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Length and age composition of commercial snapper landings in SNA 8, 2012–13

New Zealand Fisheries Assessment Report 2014/63

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

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This report presents the results of Objective 1 of the Ministry for Primary Industries project "Estimation of snapper year class strength in SNA 8" (SNA2012/02, Objective 1). The general objective was to determine the length frequency and age structure of commercial landings from SNA 8 market samples for use in stock assessment models.

The length frequency and age-length key sampling approach was employed during spring and summer 2012–13 to estimate catch-at-age for snapper caught by bottom trawl (i.e. the main fishing method) in SNA 8. Length frequency samples were collected from the fishery, and age data were collected randomly in the form of a semi-fixed allocation age-length key, mainly to ensure that fish in the large length intervals were well accounted for. Fifteen landings were sampled for length frequency from the bottom trawl fishery with a total of 9772 fish measured. The age-length key was based on 565 otolith pairs.

Relative year class strengths inferred from the SNA 8 landings in 2012–13 were generally consistent with trends observed in recent years. Bottom trawl landings were dominated by young snapper, those 4 to 7 years of age, collectively making up over three-quarters (78%) of the number landed. The 2006 year class (7-year-olds) has remained dominant in SNA 8, and although it accounts for about one in every five fish landed, it is likely to be more significant in terms of its contribution by weight, and for the short term sustainability and continued rebuilding of the fishery. Snapper over 10 years old make up a low proportion (7%) of the bottom trawl catch by number, the aggregate (over 19) age group estimate is likely to be the lowest documented proportion (0.3%) for any New Zealand snapper stock. These larger fish are either not as well represented in catch-at-age estimates because they now exceed the optimum selectivity of the bottom trawl method, or, more likely as in most recent years, they are of very low relative abundance in the fishery as a result of fishing mortality. The newly recruited 2010 year class (3-year-olds), although not yet fully recruited to the fishery, appears to be of average strength, making up about 5% of the bottom trawl catch by number in 2012–13.

Although SNA 8 landings have largely been comprised of snapper 10 years and younger since the introduction of the Quota Management System in 1986, cumulative plots of proportion at age data collected from bottom trawl show the 2012–13 fishing year estimate to be above the 24 year long-term mean, and likely to be indicative of a broadening age composition, supported by a steady increase in mean age since 2007–08. At 6.4 years, mean age is now the second highest estimate determined from bottom trawl landings for more than two decades, suggesting some improvement to the status of the fishery, quite possibly a direct effect of the Total Allowable Commercial Catch reduction in 2005. However, changes in mean length, although increasing, were much less apparent, indicating that recent growth rates have noticeably slowed. A gradual reduction in annual mean weight-at-age for the common age classes over the past two successive decades was also obvious, with estimates in 2012–13 being close to, or the lowest recorded for this period, and provides further evidence for a decrease in growth rate in SNA 8. In addition, a noticeable narrowing in 2012–13 of zones representing comparable ages found close to the otolith margin suggests somatic growth in some snapper has slowed considerably, possibly a compensatory density-dependence effect as the SNA 8 stock biomass slowly rebuilds. The reduced growth rate observed in 2012–13 and the resulting net weight loss to the fishery in terms of yield per recruit compared to that of the 1990s, will undoubtedly mean a decrease in productivity in the SNA 8 stock. With a gradual increase in stock size, the fishery is likely to land more snapper now than it did 10–20 years ago to achieve the same unit weight.

Fishery characterisations reveal that sample design adequately reflected the temporal and spatial spread of the bottom trawl catches from SNA 8 in 2012–13. However, the majority (86%) of the catch was taken in the northern half of the stock between North Cape and Kawhia Harbour, and principally from statistical areas 042 and 045 bordering the Manukau and Kaipara Harbours, and although a good proportion of the stock biomass continues to reside there, most fish are of small to medium size. Anecdotal reports from commercial and recreational sectors suggest considerable improvement in catches throughout the geographical range of SNA 8 over the past decade. Mean weighted coefficients of variation for both the unstratified and stratified age compositions were 14%, so were well within the target of 20%.

1. INTRODUCTION

Staff of the National Institute of Water and Atmospheric Research (NIWA) and, formerly MAF Fisheries, have sampled the length and age compositions of snapper (*Pagrus auratus*) from commercial landings in port (market sampling) intermittently since 1963 (Davies et al. 1993). In the 1988–89 fishing year, a structured sampling programme was designed to establish a time series of length and age composition data for the dominant fishing methods in SNA 1 and SNA 8. The time series of length and age information from the SNA 8 fishery continued uninterrupted for a period of 22 years up until 2009–10 and has been summarised in previous reports (Davies & Walsh 1995, Walsh et al. 1995, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2006a, 2006b, 2009a, 2009b, 2011b, Walsh & Davies 2004, Walsh & Buckthought 2010). Triennial sampling was adopted after 2009–10 based on research investigating the optimum frequency for market sampling (Bian et al. 2009).

This report presents the results of market sampling from the SNA 8 stock between October 2012 and February 2013. Funding for this project, SNA2012/02 (Objective 1), was provided by the Ministry for Primary Industries.

The specific objective of this project for 2012–13 was:

1. To carry out sampling and estimate the relative proportion at age and length of recruited snapper sampled from the commercial trawl catch in SNA 8 during spring and summer 2012–13. The target coefficient of variation (CV) for the catch-at-age will be 20% (mean weighted CV across all age classes).

2. METHODS

The SNA 8 stock encompasses almost all the west coast of New Zealand's North Island (Figure 1). Landings from the SNA 8 fishery were stratified by fishing method and quarter, e.g., bottom trawl – spring. The fishing method sampled was bottom trawl (BT) over the spring (October–November) and summer (December–February) quarters, the period when most of the SNA 8 stock becomes vulnerable to fishing. September, usually clustered with spring, was not included in the seasonal stratification as it lies outside the bounds of the fishing year (October to September) that the sampling relates to. As limited fishing occurs in September (the last month of the fishing year), its absence from the spring sampling stratum was deemed to have minimal effect on the final results. Although the bottom pair trawl (BPT) method had been sampled in previous years, in 2012–13, the relative effort was deemed insufficient to be considered useful for sampling purposes.

Details of the sampling design are described in Davies & Walsh (1995). Length frequency samples were collected from the SNA 8 bottom trawl fishery using a two-stage sampling procedure (West 1978). The random selection of landings and a random sample of bins within landings represent the first and second stages respectively, with a stipulation that each sampled landing comprises a minimum of 5 t of snapper, which may be relaxed to 3 t, should the average landing size of snapper, particularly during summer, be lower than this target. The targeted number of bottom trawl landings to sample from the SNA 8 fishery in 2012–13 was 15, split eight and seven for the spring and summer quarters, respectively. Although in previous years the sampling procedure was modified to account for the grading of fish according to length and quality by taking a stratified random sample of bins within a landing (Davies et al. 1993), this level of stratification was not necessary for sampling SNA 8 catches in 2012–13 as all landings were comprised only of a single stratum. All fish in bins making up the sample were measured to the nearest centimetre below the fork length. As snapper show no differential growth between sexes (Paul 1976), sex was not determined.

The age-length key method was used for collecting otoliths as described by Davies & Walsh (1995). In previous years the sample allocation for each length class interval for the age-length key was made according to the broadest proportion at length distribution of either the bottom trawl or bottom pair trawl collection from the year before. However, as large snapper (i.e., those over 65 cm) were often poorly represented or absent in proportion at length distributions from SNA 8 collections in recent years, it was felt that a proportional allocation age-length key design may under-represent fish in the large length class intervals and over-represent those in the mid-range. To determine whether a broadening of the age-length key collection had any real effect on resulting catch-at-age estimates, the sample collection in 2007–08 was altered to a semi-fixed allocation design, the same design implemented for sampling in 2012–13 (see Appendix 1).

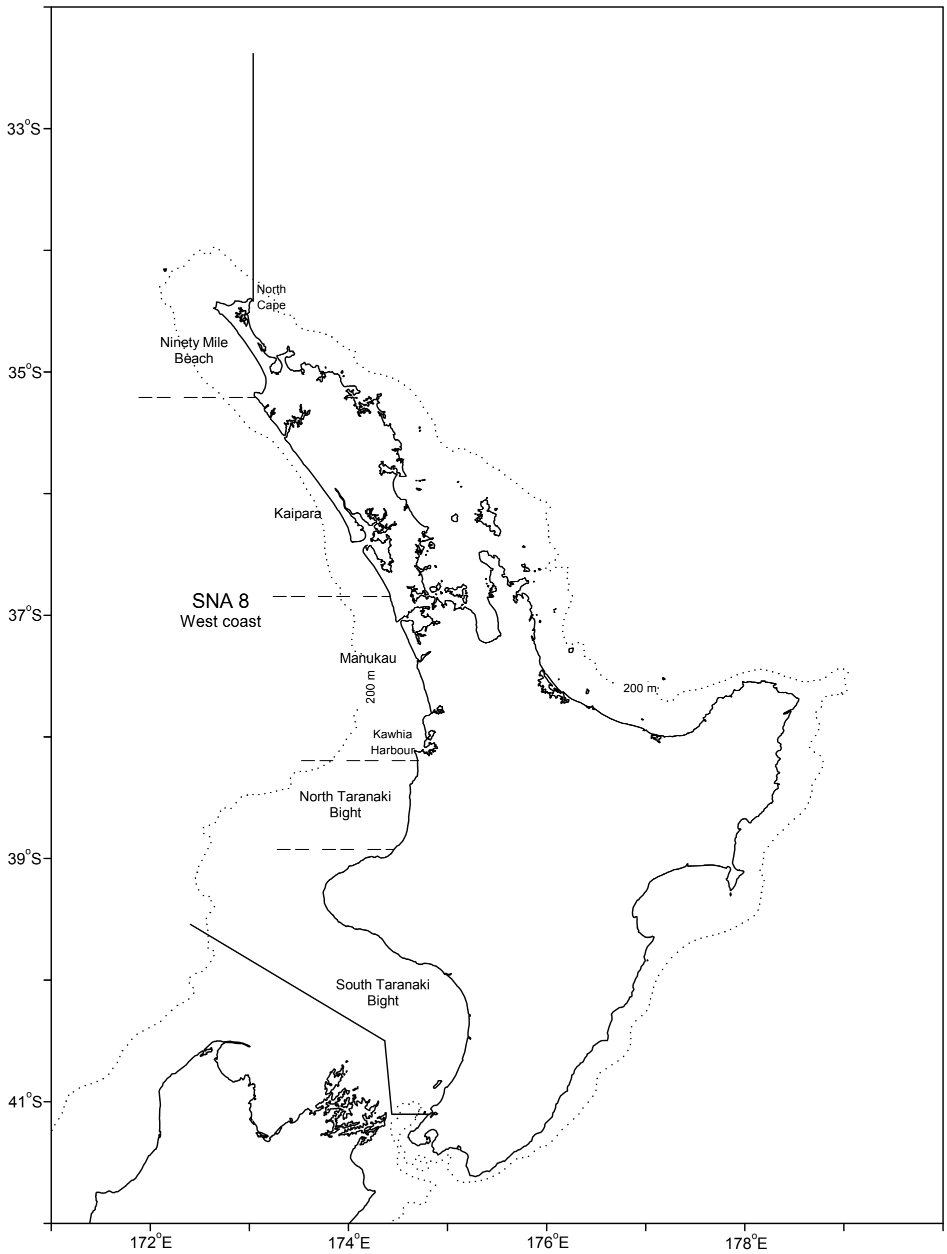


Figure 1: Quota Management Area for the west coast North Island snapper stock (SNA 8). Included are the five spatial strata used for the 2002–03 snapper tagging programme.

This would ensure that the right hand tail of the distribution, comprising the large and old snapper, was adequately sampled. A step-wise sample size of about eight fish for length intervals greater than 46 cm, six fish over 51 cm, five fish over 56 cm, four fish over 61 cm, three fish over 66 cm, two fish over 72 cm, and one fish for all length classes 78 cm and above was specified for collection. To allow for annual variability in the abundance of fish in the 25–27 cm size range, a fixed sample size of 10 otoliths was targeted for collection from each of these length intervals. It was thought that a broad, but slightly less dominant, mode (capped at 25 samples for the most common length intervals) based on the length distribution of the bottom trawl sample from 2009–10 that covered the mid-length class intervals of the age-length key collection would suitably describe the mid-range of cohorts currently present in the fishery. As in more recent years, otolith samples for fish over 70 cm were difficult to obtain because of their rarity in landings. The otolith sample size for the west coast collection (n = 565) was based on previous SNA 8 catch-at-age simulations, using length and age data, that produced mean weighted coefficients of variation (MWCV) of below 20%.

A standardised procedure for reading otoliths was followed (Davies & Walsh 1995). Otoliths were read by two readers without prior knowledge of each other's zone count obtained or of the fish length. For otoliths where both readers agreed on the zone count, the age was determined from this count. When readers disagreed, the otolith was re-read co-jointly to determine the likely source of error and the agreed count. The forced margin method was implemented to *a priori* determine margin type (wide, line, narrow) based on the month in which the fish was sampled. To determine the age of a fish using the forced margin for the fishing year in which the sample collection took place, 'wide' readings were increased by 1 year and 'line' and 'narrow' readings remain the same as the zone count. Age was defined as the rounded whole year from a nominal birth date of 1 January.

The age-length key derived from the age data is assumed to be representative of the spring-summer period. The main assumption to be satisfied for an age-length key is that the sample was taken randomly with respect to age from within each length interval (Southward 1976).

NIWA's 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 from length frequency samples and the age-length keys. For sample collections from the SNA 8 bottom trawl fishery in 2012–13, estimates of proportion at length and age were calculated according to two possible designs; unstratified and stratified. In the unstratified design, length and age data were pooled across temporal strata (spring and summer), thus treating the fishery as a single stratum. In the stratified design, estimates of proportion at age and length (and coefficient of variation) were calculated for each stratum, and then combined to calculate weighted mean estimates. The stratum estimates were combined, weighted by the weight of fish landed in each stratum. CALA scales up the numbers of fish in the samples to numbers of fish in landings and finally the numbers of fish in each seasonal stratum, based on the weights of both samples and landings. Bootstrap variances were determined for both stratified and unstratified combined spring and summer proportion at length and proportion at age estimates. The calculation of mean weight-at-age and variances followed Quinn II et al. (1983), with a length-weight relationship: $w\ (g) = 0.04467\ l^{2.793}\ (cm)$ (Paul 1976). 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 fishing year age classes (herein referred to as "age classes" encompassing October 2012 to February 2013) recruited, with the maximum age being an aggregate of all age classes over 19 years. Estimates of mean age determined from spring-summer catch-at-age estimates were calculated such that all fish comprising the aggregate (over 19 years) age group were assigned an age of 20.

Snapper length and age data are stored on the Ministry for Primary Industries *market* and *age* databases respectively, administered by NIWA.

3. RESULTS

3.1 Relative SNA 8 catch by method and statistical area in 2012–13

Bottom trawl was by far the most dominant method in the SNA 8 fishery over spring–summer 2012–13, taking about 87% of the total landed catch of 744 t (Figure 2). Eighty four percent of the landed catch in 2012–13 was taken from the northern half of SNA 8 (statistical areas 042–047), most of this coming from 042 and 045, which border the Manukau and Kaipara Harbours, respectively.

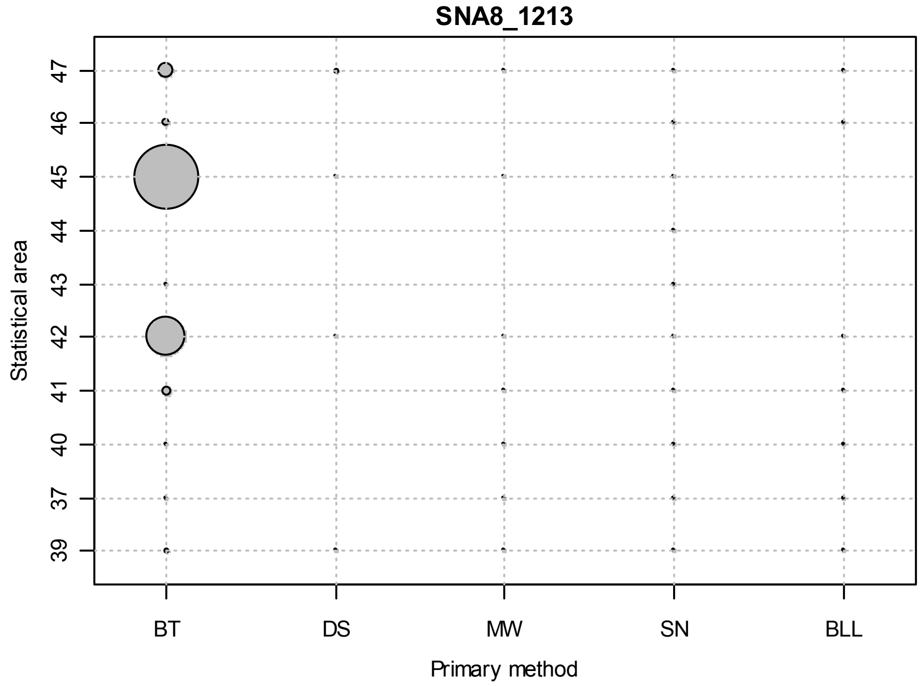


Figure 2: Relative catch by method and statistical area in SNA 8 in 2012–13 (BT, bottom trawl; DS, Danish seine; MW, Midwater trawl; SN, Set net; BLL, Bottom longline).

3.2 Sampling of the SNA 8 bottom trawl fishery in 2012–13

Sample collections

Summaries of the length frequency sample sizes for bottom trawl-season strata are given in Table 1. A total of 15 bottom trawl landings were successfully sampled for length information (number of fish measured = 9772) from the SNA 8 fishery over spring and summer 2012–13 (eight and seven landings, respectively), meeting the required target. The number and weight of landings is summarised in Table 1 and for all subsequent figures is for all bottom trawl landings containing snapper (target and bycatch) caught from SNA 8.

Table 1: Summary of the catch (total number and weight of landings) and samples (number of landings and weight sampled, and number of fish measured) in method–season strata for the SNA 8 snapper bottom trawl fishery from spring and summer 2012–13.

		Number of landings			No. of fish	Weight of landings (t)		
Method	Season	Total	Sampled	% of total	measured	Total	Sampled	% of total
Bottom trawl	Spring	79	8	10.1	5 274	237	86	36.3
	Summer	169	7	4.1	4 498	410	46	11.2
	Combined	248	15	6.0	9 772	647	132	20.4

A total of 565 pairs of snapper otoliths were subsampled from landings sampled for length frequency (Table 2).

Table 2: Details of snapper otolith samples collected in 2012–13 from SNA 8.

Method	Sampling period	Sampling method	Length range	No. aged
Bottom trawl	Spring, summer	Stratified random	24–73	565

Sampling representativeness

The landed catch of snapper from the bottom trawl fishery in SNA 8 was relatively evenly spread over the October to February period, although the number of landings from the fishery steadily increased over each subsequent month (Figure 3). The weight of the sampled landings during spring, October to November, was almost twice that landed during summer, December to February (Figure 3, Table 1), and is reflected by the average size of sampled landings over the two seasons: 10.7 t (range 7.4–23.3 t) and 6.5 t (range 2.8–10.3 t), respectively. The sampled component accounted for 20.4% by weight and 6.0% by number of landings of the total bottom trawl catch of SNA 8 over the sampling period (Figure 3, Table 1).

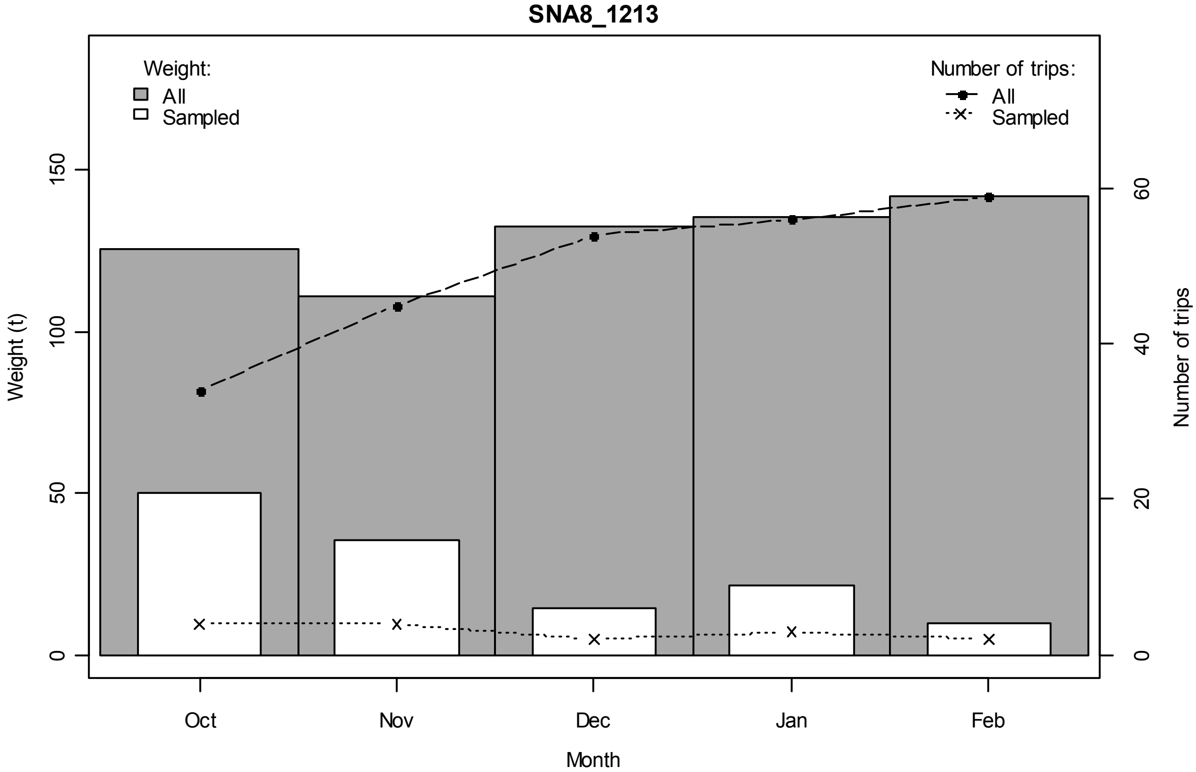


Figure 3: Comparison of the monthly distribution of landed weight (grey bars) and numbers of landings (dashed line) of snapper in the SNA 8 bottom trawl fishery for all landings where snapper was caught for the period October to February 2012–13. Included are corresponding estimates for all sampled landings (white bars and dotted line) to show the representativeness of sampling.

The sampling performance relative to the cumulative proportion of the total number of landings throughout the sampling period is illustrated in Figure 4. A disproportionately higher number of landings were sampled in the early months of the 2012–13 fishing year relative to the fishery operation.

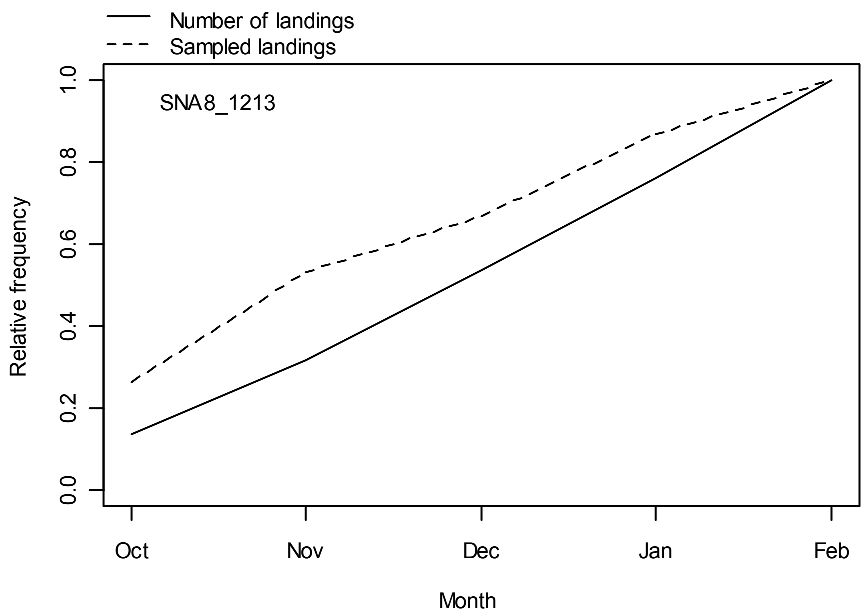


Figure 4: The cumulative proportion of the number of landings and samples taken from the SNA 8 bottom trawl fishery in 2012–13.

The number of otoliths subsampled from landings in each month is given in Figure 5 and shows a reasonable level of temporal consistency in the otolith collection, although proportionally more otoliths were collected over spring (October–November, *n* = 310) compared to summer (December–February, *n* = 255). A comparison of the length distribution of snapper subsampled for the otolith collection to that targeted from the SNA 8 fishery in 2012–13 illustrates the size range of samples achieved for the age-length key (Appendix 1). The collection was relatively broad with almost all length intervals from 25 to 68 cm being well represented and meeting the required targets. Despite this, however, only three snapper above this size range (69, 70 and 73 cm) were sampled for age, with all remaining size classes (71–72 cm and over 73 cm) absent from catch samples collected from the 15 SNA 8 bottom trawl landings in 2012–13.

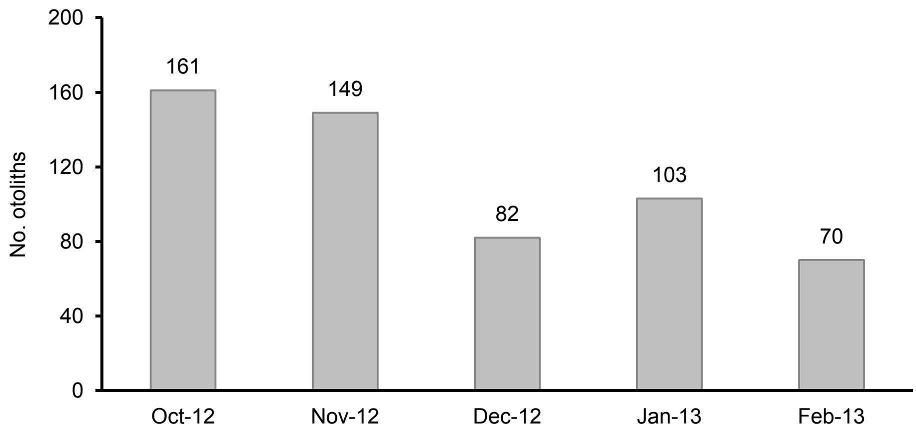


Figure 5: Numbers of otolith pairs by month collected from the SNA 8 bottom trawl fishery from October 2012 to February 2013.

Fine scale spatial comparisons (0.1 degree blocks) of the proportional distribution of the estimated SNA 8 bottom trawl fishery catch and sampled catch for 2012–13 is presented in Figure 6 and by statistical area in Figure 7. The majority (86%) of the bottom trawl catch was taken in the northern half of the stock between North Cape and Kawhia Harbour (principally statistical areas 042–047) with the greatest proportion (about 43% of the catch) from statistical area 045 alone, north of the main West Coast North Island port of Onehunga in the Manukau Harbour.

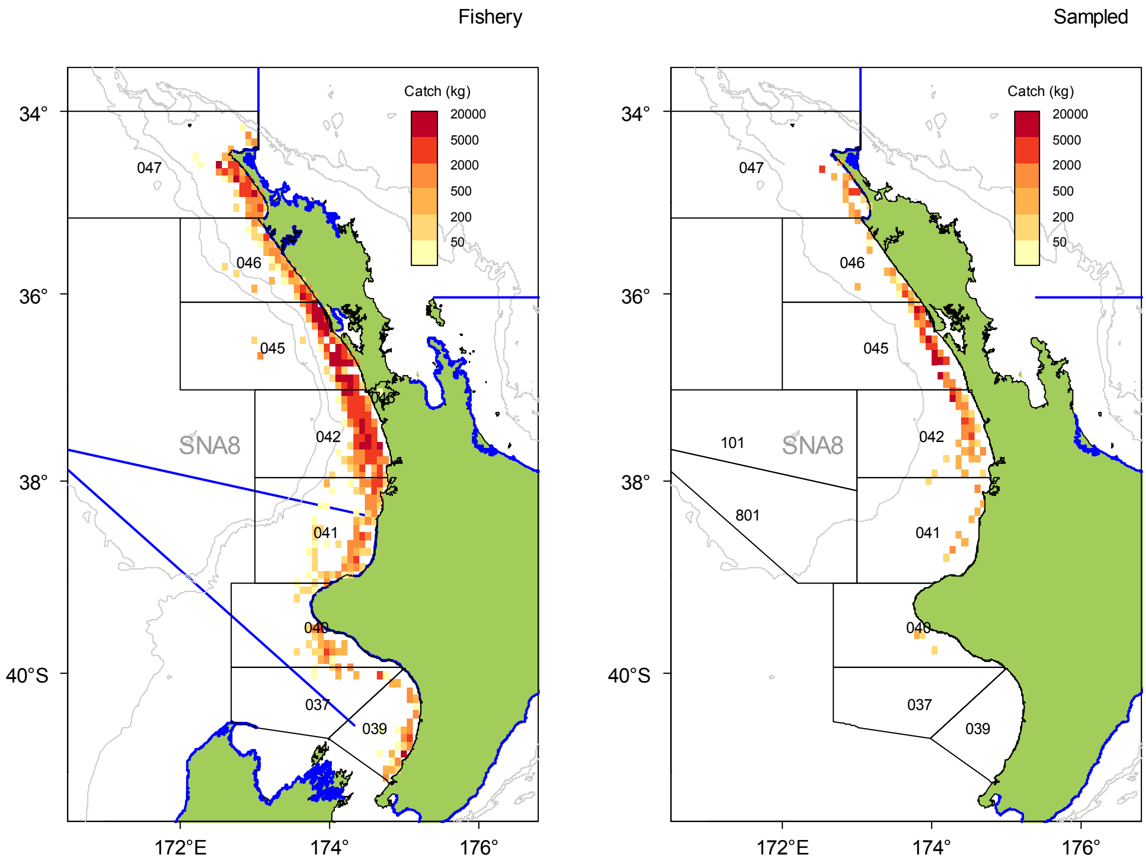


Figure 6: Comparison of the spatial distribution of the bottom trawl catch and the sampled component for the SNA 8 stock in 2012–13.

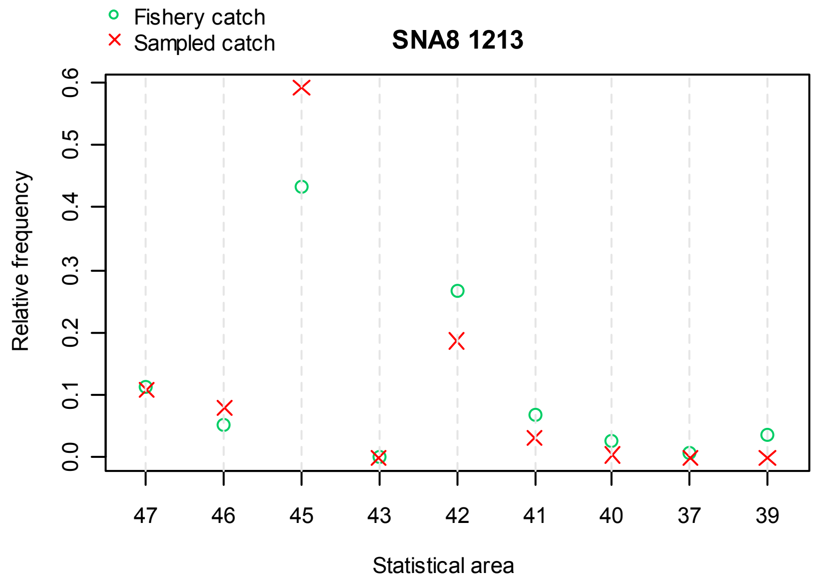


Figure 7: Comparison of the proportional distribution of the estimated bottom trawl catch and the sampled component by statistical area over the sampling period for the SNA 8 stock in 2012–13.

A similar comparison depicting the SNA 8 bottom trawl catch by target species shows that almost three-quarters (72%) of the snapper catch in spring and summer 2012–13 was taken when trevally (*Pseudocaranx dentex*) was the target species, with snapper (13%) and red gurnard (*Chelidonichthys kumu*) (12%) the two other significant target species (Figure 8). The proportionality of the sampled component to that of the fishery suggests that the sampled landings, by and large, are representative of the operation of the SNA 8 bottom trawl fleet as a whole.

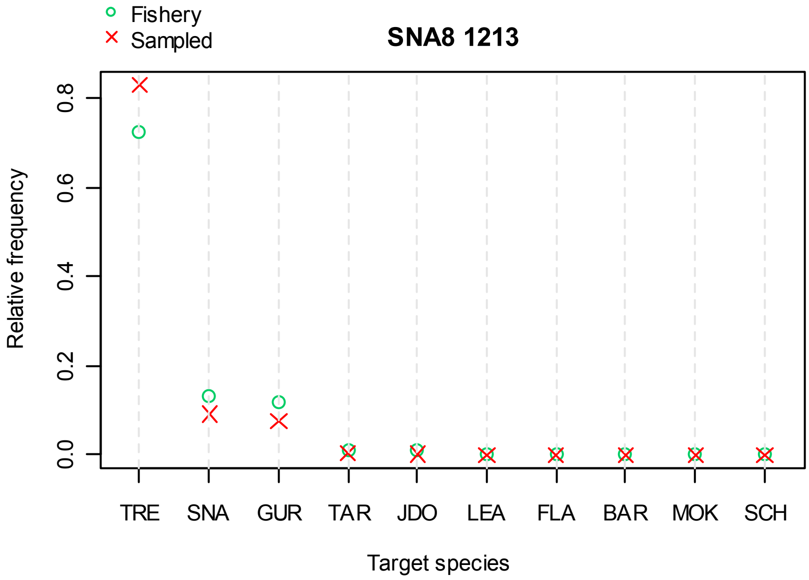


Figure 8: Comparison of the proportional distribution of the estimated bottom trawl catch and the sampled component by target species over the sampling period for the SNA 8 stock in 2012–13.

3.3 Otolith readings

All SNA 8 otolith samples selected for ageing from the 2012–13 collection were successfully aged. Between-reader tests with graphical comparisons of these are given in Figure 9 and showed a high level of consistency between readers. There appeared to be only minor systematic differences (bias) in first counts of snapper otoliths between the readers. The slight positive weighting of the histogram in Figure 9(a), the relative clustering of plotted points about the zero line in Figure 9(b), and the slight deviation from the one-to-one line on the age-bias plot for some of the older age classes (Figures 9(c)) indicate that the second reader slightly undercounted zones relative to the first reader. The overall percentage agreement between readers was 92.4%, and in only four of the 565 readings (0.7%) did the readers disagree by more than 1 year. The between reader CV and IAPE were less than 1% (Figure 9(c)) and the profiles show that precision was high across almost all age classes (Figure 9(d)). Comparisons of the age-bias plots for reader 1 and 2 with the agreed age show that overall agreement was excellent (99.6 and 92.8%) and precision high with CV and IAPE estimates less than 1% (Figures 9(e) and (f)).

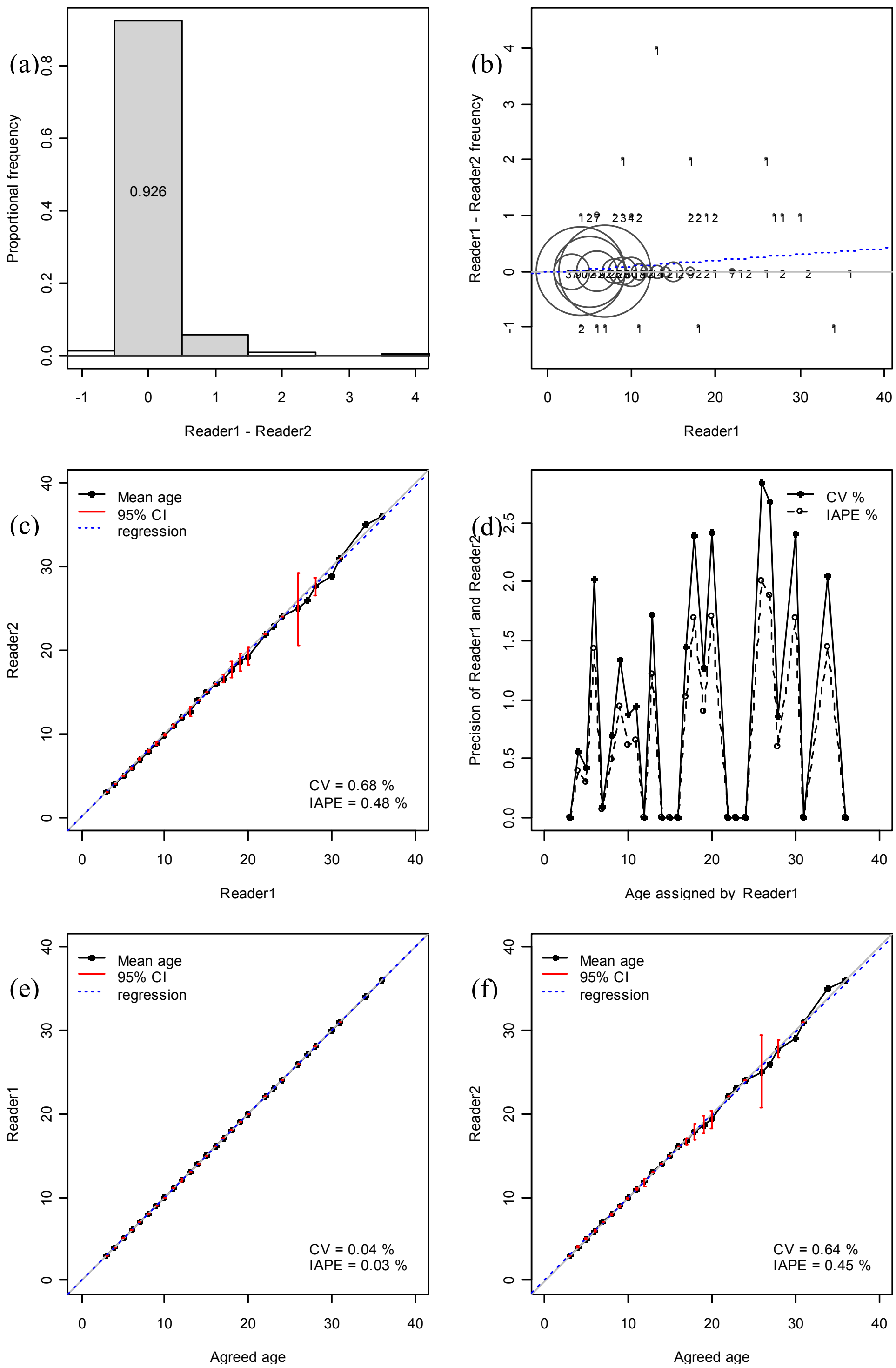


Figure 9: Results of between-reader comparison test (reader 1 and 2) for SNA 8 otoliths collected in 2012–13 (*n* = 565): (a) histogram of differences between readings for the same otolith; (b) differences between readers for a given age assigned by reader 1; (c) bias plot between readers; (d) CV and 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).

3.4 Length and age distributions

For the SNA 8 bottom trawl fishery in 2012–13, catch-at-age compositions (using the length frequency and age-length key approach) were derived from the combined spring and summer length distributions, and used to identify year class strengths. Although otolith samples were collected from each sampled landing, they were not collected consistently across the entire spring or summer period. In combining the seasonal data, it is assumed that an age-length key collected from spring and/or summer can be applied to the combined spring and summer length data. Because the growth of snapper over 25 cm long is not great between spring and summer, this assumption is reasonable. This assumption has been accepted for other species with growth rates comparable to those of snapper (Westrheim & Ricker 1978).

The age-length key is presented in Appendix 2 and an age-at-length scatterplot (using decimalised ages and not fishing year ages) is given in Appendix 3.

3.5 Catch-at-length and catch-at-age estimates

The unstratified and stratified length distributions of the SNA 8 bottom trawl catch in spring-summer 2012–13 comprised mainly of small to medium sized snapper, were relatively similar, and characterised by a single mode at 35 cm, and a tail of the distribution extending to over 55 cm (Figure 10, Appendix 4). The mean lengths of snapper sampled from the fishery for unstratified and stratified approaches were identical at 36.3 cm, as were the bootstrap proportion at length MWCVs at 0.13.

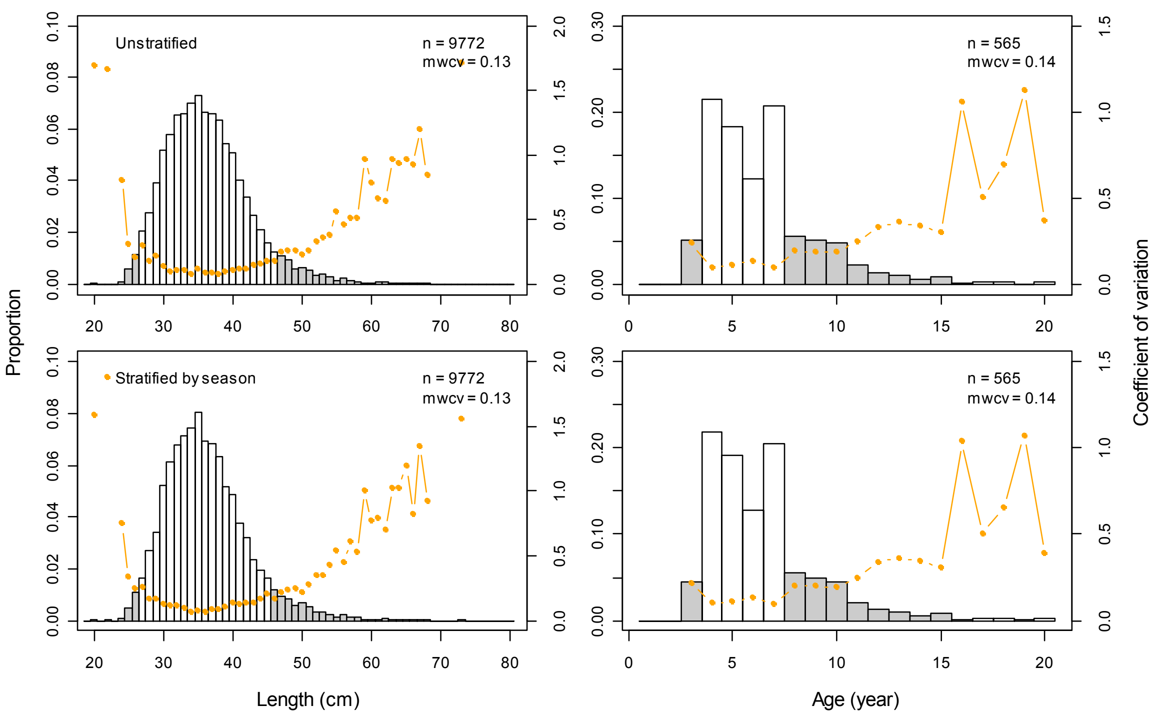


Figure 10: Unstratified (top) and seasonally stratified (bottom) proportions at length and age distributions (histograms) and bootstrap CVs (lines) determined from snapper landings sampled from the SNA 8 bottom trawl fishery in 2012–13 using the length frequency and age-length key approach (*n*, sample size; MWCV, mean weighted CV).

The corresponding unstratified and stratified age distributions in 2012–13 were also alike, and were dominated by young snapper 4 to 7 years of age, which comprised over three quarters (78%) of the number landed (Figure 10, Appendix 5). The 2009 year class (4-year-olds) was marginally the most dominant in the fishery, followed closely by the 2006 and 2008 year classes respectively (7- and 5-

year-olds). Aside from the 2003 to 2005 year classes (8–10 year olds), being of similar relative strength and accounting for around 15% of the catch, the proportion of most other age classes in the fishery was low, particularly those over 10 years of age, which made up just 7% of the bottom trawl catch in 2012–13. Although represented by a total of 24 fish (4%) in the age-length key collection, the aggregate (over 19) age group made up just 0.3% of the overall catch by number in 2012–13, reflecting the low number of fish of this age range (Appendix 6). The oldest fish sampled from the fishery over spring and summer 2012–13 was 36 years (Appendix 3).

The 2008 year class (5-year-olds) appears fully recruited as it contains no fish under 27 cm, unlike the 2010 and 2009 year classes (3- and 4-year-olds) (see Appendix 2). Based on relative proportions in the catch-at-age distribution, the 2010 year class appears to be of average strength. The mean ages of snapper from the spring-summer bottom trawl fishery were 6.4 and 6.3 years for the unstratified and stratified approaches, respectively, and the catch-at-age bootstrap MWCVs were 0.14.

The spring and summer length and age distributions for the SNA 8 bottom trawl fishery in 2012–13 were relatively similar with few obvious temporal differences apparent in either the size or age (Figures 11 and 12, Appendices 4 and 5). The mean length and age of snapper landed over the spring period was 36.4 cm and 6.4 years, and during summer, 36.1 cm and 6.3 years. Seasonal catch-at-length and -age bootstrap MWCVs ranged between 0.15–0.18.

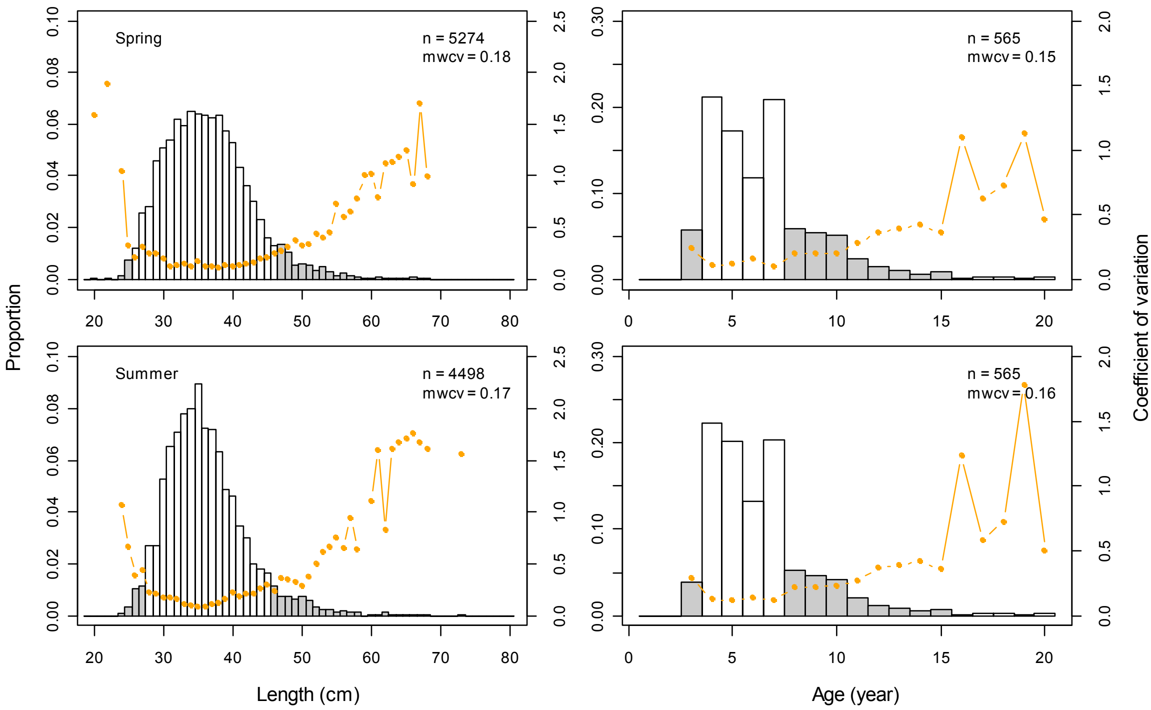


Figure 11: Seasonal proportions at length and age distributions (histograms) and bootstrap CVs (lines) determined from snapper landings sampled from the SNA 8 bottom trawl fishery in spring (top) and summer (bottom) 2012–13 using the length frequency and age-length key approach (*n*, sample size; MWCV, mean weighted CV).

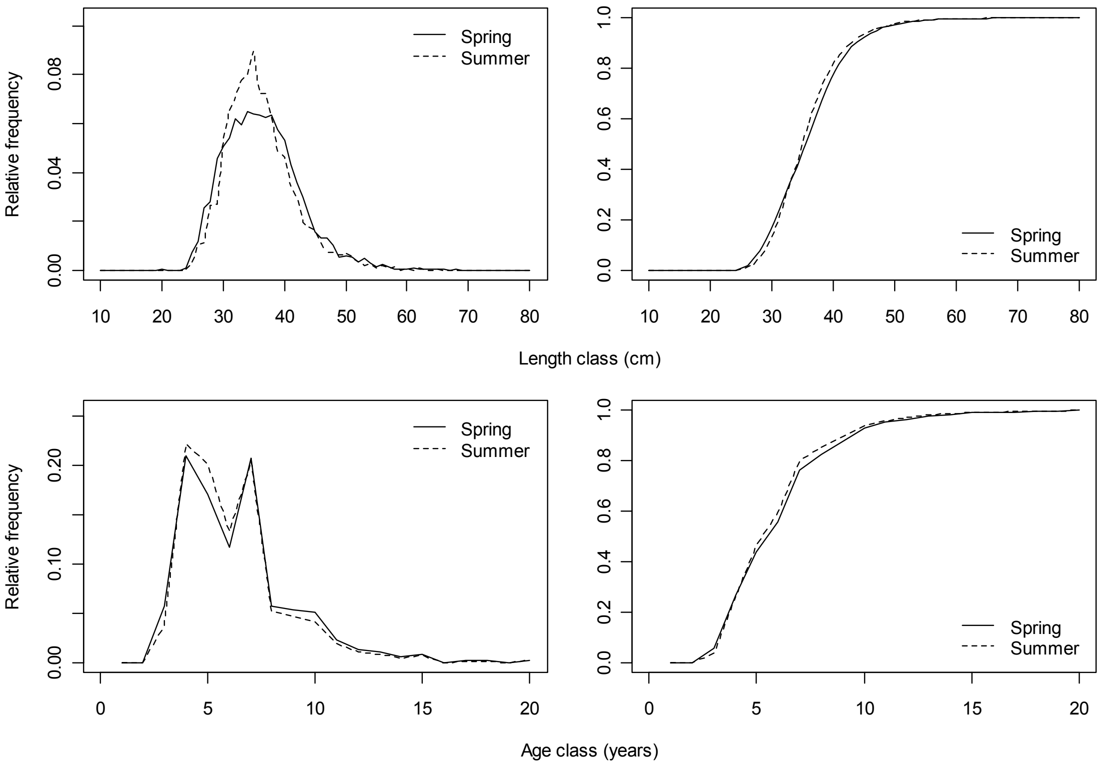


Figure 12: Comparison of the proportion and cumulative proportion at length and age distributions determined from snapper landings sampled over the spring and summer seasons from the SNA 8 bottom trawl fishery in 2012–13.

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

With the exception of the 18 year old and aggregate (over 19 years) age groups, a trend of increasing mean length-at-age and mean weight-at-age over successive age classes was evident in data collected from the SNA 8 bottom trawl fishery in 2012–13 (Figure 13, Appendices 7 and 8). For 3 year old snapper, estimates of mean length-at-age and mean weight-at-age 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. Similarly, older fish may be under-represented in the catch because bottom trawl gear has dome-shaped selectivity.

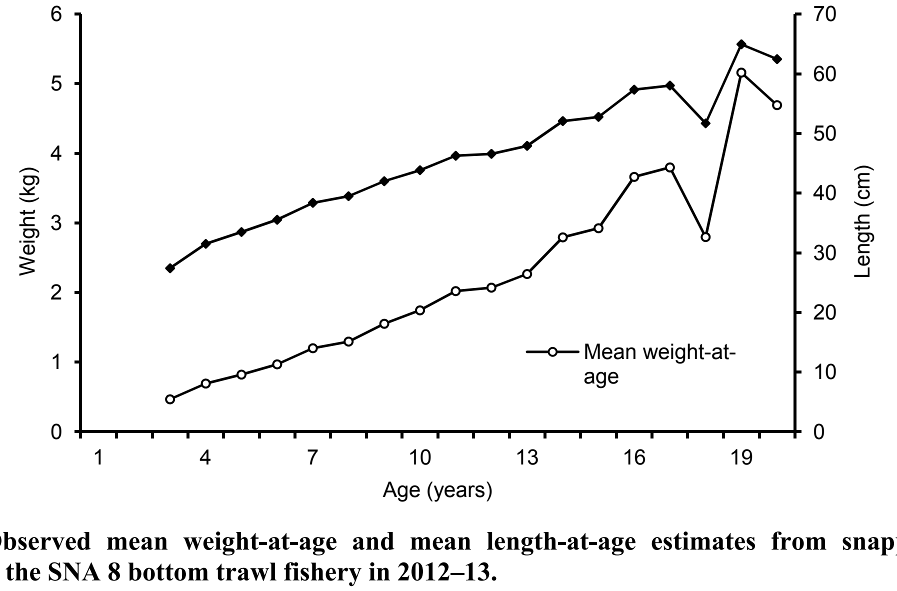
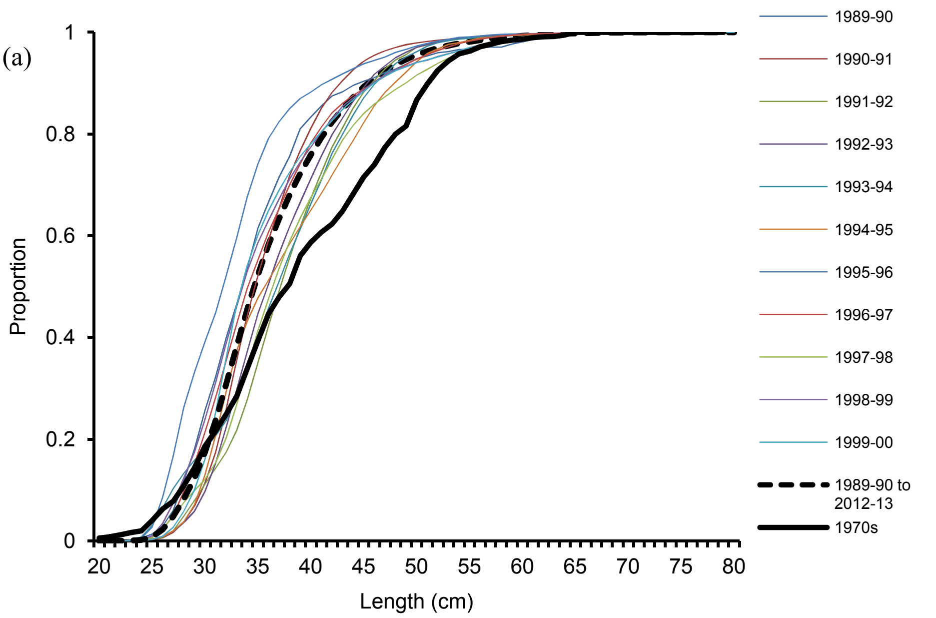


Figure 13: Observed mean weight-at-age and mean length-at-age estimates from snapper landings sampled from the SNA 8 bottom trawl fishery in 2012–13.

3.7 Comparisons of estimates from 2012–13 to those of the SNA 8 time series

Cumulative proportions at length and age

Cumulative plots of proportion at length and age data collected from the SNA 8 bottom trawl fishery between 1989–90 and 2012–13 are given in Figures 14a, b and 15a, b respectively. A comparison of the 2012–13 estimates indicates proportion at length to be similar to the 24 year long-term mean (Figure 14b) and proportion at age to be above the mean, and having one of the broadest age compositions seen in the fishery for the past two decades (Figure 15b, Appendix 9).



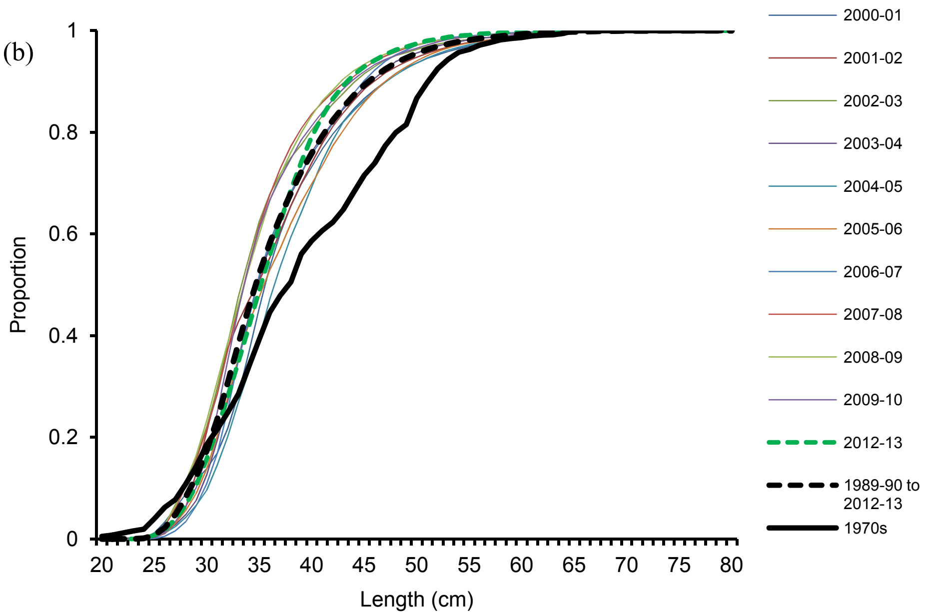
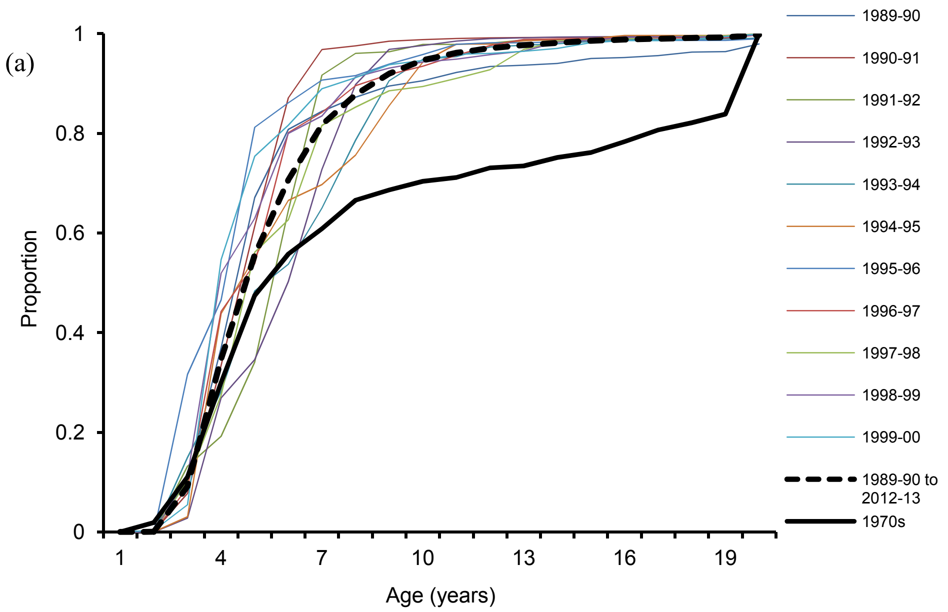


Figure 14: Time series of cumulative proportion at length distributions determined from snapper landings sampled over the spring and summer seasons from the SNA 8 bottom trawl fishery from (a) 1989–90 to 1999–00 and (b) 2000–01 to 2012–13. Included are the average estimates for the 24 fishing year period 1989–90 to 2012–13 (excluding 2010–11 and 2011–12) and 1974–75 to 1975–76.



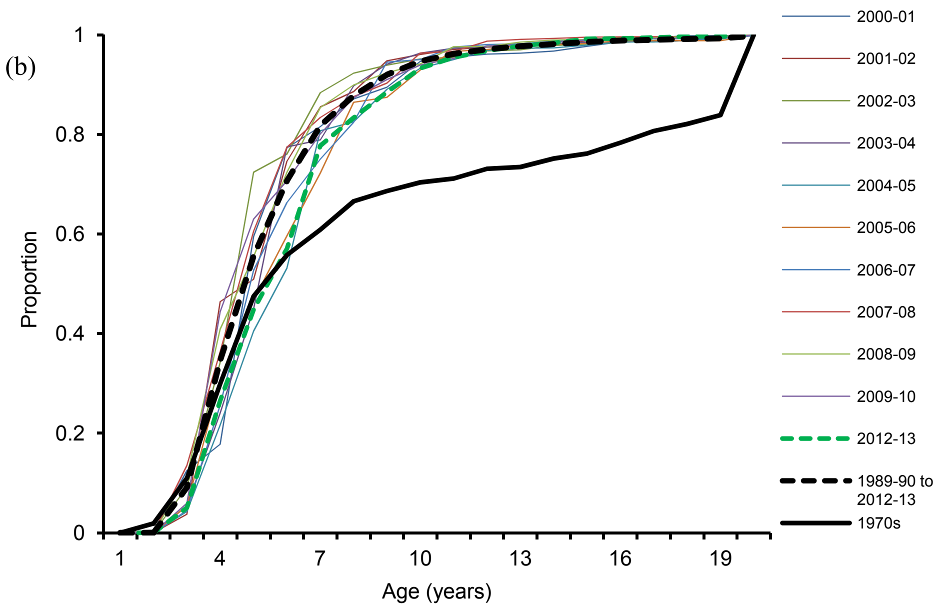


Figure 15: Time series of cumulative proportion at age distributions determined from snapper landings sampled over the spring and summer seasons from the SNA 8 bottom trawl fishery from (a) 1989–90 to 1999–00 and (b) 2000–01 to 2012–13. Included are the average estimates for the 24 fishing year period 1989–90 to 2012–13 (excluding 2010–11 and 2011–12) and 1974–75 to 1975–76.

Mean length and mean age

Estimates of mean length and mean age for snapper sampled from the SNA 8 bottom trawl and bottom pair trawl fisheries between 1974–75 and 2012–13 are given in Figure 16. The mean length (36.3 cm) in 2012–13 was slightly below the average (36.6 cm) estimated over the previous 24 years (since 1989–90), while mean age (6.4 years) was the second highest estimate determined over this period, where the average was 5.8 years (Figure 16).

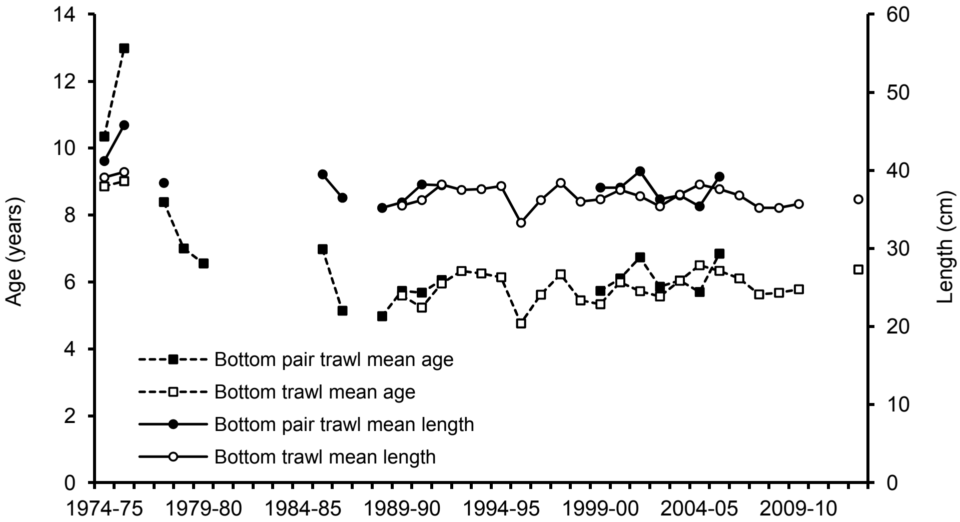


Figure 16: Time series of mean length and mean age estimates from the SNA 8 bottom pair trawl (1974–75 to 2005–06) and bottom trawl fisheries (1974–75 to 2012–13). Note: The 2012–13 length and age estimates lie to the right hand side of the figure detached from the time series.

Mean weight-at-age

A time series comparison of mean weight-at-age estimates derived from sampling the SNA 8 bottom trawl fishery between 1990–91 and 2012–13, shows a slow but gradual long-term decrease in the mean weight-at-age for snapper for the common age classes (i.e., 6–11 years old) indicative of a temporal decline in growth rate (Figures 17 and 18). Annual mean weight-at-age estimates for many of the older age classes (i.e., over 11 years of age) are highly variable from year to year and unlikely to provide realistic estimates due to the low number of individuals present (Figure 17).

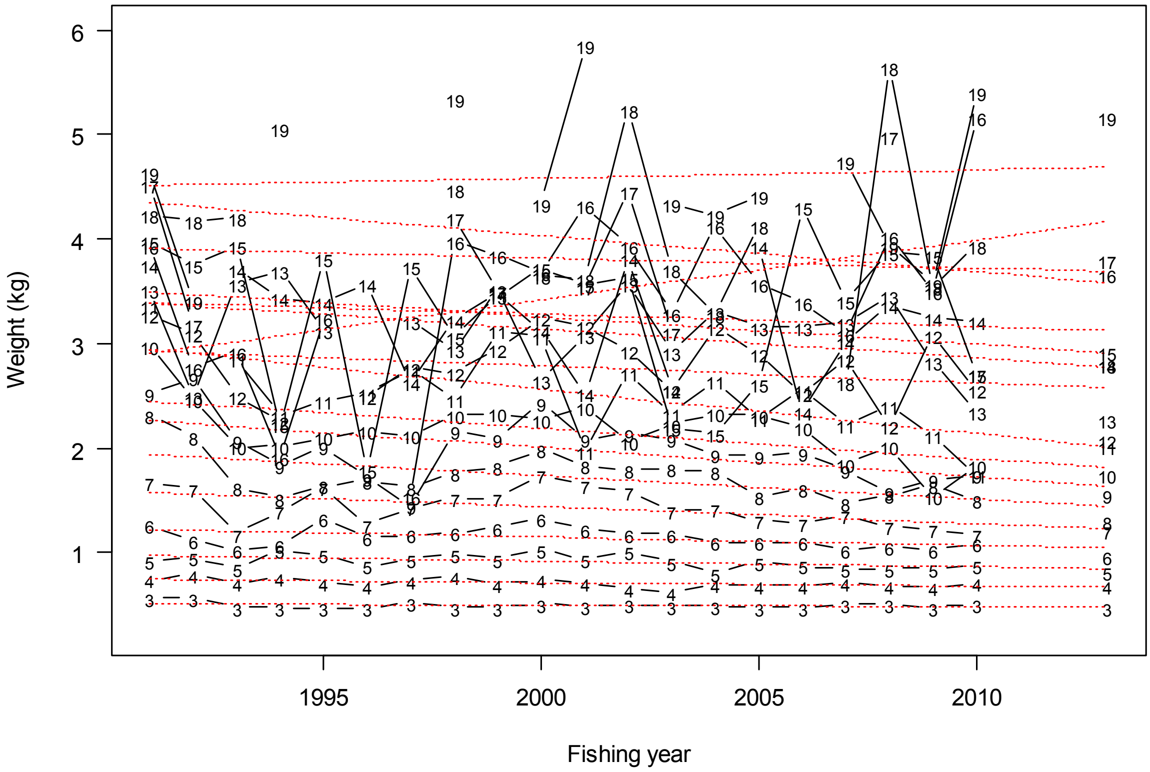


Figure 17: Mean weight-at-age estimates for 3 to >19 year old snapper sampled from the SNA 8 bottom trawl fishery between 1990–91 and 2012–13 with fitted trend lines (dotted red) for each age class depicting long-term changes in growth rates over the 23 year period. Note: No estimates were available for 2010–11 and 2011–12 due to a two year hiatus from sampling the SNA 8 fishery.

Comparisons of the average mean weight-at-age determined for the two preceding decades (1990s and 2000s) with estimates determined in 2012–13, show the decrease in mean weight-at-age to be considerable in recent years, and most apparent for the common age classes, 5–15 years old. The difference in mean weight-at-age between the first and last time periods (1990s, 2012–13) indicates the overall net weight loss/gain to the fishery, estimated conservatively at around -10% to -20% for most of the common age classes in SNA 8 (Figure 18).

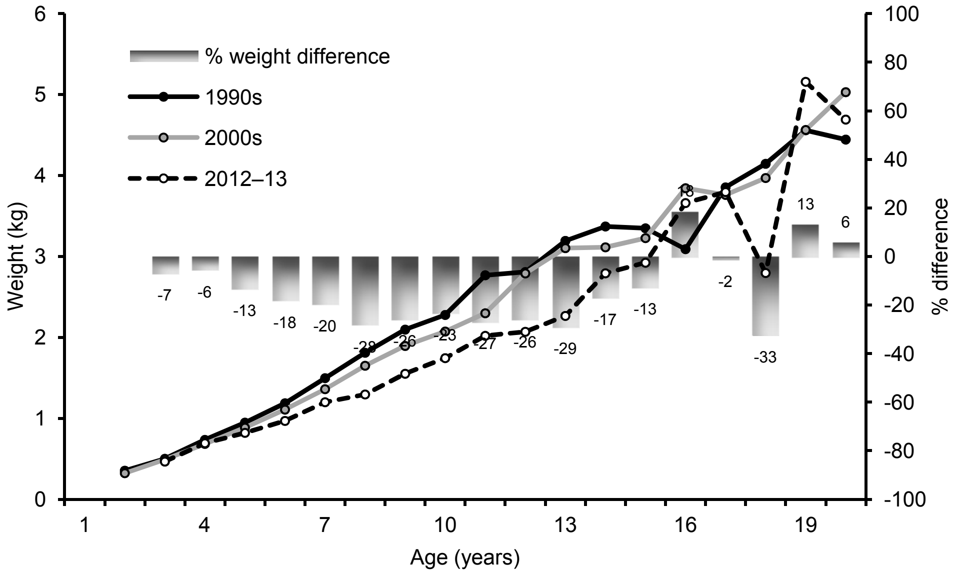


Figure 18: Mean weight-at-age estimates for snapper sampled from the SNA 8 bottom trawl fishery from two distinct time periods (1990s and 2000s) and from the current sampling year 2012–13, and where each period reflects the average mean weight-at-age for those years. The percentage weight difference for each age class (positive or negative) is the difference between the first time period, 1990, and 2012–13, and indicative of a net weight gain or loss in mean weight-at-age through time.

4. DISCUSSION

Comparisons of SNA 8 age compositions (Walsh et al. 2006a, 2009a, 2011b) have suggested that only moderate change has occurred in the fishery since the introduction of the Quota Management System (QMS) in 1986. Over a 21 year period of monitoring commercial landings between 1989–90 and 2009–10, the age structure was seen to be consistent with that of a heavily exploited fishery, comprising a few young age classes, with often one or two age classes dominating, and a distinct lack of accumulation of older fish (Walsh et al. 2011b). These findings were consistent with two absolute abundance estimates from tagging programmes in 1990 and 2002 (see Davies et al. 1999, Gilbert et al. 2005) and a number of stock assessments, the most recent in 2004–05 (Davies et al. 2013), which indicated that the stock was between 8% and 12% of the unfished equilibrium biomass, B_0. Although still dominated by a high proportion of young snapper, catch sampling in 2012–13 indicates a slow but consistent rebuild may be underway in SNA 8 (e.g. broadening age composition, increasing mean age, and slowing growth rate). This is quite possibly a direct effect of the Total Allowable Commercial Catch (TACC) reduction from 1500 to 1300 t in 1 October 2005. However, as proportional catch-at-age data are not a direct index of absolute abundance, inferences from these data in respect to changes in stock size may not be totally reliable and should be interpreted with caution. Only a tagging programme to estimate stock biomass would ultimately clarify this uncertainty.

Catch samples from 2012–13 provide the first opportunity to view the age composition of the SNA 8 fishery for three years, following a two year hiatus from sampling over 2010–11 and 2011–12. Bottom trawl landings in spring-summer were largely dominated by young snapper, 4 to 7 years of age, and collectively make up over three-quarters (78%) of the number landed, while the combined total of old fish has remained low, and not dissimilar to estimates seen in the fishery in the past two decades. Snapper over 10 years old make up just 7% of the bottom trawl catch by number, and the aggregate (over 19) age group 0.3%, currently the lowest documented proportion for any New Zealand snapper stock (refer Walsh et al. 2011b). Nevertheless, an examination of the time series of cumulative plots of proportion at length and age data places the 2012–13 fishing year proportion at age estimate to be above the 22 year long-term mean based on data collected from 1989–90 to 2012–

13, an indication of a broadening age composition, supported by a slow but steady increase in mean length and mean age since 2007–08. The mean age of snapper landed by bottom trawl in 2012–13 stands at 6.4 years, marginally the second highest estimate over the previous two decades (see Figure 16, Appendix 9), and suggests some improvement to the status of the fishery.

Broadening of the catch-at-age composition becomes most apparent when one or more dominant year classes of above average strength recruit into the fishery and remain strong for a number of years. In 2008–09, Walsh & Buckthought (2010) predicted the newly recruited 2006 year class (3-year-olds at that time) to be of above average strength, and in 2009–10 it was confirmed to be one of the strongest year classes to recruit into the SNA 8 fishery in that decade and to be important for the short term sustainability and rebuild of the stock (Walsh et al. 2011b). Although unmonitored until 2012–13 due to the two year gap in sampling, the 2006 year class has remained dominant in SNA 8 (see (Appendices 9 and 10), and now accounts for about one in every five fish landed (21%), significant in the short term catch by number, but more importantly in its contribution by weight, with an average individual length of about 38 cm and weight of about 1.2 kg. Although the dominance of other identified strong year classes in SNA 8 in the past (i.e., 1991, 1996, 1998) have generally been short lived (see Appendices 9–11), it is highly probable that the 2006 year class will continue to broaden the right hand limb of the age distribution at least over the next few years, should the catch from, and recruitment to, the fishery, remain relatively constant.

Recent change in snapper growth rates

Following the introduction of the QMS, when SNA 8 was one of New Zealand's most exploited inshore fisheries, growth rates for snapper were seen to be some of the fastest in New Zealand, and although research indicated that a slight decline in growth was apparent during the 1990s, estimates still well exceeded those of the SNA 1 fishery (Davies et al. 2003). However, analysis of catch sampling data collected in 2012–13 indicates a more obvious change in growth rate has recently occurred in SNA 8. Since 2007–08, catch-at-age data from the bottom trawl fishery has shown an increasing trend in mean age, while changes in mean length, although increasing, were much less apparent (see Figure 16), and although these estimates may be affected by recruitment patterns, they appear to indicate that recent growth rates have slowed. Support for this is evident in a trend of decreasing mean weight-at-age estimates for the common age classes in the fishery (i.e., those 6–11 years) over the past two successive decades, and although variation in mean weight-at-age occurs over time, estimates in recent years, particularly 2012–13, are consistently some of the lowest recorded over this period (see Figures 17 and 18). Long-term trends in mean weight-at-age estimates for older age classes (i.e., those greater than 11 years) are not as apparent, most likely due to the low number of individuals present in the otolith collections. Further support for a decline in snapper growth rates is also evident in the incremental deposition in a number of the SNA 8 otoliths aged from the 2012–13 sample collection. A greater number of otolith samples exhibited a noticeable narrowing of zones close to the margin than had generally been observed in the ageing in previous years, meaning that somatic growth in some fish had slowed considerably (Appendix 12). Aside from any possible bias associated with the sampling design or selectivity of the fishing method, temporal growth trends, like those observed in this study and documented in the past (Davies et al. 2003, 2013), are more likely to be attributable to compensatory density dependence (Rose et al. 2001) as the SNA 8 stock biomass changes, rather than temperature related effects. The reduced growth rate observed in SNA 8 in 2012–13 and the resulting net weight loss to the fishery in terms of yield per recruit compared to that of the 1990s suggests a decrease in productivity in the stock, correlating with a gradual increase in stock size, meaning that the fishery is likely to land more snapper now than it did 10–20 years ago to achieve the same catch weight. Similar density dependent growth trends in relation to changes in biomass have recently been documented for the Hauraki Gulf and Bay of Plenty sub-stocks of SNA 1 (Walsh et al. 2011a,c).

Past research has shown bottom trawl to be less selective for large old snapper than bottom pair trawl (Sullivan & Gilbert 1978, Davies et al. 2006), although in the absence of large fish, length and age compositions from SNA 8 suggest that the population is equally vulnerable to either method (Walsh et al. 2001, 2002, 2003, 2004, Walsh & Davies 2004). Nevertheless, catch sampling data from SNA 8 in the 1970s and more recently in SNA 2 (Walsh et al. 2012), clearly indicate that bottom trawl is capable of capturing a significant proportion of large old snapper should they be present in the fishery. This was not apparent in sampled SNA 8 bottom trawl landings from the spring or summer seasons in 2012–13 and is unlikely to change for some years, given the paucity of large and old snapper currently present in the commercial fishery, or at least spatially where it operates, coupled with a diminishing growth rate. The average size and weight of snapper landed by bottom trawl over spring-summer 2012–13 was 36.3 cm and 1.1 kg.

Length and age collections from the SNA 8 bottom trawl fishery were made over the spring and summer seasons, when most of the annual catch of snapper has historically been caught, when fish aggregate for spawning (Davies et al. 2013). In 2012–13 approximately 57% of the TACC was taken during spring-summer. The decline in SNA 8 landings in recent years during spring-summer can be attributed to the broadening of the fishing season, the availability of ACE (Annual Catch Entitlement) and high relative lease prices compared with other species, the decline in the number of vessels over the past decade, as well as economic and market related factors (Walsh et al. 2009a). The recent trend for commercial fishers to target other inshore species such as trevally and red gurnard, taking snapper mainly as a bycatch, has continued in the west coast North Island fishery, with snapper the principal target in only 13% of fishing events in 2012–13 (see Figure 8). Bottom trawl remains by far the most dominant fishing method in the SNA 8 fishery as it has been for over a decade, and the fact that the greater proportion of the landed catch (86%) of snapper in 2012–13 was taken from the northern half of the stock (principally statistical areas 042 and 045, bordering the Manukau and Kaipara Harbours, respectively), indicates that a good proportion of the stock biomass continues to reside there. These areas were the most heavily fished in the past (Reid 1969) and are still considered the main areas to catch snapper commercially today.

Anecdotal reports from commercial and recreational sectors suggest considerable improvement throughout the entire SNA 8 fishery in recent years. It is likely that greater spatial dispersion of the stock has occurred due to increased abundance, particularly from areas where catches had been mediocre in the late 1980s and early 1990s, such as the southern half of SNA 8 (statistical areas 037–041). The most recent abundance estimates determined from the SNA 8 tagging programme in 2002 (Gilbert et al. 2005) indicated the highest biomass to be associated with the Manukau stratum (38% of total actual biomass), followed by the North (24%) and South Taranaki Bight (21%) strata, while that from the Kaipara (9.8%) and Ninety Mile Beach (7.6%) strata in the north of the fishery were comparatively low (see Figure 1 for spatial strata). Given that 75% of tagged snapper were recaptured within 50 nautical miles from their release point (Walsh et al. 2006c), implying that most snapper do not move long distances, continued high commercial fishing pressure in the northern half of the stock may continue to result in predominantly small to medium sized snapper being available to that component of the fishery. It is expected that the size and age range of fish in the lower half of the stock will broaden with an increasing presence of large and older fish should commercial fishing pressure continue to remain low and recreational fishing stable. Again, a tagging programme to estimate stock biomass would ultimately clarify any uncertainties associated with spatial depletion and dispersion impacting upon the stock.

Precision in catch-at-age

It is expected that the derived proportional length and age distributions from these landings are adequate and representative descriptions of commercial bottom trawl landings from SNA 8 in 2012–13, and are therefore comparable to those collections from past years over the 'school season', although snapper may have been more frequently used as the target species before the TACC reduction in October 2005. The MWCV (bootstrap estimates) for the combined spring-summer length and age distributions sampled from the SNA 8 bottom trawl fishery in 2012–13 were 0.13 and 0.14, respectively. The level of precision in the catch-at-age estimates has been similar in recent years and reflects the rigorous sampling methodology and precise ageing.

5. ACKNOWLEDGMENTS

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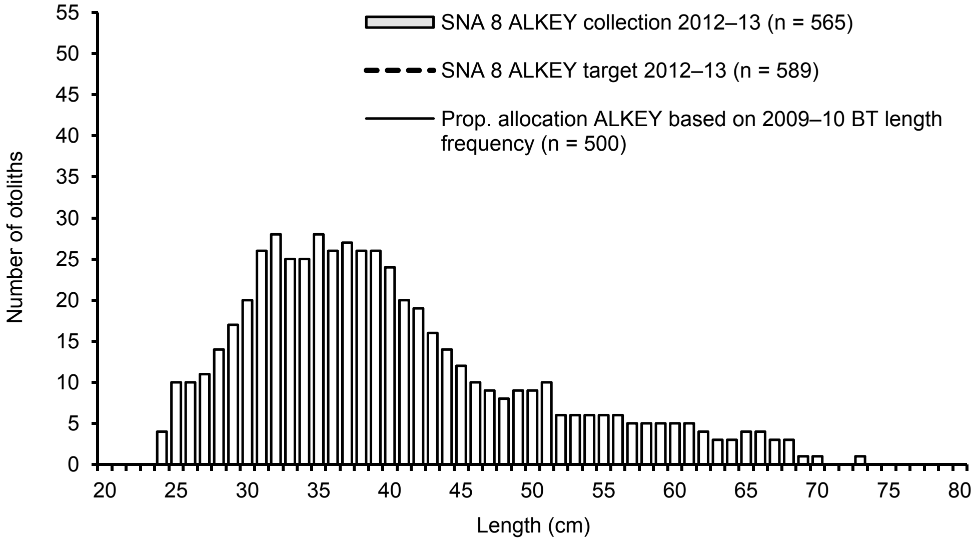
7. APPENDICES

Appendix 1: Length distributions of the target semi-fixed allocation otolith sample (dashed line) and the achieved otolith collection (histogram) sampled from the SNA 8 fishery in 2012–13. For comparison, the proportional allocation otolith sample of 500 fish based on the bottom trawl length distribution from 2009–10, the previous fishing year in which catch sampling was undertaken in SNA 8, is also given (solid line).

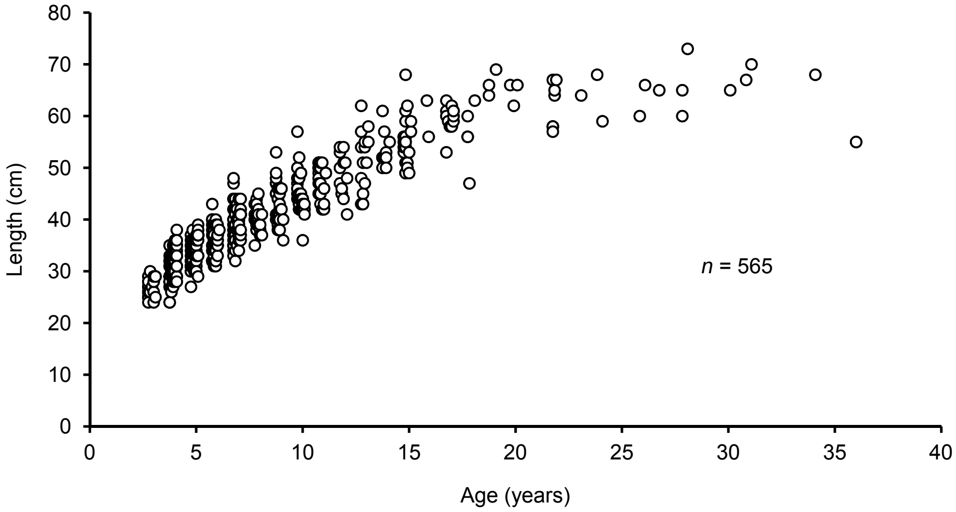


Appendix 2: Age-length key derived from snapper otolith samples collected from SNA 8 in 2012–13.

Estimates of proportion of age at length for snapper sampled from SNA 8, spring and summer 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	0.50	0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
25	0	0	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
26	0	0	0.80	0.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
27	0	0	0.55	0.36	0.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
28	0	0	0.36	0.64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
29	0	0	0.29	0.65	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
30	0	0	0.05	0.55	0.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
31	0	0	0	0.46	0.46	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26
32	0	0	0	0.50	0.29	0.18	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	28
33	0	0	0	0.60	0.28	0.08	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	25
34	0	0	0	0.12	0.44	0.32	0.12	0	0	0	0	0	0	0	0	0	0	0	0	0	25
35	0	0	0	0.25	0.29	0.25	0.18	0.04	0	0	0	0	0	0	0	0	0	0	0	0	28
36	0	0	0	0.08	0.19	0.31	0.35	0	0.04	0.04	0	0	0	0	0	0	0	0	0	0	26
37	0	0	0	0	0.33	0.19	0.37	0.11	0	0	0	0	0	0	0	0	0	0	0	0	27
38	0	0	0	0.04	0.08	0.12	0.54	0.15	0.08	0	0	0	0	0	0	0	0	0	0	0	26
39	0	0	0	0	0.04	0.23	0.50	0.15	0.08	0	0	0	0	0	0	0	0	0	0	0	26
40	0	0	0	0	0	0.13	0.50	0.21	0.17	0	0	0	0	0	0	0	0	0	0	0	24
41	0	0	0	0	0	0	0.50	0.20	0.20	0.05	0	0.05	0	0	0	0	0	0	0	0	20
42	0	0	0	0	0	0	0.42	0.05	0.11	0.32	0.11	0	0	0	0	0	0	0	0	0	19
43	0	0	0	0	0	0.06	0.06	0.19	0.06	0.38	0.13	0	0.13	0	0	0	0	0	0	0	16
44	0	0	0	0	0	0	0.36	0.07	0.14	0.36	0	0.07	0	0	0	0	0	0	0	0	14
45	0	0	0	0	0	0	0	0.08	0.25	0.25	0.17	0.17	0.08	0	0	0	0	0	0	0	12
46	0	0	0	0	0	0	0	0	0.50	0.20	0.20	0.10	0	0	0	0	0	0	0	0	10
47	0	0	0	0	0	0	0.11	0	0.22	0.11	0.22	0.11	0.11	0	0	0	0	0.11	0	0	9
48	0	0	0	0	0	0	0.13	0	0.13	0.38	0.13	0.13	0.13	0	0	0	0	0	0	0	8
49	0	0	0	0	0	0	0	0	0.11	0.22	0.33	0	0	0	0.33	0	0	0	0	0	9
50	0	0	0	0	0	0	0	0	0	0.22	0.33	0.11	0	0.22	0.11	0	0	0	0	0	9
51	0	0	0	0	0	0	0	0	0	0	0.40	0.20	0.20	0	0.20	0	0	0	0	0	10
52	0	0	0	0	0	0	0	0	0	0.17	0	0	0	0.83	0	0	0	0	0	0	6
53	0	0	0	0	0	0	0	0	0.17	0	0	0.17	0	0.17	0.33	0	0.17	0	0	0	6
54	0	0	0	0	0	0	0	0	0	0	0	0.33	0.33	0	0.33	0	0	0	0	0	6
55	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0.17	0.33	0	0	0	0	0.17	6
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.50	0.17	0	0.33	0	0	6
57	0	0	0	0	0	0	0	0	0	0.20	0	0	0.20	0.20	0.20	0	0	0	0	0.20	5
58	0	0	0	0	0	0	0	0	0	0	0	0	0.20	0	0	0	0.40	0	0	0.40	5
59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.40	0	0.40	0	0	0.20	5
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.40	0.20	0	0.40	5
61	0	0	0	0	0	0	0	0	0	0	0	0	0	0.20	0.20	0	0.60	0	0	0	5
62	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0.25	0	0.25	0	0	0.25	4
63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0.33	0.33	0	0	3
64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	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	4
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.75	4
67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	3
68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0	0	0.67	3
69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	0	1
70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	1
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	1.00	1
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
76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total																					565

Appendix 3: Scatterplot of age-at-length data for snapper sampled from the SNA 8 bottom trawl fishery in 2012–13 (*n*, sample size). Age is decimalised as of the month of collection relative to an assumed January 1 "birthdate".



Appendix 4: Estimates of proportion at length with CVs (bootstrap estimates) for snapper from the SNA 8 bottom trawl fishery in 2012–13.

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

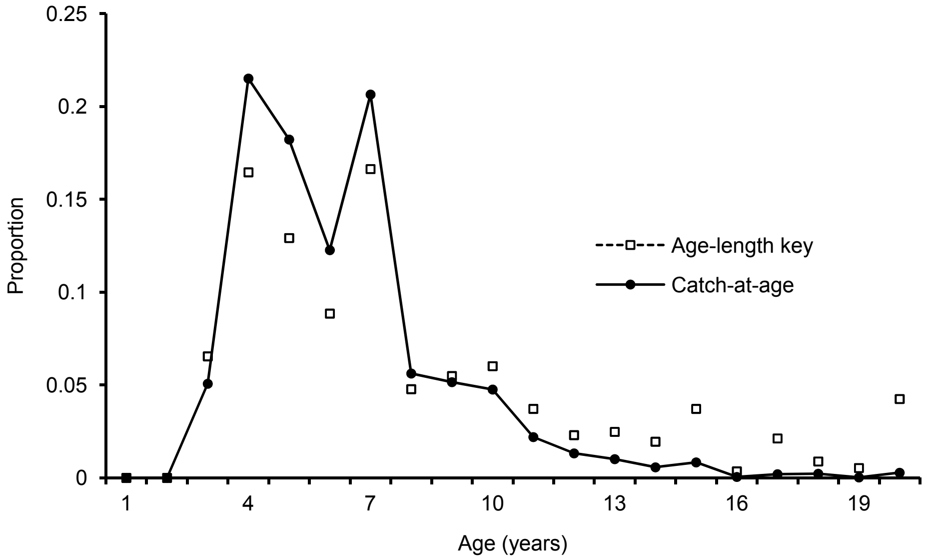
Length	Spring		Summer		Spr-sum (unstratified)		Spr-sum (stratified)	
(cm)	*P.i.*	c.v.	*P.i.*	c.v.	*P.i.*	c.v.	*P.i.*	c.v.
20	0.0004	1.70	0.0000	0.00	0.0003	1.69	0.0001	1.70
21	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
22	0.0001	1.65	0.0000	0.00	0.0001	1.66	0.0000	1.65
23	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
24	0.0013	1.00	0.0006	1.11	0.0010	0.81	0.0008	0.74
25	0.0074	0.33	0.0032	0.73	0.0059	0.31	0.0047	0.36
26	0.0119	0.21	0.0102	0.41	0.0113	0.21	0.0108	0.26
27	0.0257	0.31	0.0114	0.45	0.0206	0.30	0.0166	0.26
28	0.0280	0.25	0.0268	0.23	0.0276	0.18	0.0273	0.18
29	0.0459	0.25	0.0271	0.19	0.0392	0.22	0.0339	0.16
30	0.0509	0.19	0.0530	0.17	0.0516	0.14	0.0522	0.13
31	0.0539	0.12	0.0656	0.16	0.0580	0.10	0.0614	0.12
32	0.0621	0.13	0.0710	0.16	0.0653	0.10	0.0678	0.11
33	0.0596	0.15	0.0779	0.11	0.0661	0.11	0.0713	0.09
34	0.0647	0.12	0.0800	0.09	0.0702	0.08	0.0745	0.07
35	0.0639	0.17	0.0896	0.09	0.0730	0.12	0.0803	0.08
36	0.0635	0.13	0.0724	0.08	0.0667	0.09	0.0692	0.07
37	0.0624	0.12	0.0720	0.10	0.0658	0.09	0.0686	0.08
38	0.0636	0.11	0.0636	0.12	0.0636	0.08	0.0636	0.08
39	0.0575	0.13	0.0487	0.15	0.0544	0.10	0.0519	0.10
40	0.0530	0.12	0.0461	0.22	0.0506	0.10	0.0486	0.14
41	0.0432	0.13	0.0344	0.18	0.0401	0.11	0.0376	0.12
42	0.0360	0.14	0.0300	0.20	0.0339	0.12	0.0322	0.14
43	0.0301	0.17	0.0197	0.21	0.0264	0.15	0.0235	0.14
44	0.0228	0.20	0.0179	0.25	0.0211	0.16	0.0197	0.17
45	0.0159	0.22	0.0165	0.30	0.0161	0.18	0.0163	0.21
46	0.0132	0.26	0.0114	0.24	0.0126	0.18	0.0121	0.17
47	0.0133	0.28	0.0073	0.36	0.0112	0.25	0.0095	0.23
48	0.0104	0.30	0.0072	0.35	0.0093	0.25	0.0084	0.24
49	0.0054	0.36	0.0064	0.33	0.0057	0.26	0.0060	0.25
50	0.0062	0.32	0.0072	0.28	0.0065	0.23	0.0068	0.21
51	0.0053	0.34	0.0056	0.36	0.0054	0.26	0.0055	0.26
52	0.0036	0.42	0.0035	0.51	0.0036	0.33	0.0035	0.36
53	0.0048	0.39	0.0022	0.57	0.0039	0.36	0.0031	0.34
54	0.0029	0.43	0.0023	0.64	0.0027	0.38	0.0025	0.41
55	0.0013	0.75	0.0013	0.76	0.0013	0.56	0.0013	0.55
56	0.0026	0.59	0.0019	0.67	0.0024	0.46	0.0022	0.47
57	0.0016	0.64	0.0012	0.86	0.0014	0.51	0.0013	0.56
58	0.0007	0.79	0.0013	0.62	0.0009	0.51	0.0011	0.50
59	0.0004	0.99	0.0000	0.00	0.0002	0.97	0.0001	0.99
60	0.0005	1.02	0.0005	1.14	0.0005	0.79	0.0005	0.82
61	0.0009	0.75	0.0003	1.62	0.0007	0.67	0.0005	0.75
62	0.0004	1.02	0.0011	0.83	0.0007	0.65	0.0009	0.71
63	0.0003	1.25	0.0002	1.64	0.0003	0.97	0.0003	1.08
64	0.0004	1.18	0.0002	1.71	0.0003	0.94	0.0003	1.03
65	0.0003	1.19	0.0004	1.60	0.0004	0.97	0.0004	1.10
66	0.0008	0.93	0.0001	1.73	0.0005	0.92	0.0003	0.83
67	0.0001	1.75	0.0003	1.75	0.0002	1.20	0.0002	1.40
68	0.0005	0.94	0.0002	1.56	0.0004	0.85	0.0003	0.88
69	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
71	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
73	0.0000	0.00	0.0002	1.61	0.0001	1.71	0.0001	1.61
74	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
76	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
77	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
78	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
79	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
80	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
Nt	214 559		384 205		646 886			
n	5 274		4 498		9 772			

Appendix 5: Estimates of proportion at age with CVs (bootstrap estimates) for snapper from the SNA 8 bottom trawl fishery in 2012–13.

P.j., proportion of fish in age class; c.v., coefficient of variation; *n* , otolith sample size

Age	Spring		Summer		Spr-sum (unstratified)		Spr-sum (stratified)		
(years)	*P.j.*	c.v.	*P.j.*	c.v.	*P.j.*	c.v.	*P.j.*	c.v.	*n*
1	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	–
2	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	–
3	0.0577	0.24	0.0380	0.30	0.0507	0.24	0.0451	0.22	37
4	0.2108	0.10	0.2229	0.12	0.2151	0.09	0.2185	0.10	93
5	0.1715	0.12	0.2017	0.12	0.1823	0.11	0.1908	0.11	73
6	0.1169	0.14	0.1331	0.13	0.1227	0.14	0.1273	0.13	50
7	0.2080	0.10	0.2038	0.12	0.2065	0.09	0.2053	0.10	94
8	0.0580	0.20	0.0529	0.22	0.0562	0.19	0.0548	0.20	27
9	0.0544	0.20	0.0464	0.23	0.0516	0.19	0.0493	0.20	31
10	0.0509	0.21	0.0415	0.23	0.0476	0.19	0.0449	0.20	34
11	0.0231	0.28	0.0200	0.26	0.0220	0.24	0.0211	0.24	21
12	0.0140	0.34	0.0117	0.36	0.0132	0.33	0.0125	0.33	13
13	0.0109	0.39	0.0087	0.38	0.0101	0.36	0.0095	0.35	14
14	0.0059	0.39	0.0054	0.42	0.0057	0.34	0.0056	0.34	11
15	0.0088	0.34	0.0076	0.34	0.0083	0.30	0.0080	0.29	21
16	0.0005	1.14	0.0004	1.26	0.0005	1.06	0.0004	1.04	2
17	0.0022	0.62	0.0016	0.58	0.0020	0.50	0.0018	0.50	12
18	0.0026	0.75	0.0016	0.74	0.0022	0.69	0.0020	0.68	5
19	0.0003	1.29	0.0001	1.88	0.0002	1.12	0.0002	1.16	3
>19	0.0028	0.47	0.0027	0.51	0.0028	0.37	0.0027	0.38	24

Appendix 6: Comparison of the unweighted (age-length key) and weighted (unstratified catch-at-age estimate) proportions at age sampled from the SNA 8 bottom trawl fishery in 2012–13.



Appendix 7: Estimates of mean length-at-age (cm) with CVs for snapper from the SNA 8 bottom trawl fishery in 2012–13.

c.v., coefficient of variation

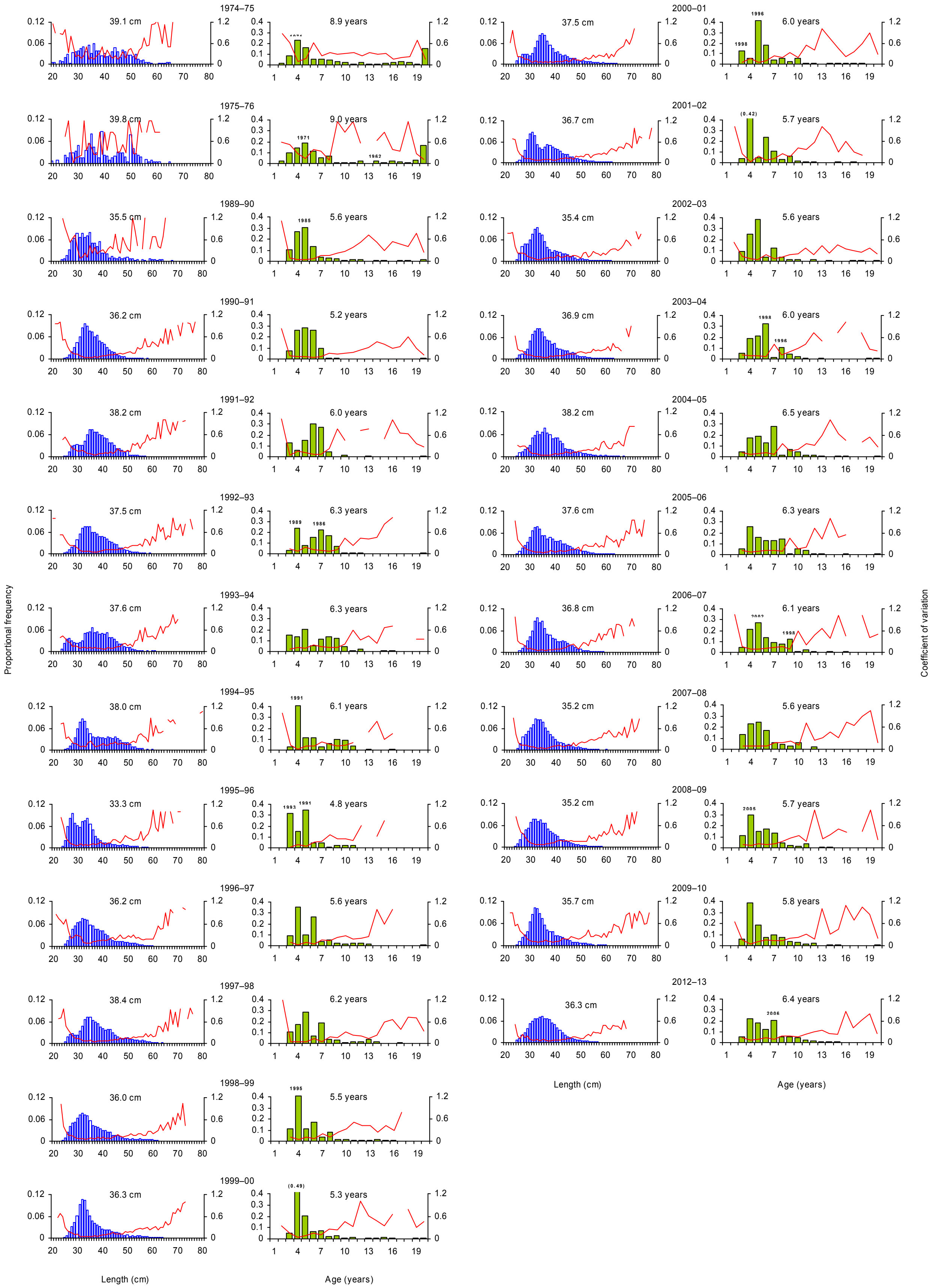
Length	Spring		Summer		Spr-sum (unstratified)		Spr-sum (stratified)	
(cm)	Mean	c.v.	Mean	c.v.	Mean	c.v.	Mean	c.v.
1	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–
3	27.32	0.01	27.48	0.01	27.36	0.01	27.40	0.01
4	31.17	0.01	31.66	0.01	31.35	0.01	31.49	0.01
5	33.40	0.01	33.51	0.01	33.45	0.01	33.48	0.01
6	35.73	0.01	35.44	0.01	35.62	0.01	35.54	0.01
7	38.65	0.01	38.19	0.01	38.49	0.01	38.36	0.01
8	39.69	0.01	39.36	0.01	39.58	0.01	39.48	0.01
9	42.16	0.02	41.88	0.02	42.07	0.02	41.99	0.02
10	43.85	0.01	43.82	0.02	43.84	0.01	43.83	0.01
11	46.03	0.02	46.40	0.02	46.15	0.02	46.25	0.02
12	46.62	0.03	46.53	0.03	46.59	0.03	46.57	0.03
13	47.40	0.03	48.28	0.04	47.66	0.03	47.91	0.03
14	52.32	0.01	51.91	0.01	52.18	0.01	52.07	0.01
15	53.15	0.02	52.51	0.02	52.95	0.02	52.76	0.02
16	57.33	0.55	57.32	0.64	57.33	0.51	57.32	0.49
17	57.56	0.05	58.36	0.11	57.79	0.03	58.01	0.03
18	51.24	0.14	52.08	0.22	51.45	0.14	51.68	0.13
19	65.18	0.64	64.50	1.10	65.08	0.50	64.94	0.54
>19	62.54	0.03	62.40	0.07	62.49	0.02	62.45	0.03

Appendix 8: Estimates of mean weight-at-age (kg) with CVs for snapper from the SNA 8 bottom trawl fishery in 2012–13.

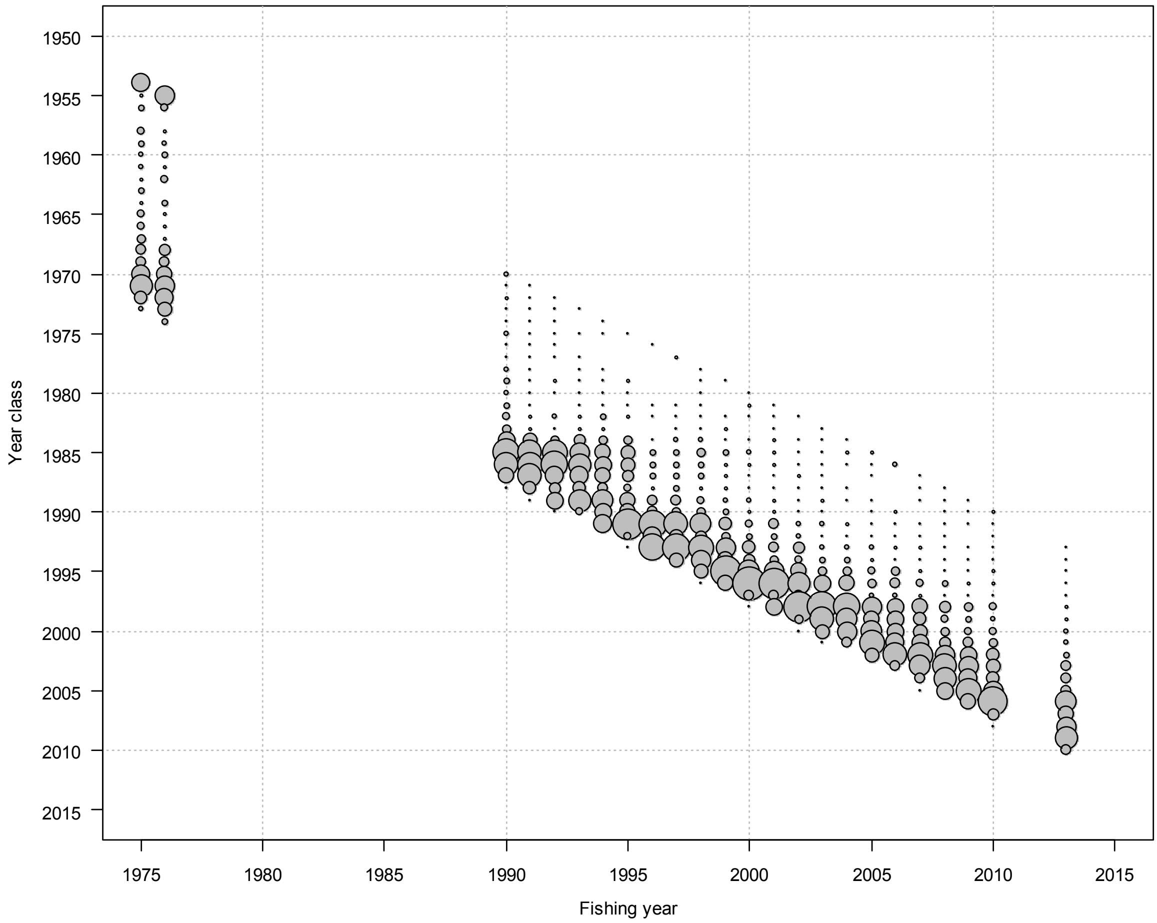
c.v., coefficient of variation

Age	Spring		Summer		Spr-sum (unstratified)		Spr-sum (stratified)	
(years)	Mean	c.v.	Mean	c.v.	Mean	c.v.	Mean	c.v.
1	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–
3	0.46	0.03	0.47	0.04	0.46	0.03	0.47	0.03
4	0.67	0.03	0.70	0.02	0.68	0.03	0.69	0.02
5	0.82	0.03	0.82	0.02	0.82	0.02	0.82	0.02
6	0.98	0.03	0.96	0.03	0.98	0.03	0.97	0.03
7	1.23	0.02	1.19	0.02	1.21	0.02	1.20	0.02
8	1.31	0.03	1.28	0.03	1.30	0.03	1.30	0.03
9	1.57	0.04	1.54	0.04	1.56	0.04	1.55	0.04
10	1.74	0.04	1.74	0.04	1.74	0.04	1.74	0.04
11	1.99	0.04	2.04	0.04	2.01	0.04	2.02	0.04
12	2.08	0.07	2.07	0.07	2.07	0.07	2.07	0.07
13	2.19	0.09	2.32	0.11	2.23	0.09	2.27	0.10
14	2.83	0.04	2.77	0.04	2.81	0.04	2.79	0.04
15	2.98	0.05	2.88	0.06	2.95	0.05	2.92	0.05
16	3.66	0.57	3.66	0.66	3.66	0.53	3.66	0.51
17	3.72	0.10	3.86	0.14	3.76	0.08	3.80	0.08
18	2.73	0.25	2.86	0.29	2.76	0.23	2.80	0.23
19	5.21	0.64	5.06	1.10	5.19	0.50	5.16	0.54
>19	4.69	0.08	4.69	0.12	4.69	0.07	4.69	0.08

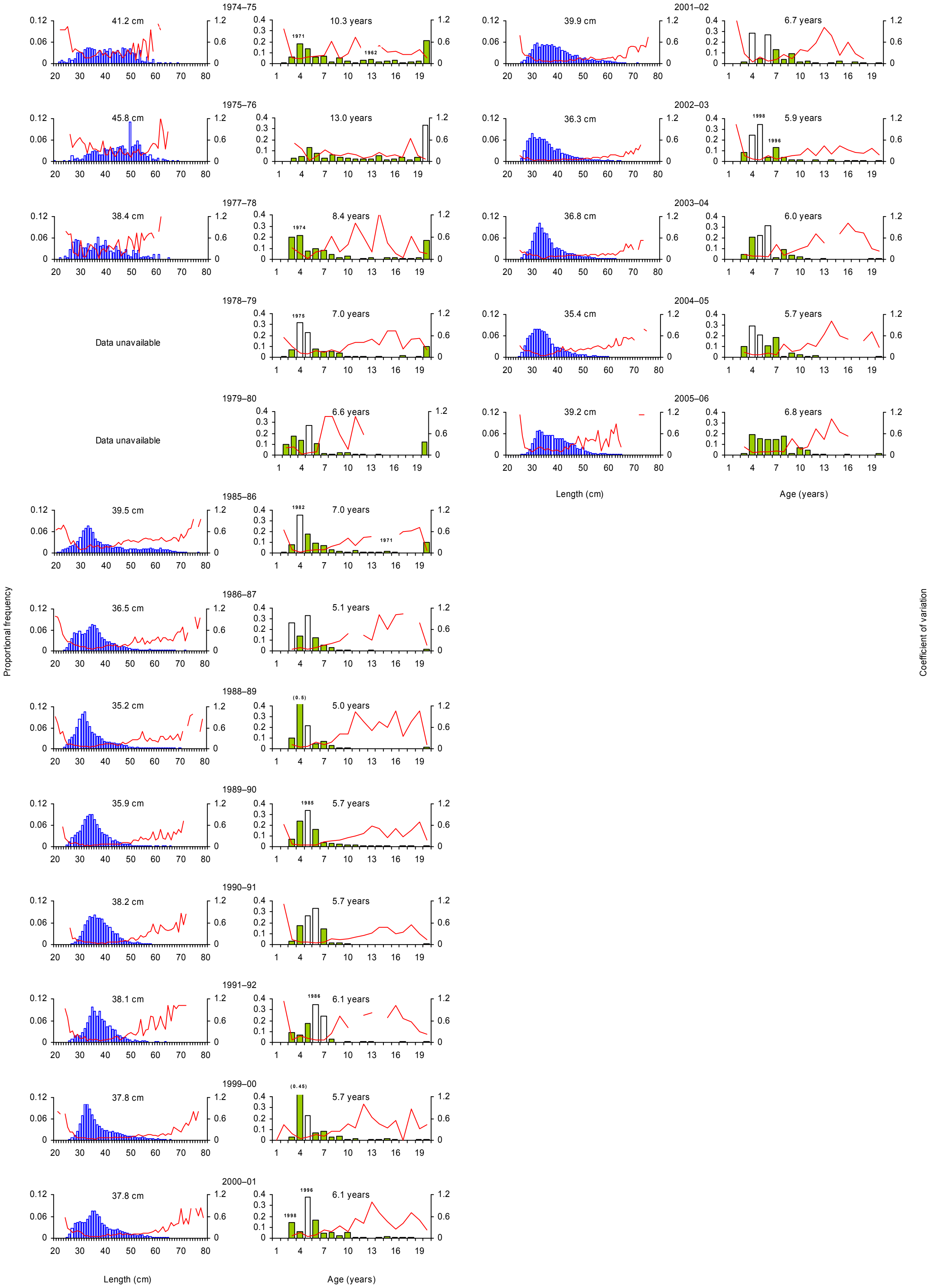
Appendix 9: Time series of proportion at length and age distributions and CVs for snapper from the SNA 8 bottom trawl fishery from 1974–75 to 1975–76, 1989–90 to 2009–10 and 2012–13. Data are from spring-summer and plots are annotated with estimates of mean length or age.



Appendix 10: Time series of age frequency distributions by year class and year from the SNA 8 bottom trawl spring-summer fishery from 1974–75 to 2012–13. Symbol area is proportional to the proportion at age.



Appendix 11: Time series of proportion at length and age distributions and CVs for snapper from the SNA 8 bottom pair trawl fishery from 1974–75 to 1979–80, 1985–86 to 1986–87, 1988–89 to 1991–92, and 2000–01 to 2005–06. Data are from spring-summer and plots are annotated with estimates of mean length or age.



Appendix 12: Depiction of growth rate variability in prepared otolith samples collected from the SNA 8 fishery in 2012–13 from the smallest (slowest growing, left) and largest (fastest growing, right) snapper aged in three different fishing year age classes. Slow and fast somatic growth is mirrored in otolith size and incremental growth zone width. Fish #1 and 2 aged at 7 years were 32 cm (0.714 kg) and 48 cm (2.217 kg) respectively; Fish #3 and 4 aged at 10 years were 36 cm (0.993 kg) and 57 cm (3.582 kg) respectively; Fish #5 and 6 aged at 13 years were 43 cm (1.630 kg) and 69 cm (6.108 kg) respectively. Scale bar = 500 µm. Images C. Ó Maolagáin.