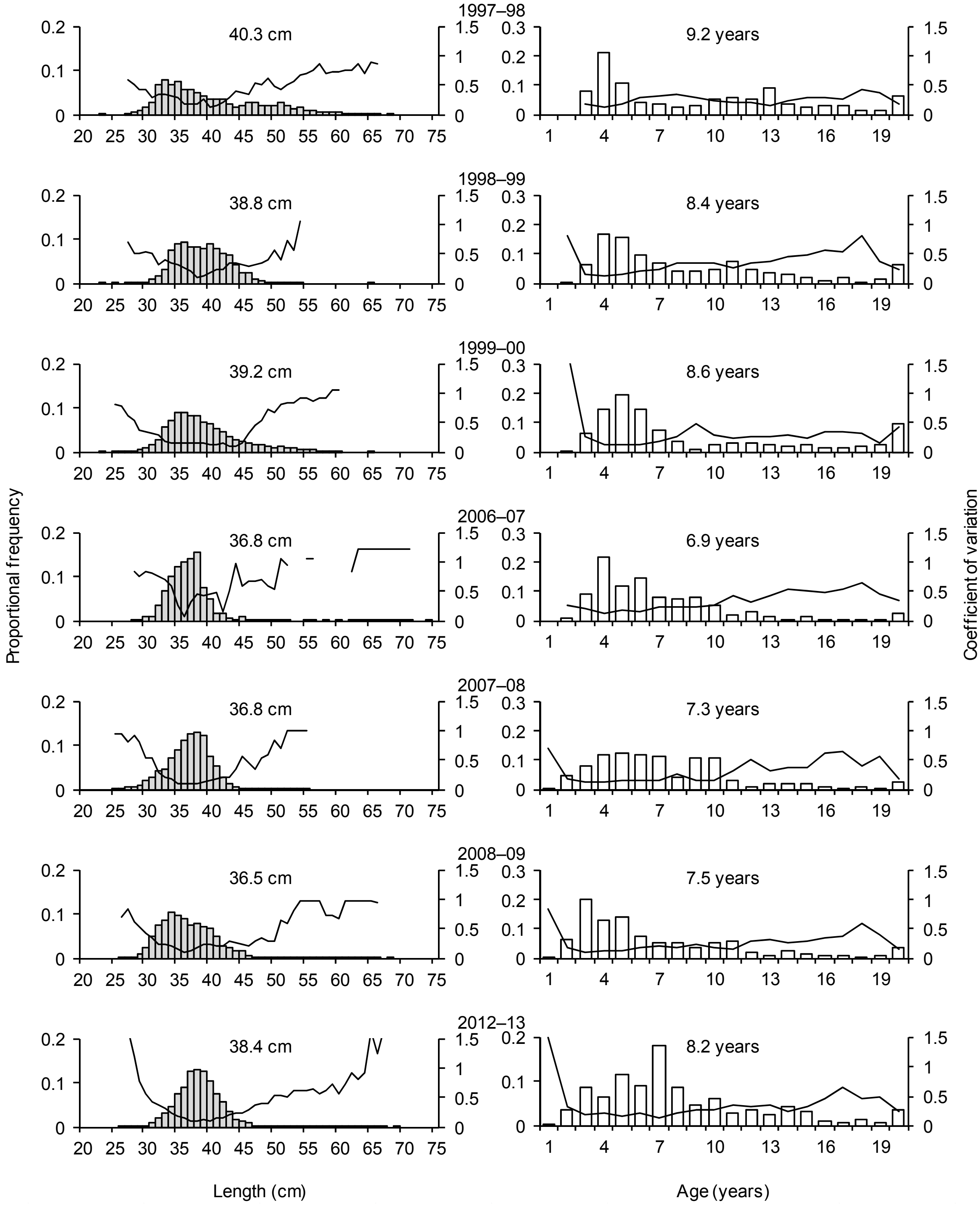
Appendix 10: Estimates of mean weight-at-age (kg) with CVs for trevally from the TRE 1 and subarea bottom trawl and purse-seine fisheries in 2012–13. ENHG, East Northland/Hauraki Gulf; BPLE, Bay of Plenty.

	Bottom trawl						Purse-seine					
Age	TRE 1		ENHG		BPLE		TRE 1		ENHG		BPLE	
(years)	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0.43	0.443	0.37	0.832	0.43	0.883	–	–	–	–	–	–
2	0.69	0.032	0.84	0.020	0.66	0.028	0.71	0.104	0.86	0.342	0.66	0.126
3	0.94	0.030	1.01	0.023	0.91	0.044	1.24	0.054	1.29	0.060	1.08	0.065
4	1.00	0.040	1.08	0.087	1.00	0.043	1.31	0.052	1.44	0.043	1.14	0.049
5	1.04	0.028	1.10	0.053	1.03	0.032	1.30	0.031	1.39	0.024	1.13	0.043
6	0.98	0.041	1.21	0.131	0.97	0.043	1.45	0.076	1.73	0.060	1.12	0.043
7	1.12	0.028	1.36	0.084	1.11	0.030	1.50	0.040	1.69	0.046	1.22	0.026
8	1.12	0.045	1.48	0.171	1.11	0.046	1.45	0.075	1.83	0.119	1.24	0.031
9	1.16	0.052	1.72	0.123	1.13	0.055	1.58	0.053	1.70	0.062	1.26	0.056
10	1.31	0.025	1.55	0.127	1.29	0.023	1.53	0.031	1.67	0.028	1.28	0.026
11	1.34	0.059	1.70	0.090	1.28	0.069	1.73	0.048	1.80	0.049	1.31	0.054
12	1.52	0.063	2.21	0.133	1.41	0.049	1.75	0.058	1.84	0.067	1.34	0.055
13	1.44	0.077	1.78	0.189	1.40	0.079	1.84	0.067	2.00	0.057	1.31	0.095
14	1.48	0.049	1.89	0.268	1.45	0.047	1.65	0.057	1.83	0.083	1.40	0.059
15	1.53	0.073	2.40	0.150	1.43	0.058	1.94	0.073	2.10	0.075	1.34	0.065
16	1.68	0.098	2.91	0.301	1.60	0.070	1.79	0.131	1.99	0.431	1.46	0.110
17	1.72	0.177	2.32	0.226	1.58	0.218	1.82	0.096	1.88	0.130	1.41	0.430
18	1.60	0.086	2.90	0.336	1.54	0.068	1.72	0.079	1.91	0.396	1.43	0.089
19	1.85	0.117	2.83	0.327	1.72	0.094	2.04	0.164	2.11	0.342	1.55	0.265
>19	1.93	0.058	2.86	0.222	1.81	0.043	1.95	0.115	2.07	0.145	1.51	0.047

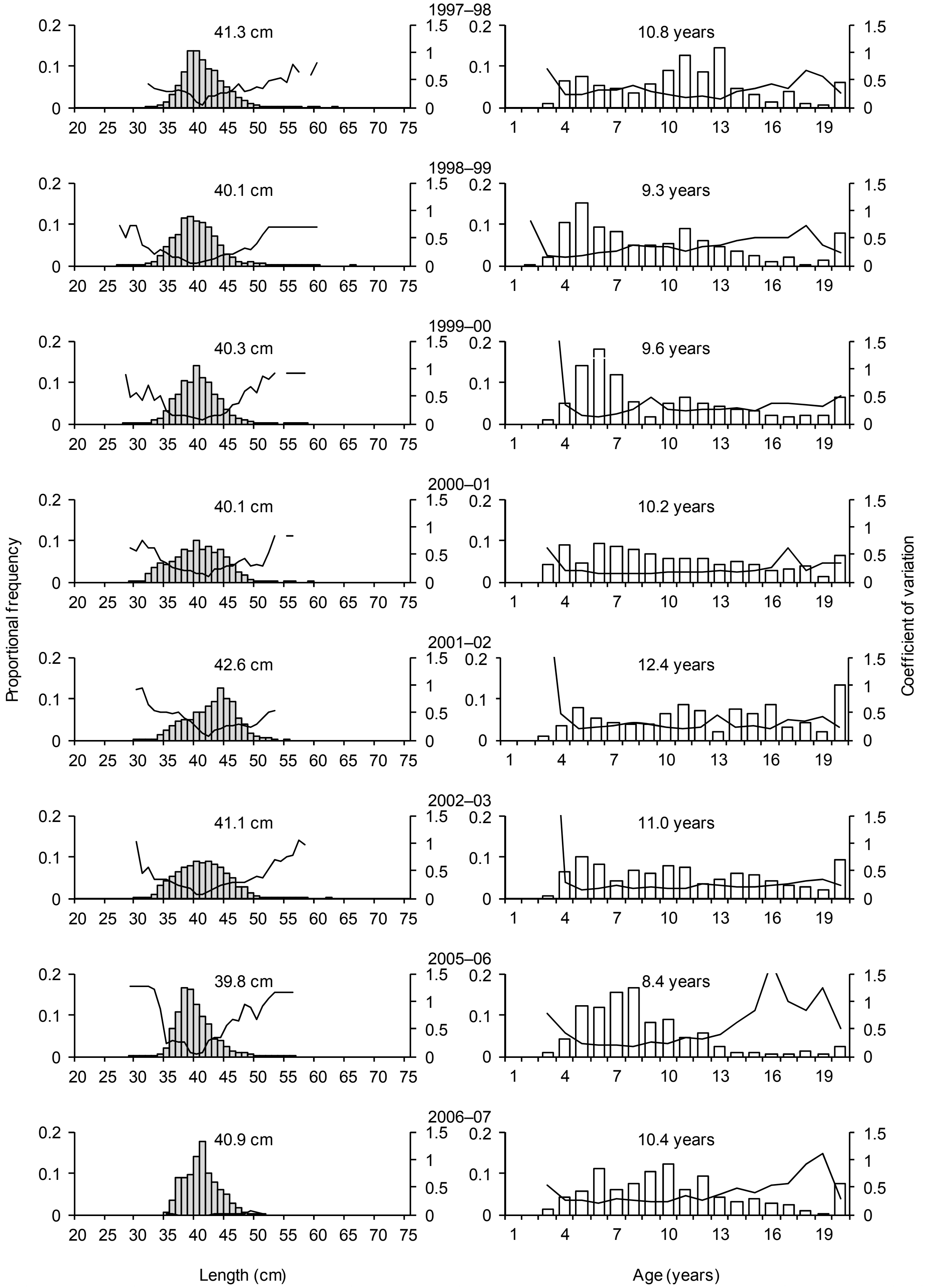
Appendix 11: Estimates of mean length-at-age (cm) with CVs for trevally from the TRE 1 and subarea bottom trawl and purse-seine fisheries in 2012–13. ENHG, East Northland/Hauraki Gulf; BPLE, Bay of Plenty.

	Bottom trawl						Purse-seine					
Age	TRE 1		ENHG		BPLE		TRE 1		ENHG		BPLE	
(years)	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	27.8	0.433	26.6	0.811	28.0	0.883	–	–	–	–	–	–
2	32.5	0.010	34.7	0.007	32.1	0.009	32.8	0.069	34.9	0.339	32.0	0.112
3	36.0	0.010	36.8	0.007	35.5	0.014	39.3	0.017	39.9	0.019	37.6	0.022
4	36.7	0.013	37.4	0.028	36.6	0.014	40.1	0.017	41.4	0.015	38.3	0.016
5	37.1	0.009	37.7	0.017	37.0	0.011	40.0	0.010	40.8	0.008	38.2	0.014
6	36.3	0.014	38.7	0.041	36.2	0.014	41.2	0.025	43.9	0.021	38.1	0.014
7	38.0	0.010	40.3	0.026	37.9	0.010	41.7	0.012	43.4	0.014	39.2	0.008
8	37.9	0.015	41.2	0.061	37.8	0.015	41.2	0.023	44.4	0.049	39.4	0.010
9	38.4	0.017	43.5	0.037	38.1	0.018	42.5	0.016	43.5	0.019	39.6	0.019
10	40.0	0.008	41.9	0.039	39.9	0.007	42.1	0.010	43.4	0.009	39.8	0.008
11	40.2	0.019	43.4	0.029	39.7	0.038	43.7	0.015	44.4	0.016	40.1	0.018
12	41.8	0.019	47.1	0.042	41.0	0.016	43.9	0.017	44.6	0.020	40.4	0.018
13	41.1	0.025	43.6	0.060	40.8	0.026	44.5	0.023	45.9	0.019	40.1	0.030
14	41.5	0.017	43.7	0.080	41.3	0.017	43.1	0.019	44.5	0.027	41.0	0.020
15	41.9	0.022	48.2	0.052	41.1	0.019	45.3	0.024	46.6	0.025	40.4	0.021
16	43.3	0.029	51.5	0.198	42.8	0.022	44.3	0.040	45.9	0.393	41.5	0.087
17	43.5	0.053	47.6	0.089	42.5	0.109	44.5	0.029	45.0	0.065	41.1	0.418
18	42.6	0.024	50.9	0.162	42.3	0.037	43.7	0.026	45.4	0.379	41.3	0.059
19	44.7	0.035	51.1	0.244	43.8	0.060	46.2	0.078	46.7	0.262	42.4	0.254
>19	45.1	0.017	50.4	0.084	44.4	0.014	45.3	0.036	46.2	0.048	42.0	0.015

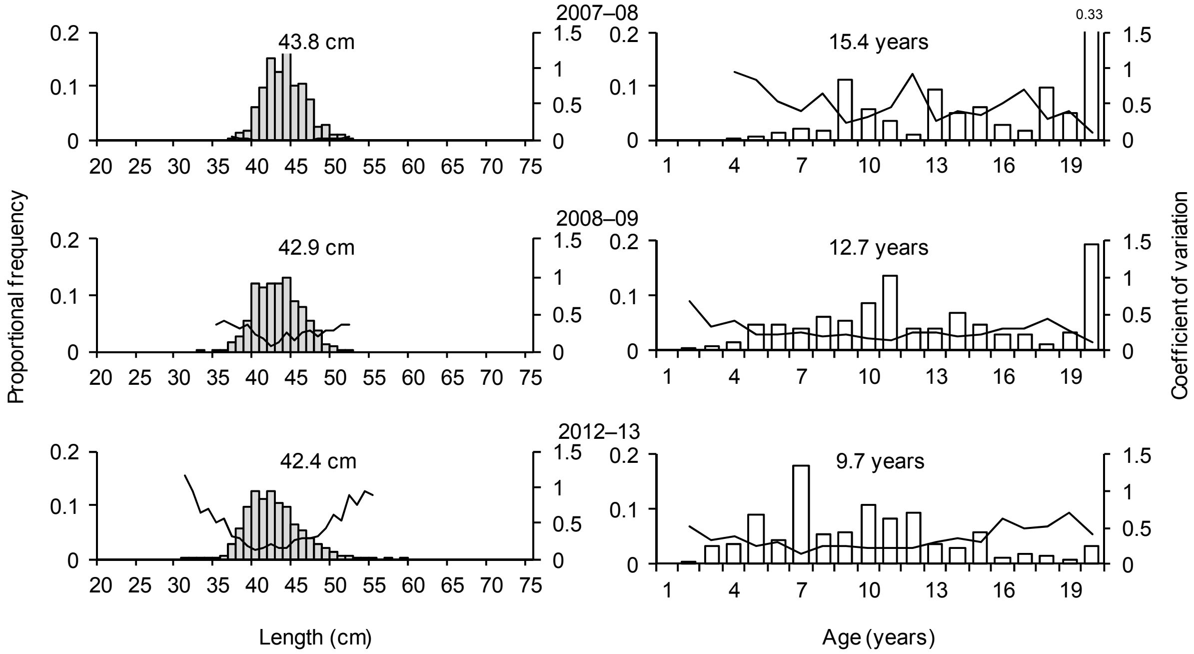
Appendix 12a: A discontinuous time series of proportion at length and age distributions and CVs for trevally from the TRE 1 bottom trawl fishery from 1997–98 to 2012–13. Plots are annotated with estimates of mean length or age.



Appendix 12b: A discontinuous time series of proportion at length and age distributions and CVs for trevally from the TRE 1 purse-seine fishery from 1997–98 to 2006–07. Plots are annotated with estimates of mean length or age.



Appendix 12b – continued: A discontinuous time series of proportion at length and age distributions and CVs for trevally from the TRE 1 purse-seine fishery from 2007–08 to 2012–13. Plots are annotated with estimates of mean length or age.



Appendix 13: Comparison of the proportion at age distributions for TRE 1 (histogram) and SNA 8 (line) bottom trawl fisheries and SNA 1 (line) bottom longline fisheries sampled in 2012–13.