Ministry for Primary Industries
Manatū Ahu Matua

Length and age composition of commercial snapper landings in SNA 8, 2015–16

New Zealand Fisheries Assessment Report 2017/2

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ISSN 1179-5352 (online)
ISBN 978-1-77665-466-6 (online)

January 2017

New Zealand Government

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EXECUTIVE SUMMARY

Walsh, C.; Armiger, H.; Bian, R.; Buckthought, D.; McKenzie, J. (2017). Length and age composition of commercial snapper landings in SNA 8, 2015–16.

***New Zealand Fisheries Assessment Report 2017/02.* 40 p.**

This report presents the results of Objectives 1 and 2 of the Ministry for Primary Industries project “Estimation of snapper year class strength in SNA 8” (SNA2015/01, 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.

A length frequency and age-length key sampling approach was employed during spring and summer 2015–16 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. Sixteen landings were sampled for length frequency from the bottom trawl fishery with a total of 8539 fish measured. The age-length key was based on 585 otolith pairs.

Relative year class strengths inferred from the SNA 8 bottom trawl landings in 2015–16 were generally consistent with trends observed in recent years. The age composition was dominated by 3 to 10 year old snapper, which collectively made up over 90% of the number landed. The 2010 year class (6-year-olds) was the most dominant in the fishery, accounting for one in every five fish landed, followed closely by the 2012 year class (4-year-olds). The 2006 year class (10-year-olds), previously identified as one of the strongest year classes to recruit in recent years, has remained dominant, contributing to about 8% of the catch by number, and is likely to remain significant in terms of its contribution by weight, and for the short term sustainability and continued rebuilding of the fishery.

The age composition has broadened slightly from that last described in 2012–13, mainly due to the progression of a number of strong year classes (2010, 2009, 2006), with mean age increasing to 6.9 years in 2015–16, the highest recorded estimate in 27 years. This suggests continued improvement to the status of the fishery and likely to be a direct effect of the Total Allowable Commercial Catch reduction in 2005. However, the mean length (36.6 cm) of snapper remains relatively unchanged from that sampled in 2012–13 and equal to the long-term mean, indicating that growth rates have continued to remain low. Mean weight-at-age estimates for the common age classes are now some of the lowest ever recorded, marginally lower than those from 2012–13, providing further evidence for a decrease in growth rate in SNA 8 due to a compensatory density-dependence effect as the SNA 8 stock biomass slowly rebuilds. The reduced growth rate observed in 2015–16 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 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 the sample design adequately reflected the temporal and spatial spread of the bottom trawl catches from SNA 8 in 2015–16 and that length and age estimates presented here provide representative descriptions. Mean weighted coefficients of variation for both the unstratified and stratified age compositions ranged between 17 and 18%, and are within the target of 20%.

1. INTRODUCTION

Snapper (*Pagrus auratus*) is one of New Zealand's most important commercial inshore fish species. Over 20% of the national Total Allowable Commercial Catch (TACC) of 6357 t is allocated to SNA 8 (1300 t), encompassing the west coast of the North Island (Figure 1). In most recent years the greatest proportion of the SNA 8 catch has been taken by bottom trawl from the northern half of the stock mostly as a bycatch when targeting other species, particularly trevally (*Pseudocaranx dentex)* and red gurnard (*Chelidonichthys kumu*), although some targeting of snapper does occur. The annual SNA 8 catch in recent years (2009–10 to 2013–14) has, on average, marginally exceeded the TACC of 1300 t (Figure 2, Ministry for Primary Industries 2016).

SNA 8 has been one of the most researched inshore finfish fisheries in New Zealand. Staff of the National Institute of Water and Atmospheric Research (NIWA) and, formerly MAF Fisheries, have sampled the length and age compositions of snapper from commercial landings in port (market sampling) intermittently since 1963 (Davies et al. 1993). The first sampling to determine the age composition of the fishery took place during the mid-1970s. 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), the first event undertaken in 2012–13 (Walsh et al. 2014c).

This report presents the results of market sampling from the SNA 8 stock between October 2015 and February 2016, the second triennial sampling event. Funding for this project, SNA2015/01, was provided by the Ministry for Primary Industries.

The specific objectives of this project for 2015–16 were:

1. To characterise the SNA 8 fishery by analysing existing commercial catch and effort data to the end of 2015/16 fishing year.

2. To carry out sampling and estimate the relative proportion at age and length of recruited snapper sampled from the commercial catch in SNA 8 in spring/summer of 2015/16. The target coefficient of variation (CV) for the catch-at-age will be 20 % (mean weighted CV across all age classes).

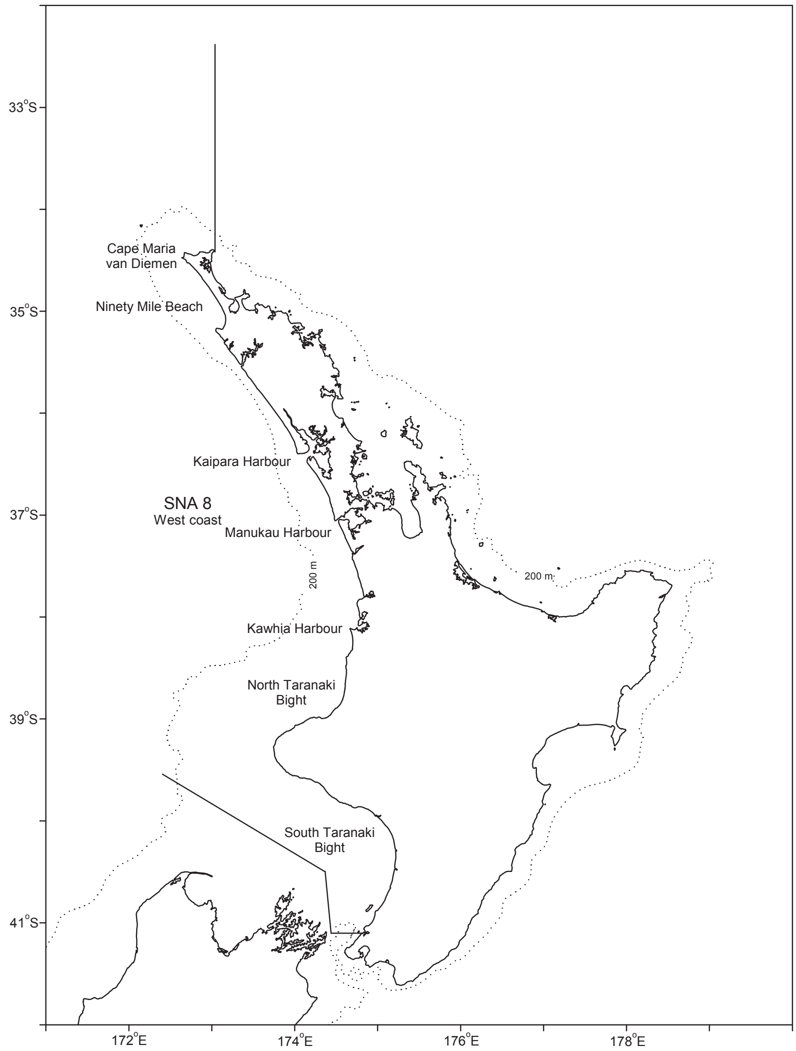

Figure 1: Quota Management Area for the west coast North Island snapper stock (SNA 8).

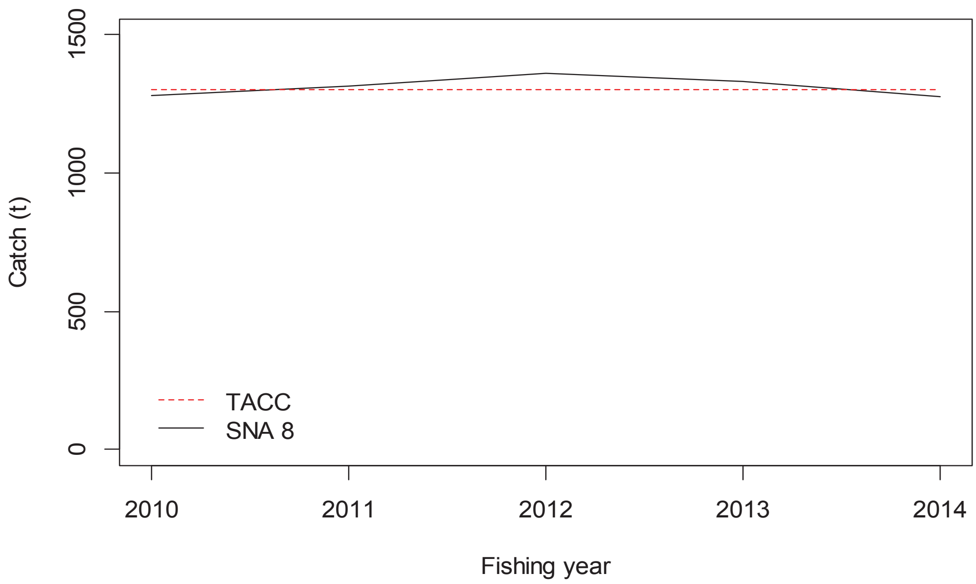

Figure 2: Reported landings of snapper in SNA 8 and TACCs for 2009–10 to 2013–14.

2. METHODS

2.1 Characterisation of recent fishery profile data for SNA 8, 2009–10 to 2013–14

A characterisation of the spatial, temporal and operational patterns in the SNA 8 fishery over the period October 2009 through to September 2014 (spanning five fishing years) was undertaken using data extracted from the MPI commercial catch reporting system, to inform the design of a catch sampling programme in 2015–16. A Northern Inshore Finfish Working Group meeting in September 2015 (NINSWG-2015/40) accepted the sample design with the two provisos: 1) that a characterisation should be undertaken using data from the two most recent years only, in order to verify the sample design; and 2) given that the relative proportion of the spring catch could vary within individual years (depending on weather), the design would need to retain a degree of flexibility (based on good communication with the fishing fleet) with an ability to adapt to changes in temporal fishing pattern.

All effort details and associated catch weights (all species including snapper) from all trips landing SNA 8 were requested. Data obtained from MPI was groomed and checked for typical reporting errors. The data used to inform the characterisation were compiled in two tables:

1. Landed catch weight: A file containing the verified green (unprocessed) landed weight of all SNA 8 trips.
2. Trip specific data: A file containing demographic information (location, method, target species, estimated catch etc).

Although the trip effort data table provided information on catch, these weights were based on fisher estimates rather than measured weights. 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).

Operational aspects such as fishery timing, gear type, target species, statistical area, fine scale spatial distribution, port of landing, and annual number of vessels and landings were summarised.

2.2 Design of SNA 8 sampling in 2015–16

The SNA 8 stock encompasses almost all the west coast of New Zealand's North Island and for sampling purposes is considered one contiguous spatial stratum (Figure 1). To be consistent with previous sampling of the SNA 8 fishery, only bottom trawl landings were sampled, as they account for the majority of the catch. Sampling usually occurs during spring (October–November) and summer (December–February) when most of the SNA 8 stock becomes vulnerable to fishing. The month of 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. Limited fishing generally occurs in September (the last month of the fishing year) and its absence from the spring sampling stratum was deemed to have minimal effect on the final results. Bottom pair trawl was last sampled from SNA 8 in 2005–06 (Walsh et al. 2006a) and as the relative catch over subsequent years was deemed insufficient for sampling purposes, only bottom trawl has been sampled since.

Details of the sampling design used in previous years are described in Davies & Walsh (1995), with sample collections undertaken in proportion to the catch of the main commercial fishing companies. However, for 2015–16, sampling effort was also further stratified for one company's vessel (VesselX) based on findings that VesselX had increasingly dominated the annual TRE 7 catch (the main west coast North Island inshore fishery) since 1999–2000 and caught larger (and older) trevally than the other core vessels in the fleet, therefore having different selectivity patterns for length and age (Langley et al. 2015).

As a result, a more structured approach to the sampling amongst the fleet (e.g. VesselX and other vessels) was proposed for SNA 8 in 2015–16, based on recommendations made for future sampling from TRE 7 (Langley et al. 2015).

2.3 Sampling SNA 8 bottom trawl landings for length and age data

Optimisation of sample sizes had previously been investigated using simulation with the aim of achieving a target level of catch-at-age precision with a mean weighted coefficient of variation (MWCV) over all age classes, of less than or equal to 0.20. Historical length frequency and otolith data from the SNA 8 bottom trawl fishery were used in optimizations to calculate the MWCV associated with different combinations of landing and otolith sample sizes using the length frequency and age-length key sampling method. The optimisation results indicated that the MWCV was more sensitive to changes in the otolith sample size than the number of landings sampled from the fishery and proposed that a sample size of 15 landings and 300–500 otoliths would adequately achieve a MWCV of about 0.15. As a result, a total of 15 bottom landings sampled for length frequency in combination with a 500 otolith age-length key have been sampled consistently from SNA 8 for more than two decades to estimate catch-at-age and reliably achieve MWCVs below 0.20. This same approach was chosen for sampling the SNA 8 fishery in 2015–16 (Table 1).

Table 1: Level of sampling proposed to describe the SNA 8 bottom trawl fishery in 2015–16 based on historical sampling for catch-at-age data that derived MWCVs below 0.20.

Stock	Sampling method	Number of landings	Number of otoliths
SNA 8	Length frequency–age-length key	15	500

In keeping with the general design of previous SNA 8 catch sampling programmes, a two-stage sampling procedure was used to obtain length frequencies (West 1978), whereby the random selection of landings and a random sample of bins within landings represent the first and second stages, respectively. 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). All fish in bins making up the sample were measured to the nearest centimetre below the fork length. It was expected that a sample size of about 400 fish would adequately describe the length distribution of each landing. 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, and this same design has been implemented for sampling ever since, including 2015–16 (see Appendix 1).

A semi-fixed allocation design for the age-length key should ensure that the right hand tail of the distribution, comprising the large and old snapper, was adequately sampled. For 2015–16, a step-wise sample size of about eight fish for length intervals greater than 45 cm, seven fish over 47 cm, six fish over 50 cm, five fish over 54 cm, four fish over 58 cm, three fish over 63 cm, two fish over 68 cm, and one fish for all length classes 75 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 2012–13 (the most recent sampling event) 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. To attain the age-length key target, between 30 to 40 otoliths from a range of fish sizes would be subsampled from each landing sampled for length until the target sample sizes for each length class (in the age-length key) were achieved (see Appendix 1).

2.4 Snapper age determination

All snapper otoliths were prepared using the break and burn technique (Chugunova 1963) and a standardised procedure for reading otoliths was followed, outlined in the age determination protocol for snapper (Walsh et al. 2014a). Two readers were used in ageing SNA 8 otolith samples in 2015–16, with each reader having no prior knowledge of the 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-examined together to determine the likely source of disagreement and a final count agreed upon. The forced margin method was implemented to anticipate the otolith margin type (wide, line, narrow) *a priori* based on the month in which the fish was sampled to provide guidance in determining age. 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) while '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).

Otolith reading precision was quantified by carrying out within and between-reader comparison tests after Campana et al. (1995), including those between each reader and the final agreed age. The Index of Average Percentage Error, IAPE (Beamish & Fournier 1981), and mean coefficient of variation (CV) (Chang 1982), were calculated for each test.

The age-length key derived from the age data was 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).

2.5 Snapper catch-at-age analysis

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 (bootstrap) from length frequency samples and the age-length key. For samples collected from the SNA 8 bottom trawl fishery in 2015–16, 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 2015 to February 2016) recruited, with the maximum age being an aggregate of all age classes over 29 years. Estimates of mean age determined from spring-summer catch-at-age estimates were calculated such that all fish comprising the aggregate (over 29 years) age group were assigned an age of 30.

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 Fishery characterisation

A characterisation of the SNA 8 fishery spanning fishing years 2009–10 to 2013–14 was conducted to provide the context for designing a catch sampling programme for the 2015–16 fishing year. The SNA 8 fishery has been dominated by bottom trawl landings which, on average, account for about 80% of the total commercial catch from SNA 8 (Figure 3a). The characterisation was therefore focused on bottom trawl landings only.

The highest bottom trawl catch consistently occurred in Statistical Area 045 (outside the Kaipara Harbour), with substantial catches made from Statistical Areas 042 and 047, and moderate catches from 041 and 046 (Figure 3b). The monthly pattern of bottom trawl catches was generally consistent over the 5 year period, with the majority occurring in October through to March/April, although information from 2013–14 showed that significant catch may continue through to September in some years (Figure 3c). An annual average of 57% of the bottom trawl catch occurred from October through to February.

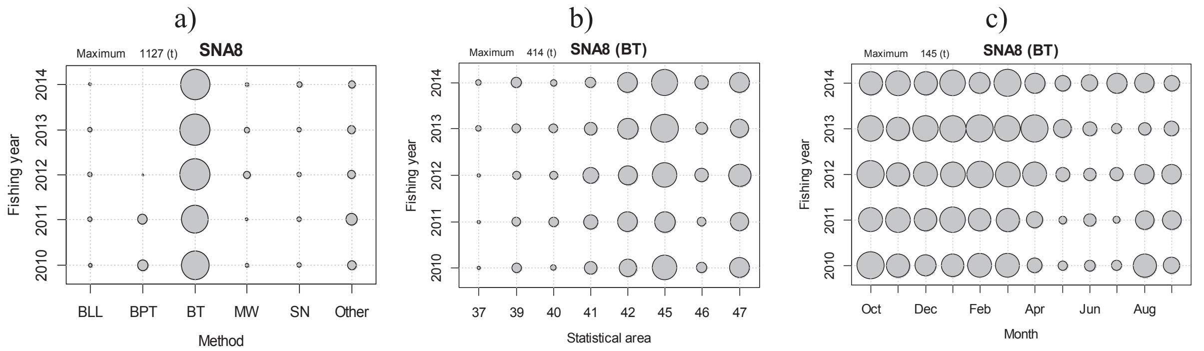

Figure 3: a) Catch of snapper in SNA 8 by gear type; b) by statistical area for bottom trawl only, and c) by month for bottom trawl only, from fishing years 2009–10 to 2013–14. (BLL, Bottom longline; BPT, Bottom pair trawl; BT, Bottom trawl; MW, Midwater trawl; SN, Set net).

3.2 Sampling design

Based on the SNA 8 fishery characterisation (2009–10 to 2013–14) described above, a landing weight criterion of 5 t of snapper was initially chosen for sampling as it reduced the number of landings available to sample by more than 80% while only reducing the total amount of catch qualifying for sampling by 40% (Figure 4a). As the majority of the SNA 8 catch in recent years had been landed into fishing companies A and D, a split of the target 15 landings by 3:12 respectively was proposed based on the relative company catch (Figure 4b, Table 2) which also included a specific target of 6 landings allocated to VesselX from company D (Table 2).

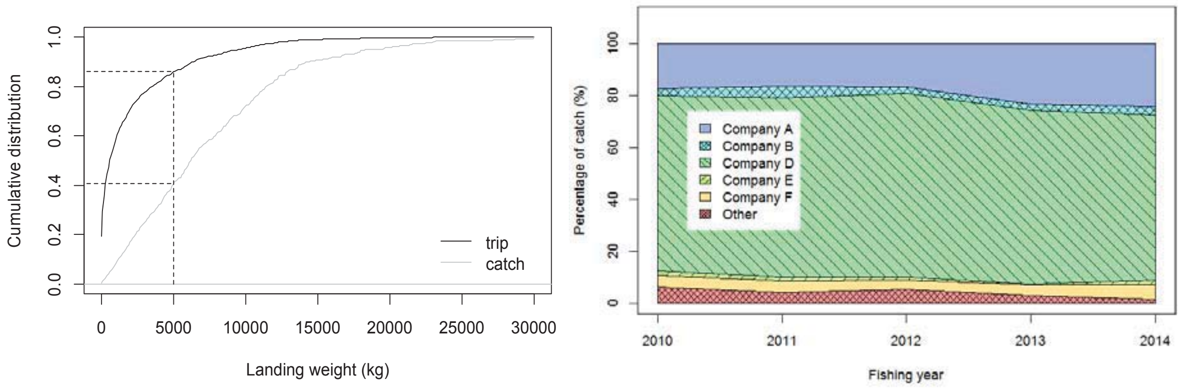

Figure 4: a) Cumulative distribution of SNA 8 landings by number of trips and weight of catch. Dashed lines indicate the proportion of trips and proportion of catch excluded with a landing weight criterion of more than 5 t. b) Percentage of the SNA 8 catch landed into the main fishing companies 2009–10 to 2013–14.

Table 2: Proposed stratification (fishing company and season) to describe the SNA 8 bottom trawl fishery in 2015–16 based on catch data from 2009–10 to 2013–14.

	Targeted number of landings for sampling			Number of otoliths to be collected for age-length key
Stratum	Spring	Summer	Total	
Company D (other vessels)	2	4	6	467
VesselX	2	4	6	
Company A	1	2	3	92
Total	5	10	15	559

Following the expected seasonal pattern of the fishery based on the recent historical catch (five years), the temporal stratification of the 15 sample landings from SNA 8 was initially split 5:10 over the spring and summer seasons respectively (Figure 5a, Table 2). Further sub-stratification of company D's fishing fleet catch over spring and summer was also deemed necessary to prorate the number of samples selected from VesselX and other vessels combined (Figure 5b, Table 2). At the request of the NINSWG (see Section 2.1), a two year summary of the expected seasonal pattern of company A and D's catch and sub-stratification of company D's fishing fleet, was compared with that generated from the longer five year time series, which produced similar results. This analysis therefore validated the sampling design that was based on the longer term five year characterisation.

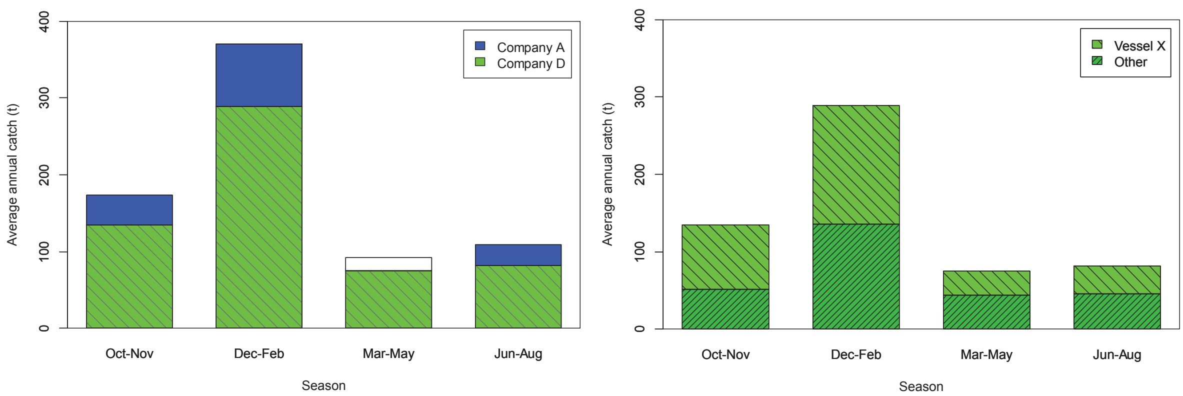

Figure 5: Comparison of the (a) seasonal catch of companies A and D and (b) the seasonal catch of company D's VesselX and "other" vessels based on catch data from 2009–10 to 2013–14.

3.3 Relative SNA 8 catch by method and statistical area in 2015–16

Bottom trawl was by far the most dominant method in the SNA 8 fishery over spring–summer 2015–16, taking about 91% of the total landed catch of 763 t (Figure 6). Seventy eight percent of the landed catch for all methods in 2015–16 was taken from the northern half of SNA 8 (Statistical Areas 042–047), approximately one-third coming from Statistical Area 045 alone, which borders the Kaipara Harbour.

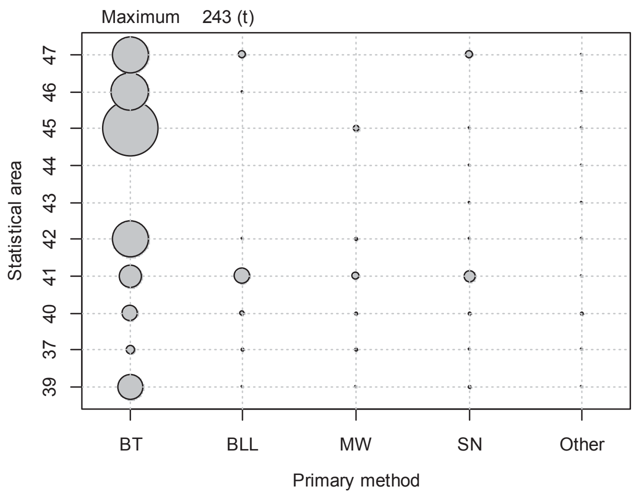

Figure 6: Relative catch by method and statistical area in SNA 8 in 2015–16 (BT, Bottom trawl; BLL, Bottom longline; MW, Midwater trawl; SN, Set net).

3.4 Sampling of the SNA 8 bottom trawl fishery in 2015–16

Sample collections

Summaries of the length frequency sample sizes for bottom trawl-season-strata are given in Table 3. A total of 16 bottom trawl landings were successfully sampled for length information (number of fish measured = 8539) from the SNA 8 fishery over spring and summer 2015–16 (four and twelve landings, respectively), exceeding the required target by one landing. Samples were selected from four different fishing vessels which contributed to almost three-quarters of the total bottom trawl catch. The number and weight of landings is summarised in Table 3.

Table 3: 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 2015–16.

		Number of landings			No. of fish	Weight of landings (t)		
Method	Season	Total	Sampled	% of total	measured	Total	Sampled	% of total
Bottom trawl	Spring	76	4	5.3	2 098	258	54	20.9
	Summer	165	12	7.3	6 441	437	93	21.3
	Combined	241	16	6.6	8 539	695	147	21.2

Based on the proposed stratification of targeted samples by fishing company (see Table 2), sample collections were closely aligned to the specified targets, with those from company D meeting the total required 12 landings over the spring-summer period (VesselX 7 landings sampled; other vessels 5 landings sampled) and company A, exceeding the required total by one landing (four landings sampled). A total of 586 snapper otolith pairs were collected from landings sampled for length frequency (Table 4) exceeding the combined overall targeted number (559) with 427 and 159 taken from company D and A vessels, respectively (see Table 2).

Table 4: Details of snapper otolith samples collected in 2015–16 from SNA 8.

Method	Sampling period	Sampling method	Length range	No. aged
Bottom trawl	Spring, summer	Stratified random	23–74	586

Sample representativeness

The number of landings from the SNA 8 bottom trawl fishery increased steadily over the October to January period, decreasing slightly in February, although there was little change in the monthly landed catch weight during spring (October to November) and summer (December to February), respectively (Figure 7). The landed weight of the sampled catch relative to that of the whole bottom trawl fishery during spring and summer was almost identical at around 21% (Figure 7, Table 3). The average size of sampled landings over the two seasons was 13.4 t (range 9.5–19.3 t) and 7.8 t (range 3.8[1]–11.6 t), respectively. The sampled component accounted for 21.2% by weight and 6.6% by number of landings of the total bottom trawl catch of SNA 8 over the sampling period (Figure 7, Table 3).

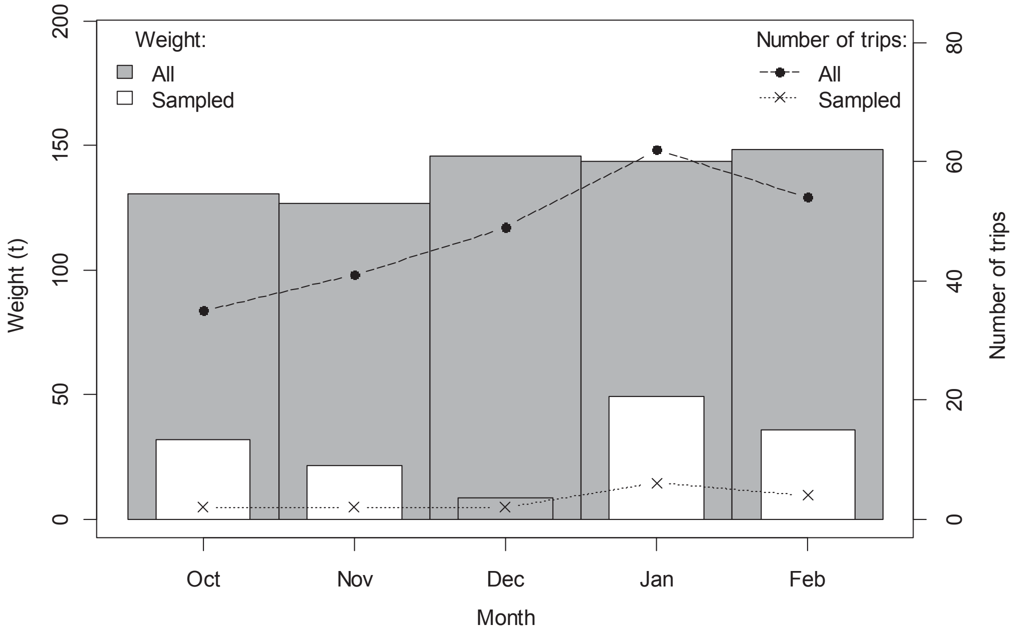

Figure 7: Comparison of the monthly distribution of landed weight (grey bars) and numbers of landings (dashed line) of snapper in the SNA 8 bottom trawl fishery for all landings where snapper was caught for the period October to February 2015–16. Included are corresponding estimates for all sampled landings (white bars and dotted line) to show the representativeness of sampling.

The sampling performance relative to the cumulative proportion of the total number and catch weight of landings throughout the sampling period is illustrated in Figures 8 and 9 and a comparison by depth is given in Figure 10. Overall, sampling was in reasonable proportion to the operation of the fishery, although a disproportionate low number of small landings was sampled during December (Figures 8 and 9) and a higher proportion of the sampled catch came from depths less than 100 m compared to that of the fishery (Figure 10).

[1] As landing size diminished during summer, the landing weight criterion was relaxed from 5 to 3 t to ensure that the targeted fifteen landings were achieved.

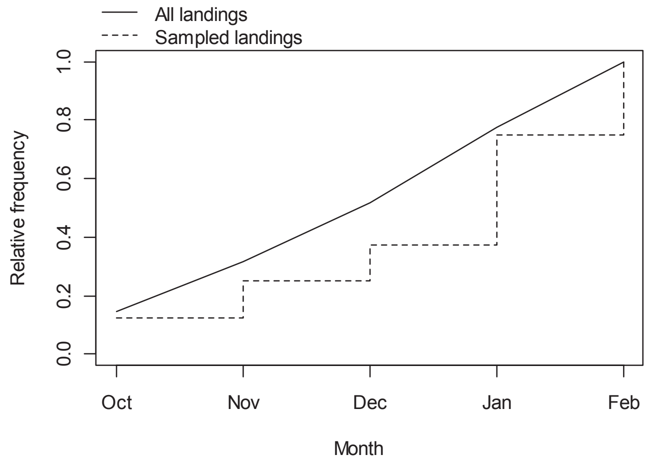

Figure 8: Comparison of the cumulative proportion of the number of landings with samples taken from the SNA 8 bottom trawl fishery in 2015–16.

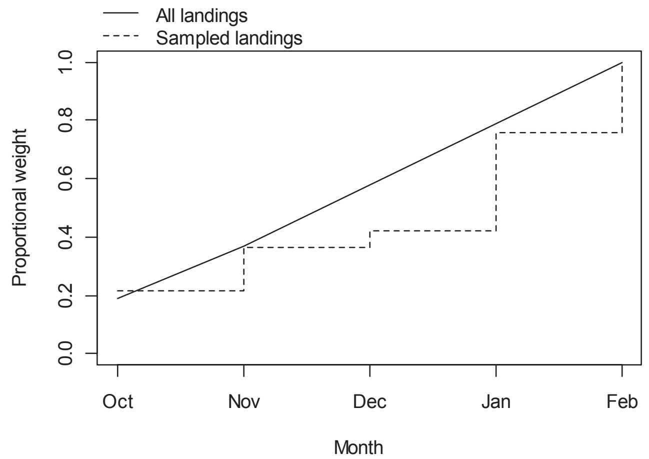

Figure 9: Comparison of the cumulative proportion of the catch weight of landings with samples taken from the SNA 8 bottom trawl fishery in 2015–16.

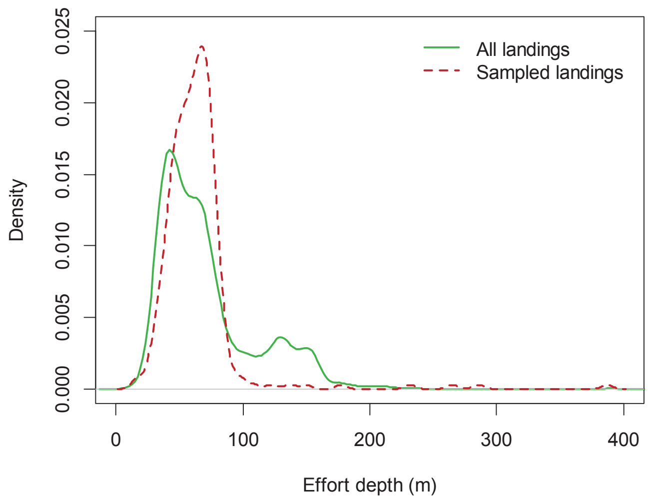

Figure 10: Comparison of the proportion of the number of tows by depth (m) for all landings with samples taken from the SNA 8 bottom trawl fishery in 2015–16.

A reasonable level of consistency was achieved between actual catches and sampled landings relative to company and vessel sampling design stratification (Figure 11).

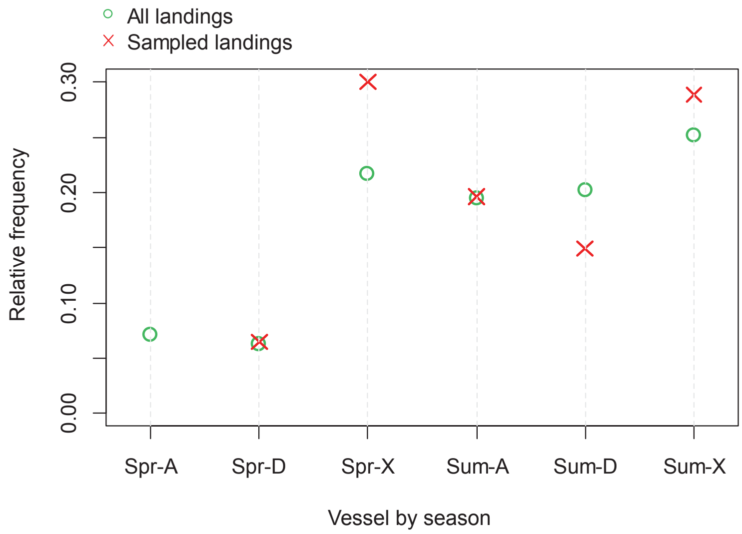

Figure 11: Comparison of the proportional distribution of the landed bottom trawl catch and the sampled component for Company A and D vessels and VesselX over spring and summer from the SNA 8 stock in 2015–16 (Spr-A, Spring-Company A vessels; Spr-D, Spring-Company D vessels; Spr-X, Spring-VesselX; Sum-A, Summer-Company A vessels; Sum-D, Summer-Company D vessels; Sum-X, Summer-VesselX).

The number of otoliths subsampled from landings in each month is given in Figure 12 which suggests a reasonable level of temporal consistency in the otolith collection, although proportionally fewer otoliths (about one quarter) were collected over spring (*n* 149) compared to summer (*n* 436). A comparison of the length distribution of snapper subsampled for the otolith collection to that targeted from the SNA 8 fishery in 2015–16 illustrates the size range of samples achieved for the age-length key (Appendix 1). The collection was relatively broad with most length intervals from 24 to 70 cm being generally well represented, often meeting or exceeding the required targets. Despite this, however, only three snapper above this size range were sampled for age (one at 73 and two at 74 cm), with all remaining size classes (71–72 cm and over 74 cm) absent in catch samples.

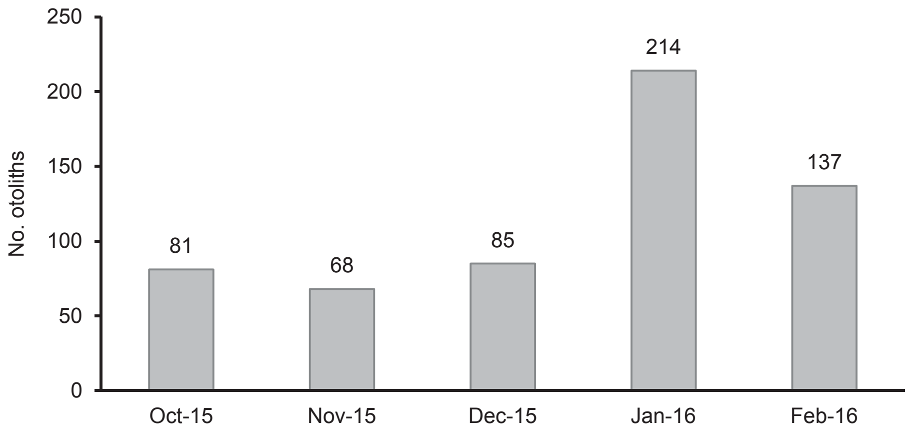

Figure 12: Numbers of otolith pairs collected by month from the SNA 8 bottom trawl fishery from October 2015 to February 2016.

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 2015–16 shows that although sporadic catches of snapper were made in the southern coastal regions of SNA 8, the majority of the catch (over 80%), as well as the sampled component (over 90%), was taken from coastal regions between Cape Maria van Diemen and Kawhia Harbour (Figures 1 and 13). With the exception of the North and South Taranaki Bight regions (principally Statistical Areas 037, 039–041), the sampled component was generally spread throughout areas where the commercial bottom trawl fishery operated in 2015–16, suggesting that sampled landings, by and large, are likely to be spatially representative of the SNA 8 fishery.

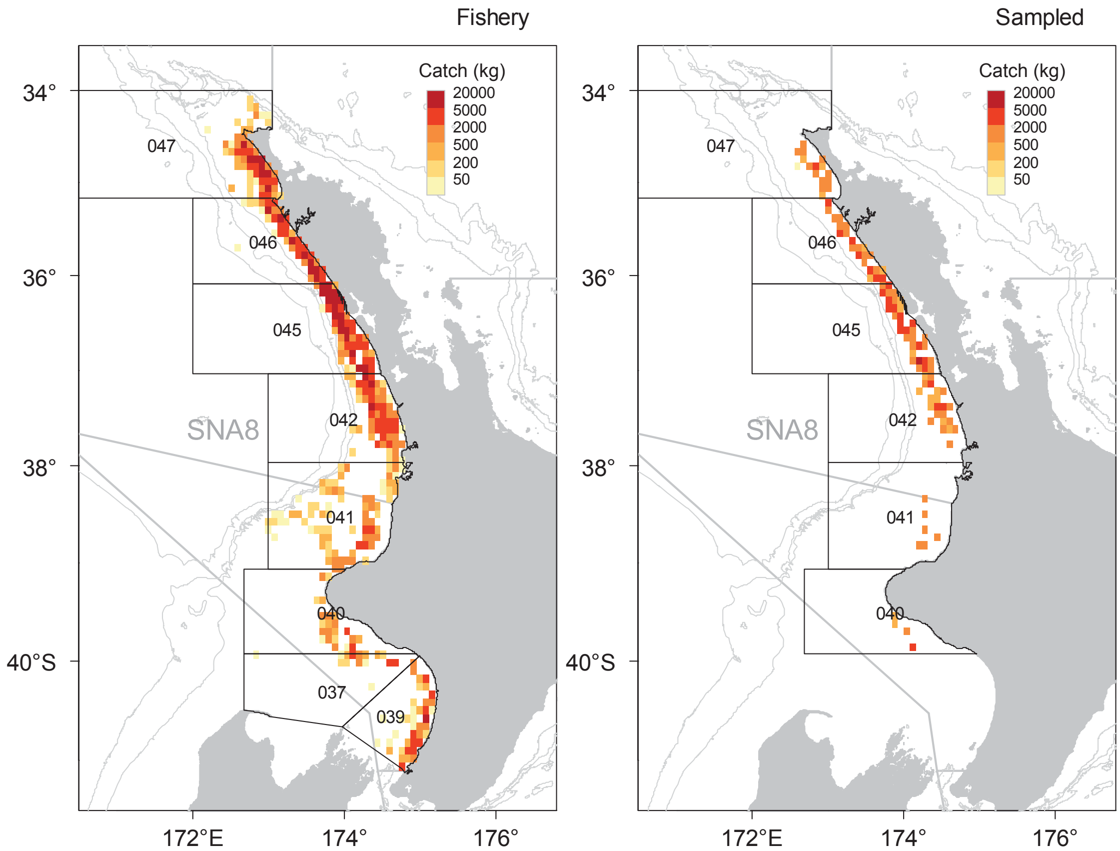

Figure 13: Comparison of the spatial distribution of the bottom trawl catch and the sampled component for the SNA 8 stock in 2015–16.

A comparison of the proportional distribution of the estimated bottom trawl catch of snapper with that sampled in 2015–16 for the statistical areas that make up SNA 8 is given in Figure 14. By far the greatest proportion of snapper caught by bottom trawl (over one-third) was from vessels fishing in Statistical Area 045 (coastal Kaipara Harbour region) with considerable catch also taken from adjacent statistical areas to the north (046–047) and south (042) (see Figures 13 and 14).

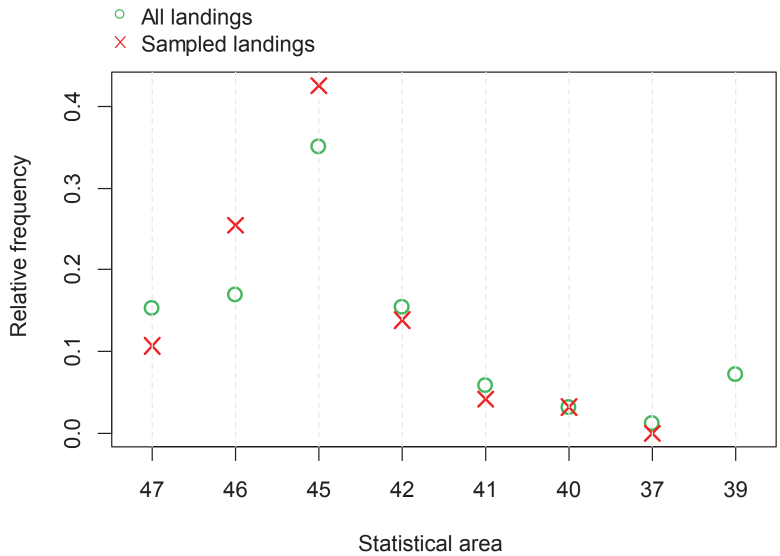

Figure 14: Comparison of the proportional distribution of the estimated bottom trawl catch and the sampled component by statistical area over the sampling period for the SNA 8 stock in 2015–16.

Over three-quarters of the total snapper catch in spring and summer 2015–16 was taken when trevally (*Pseudocaranx dentex*) was the target species, with snapper (10%) and red gurnard (*Chelidonichthys kumu*) (8%) targeted less frequently (Figure 15). 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.

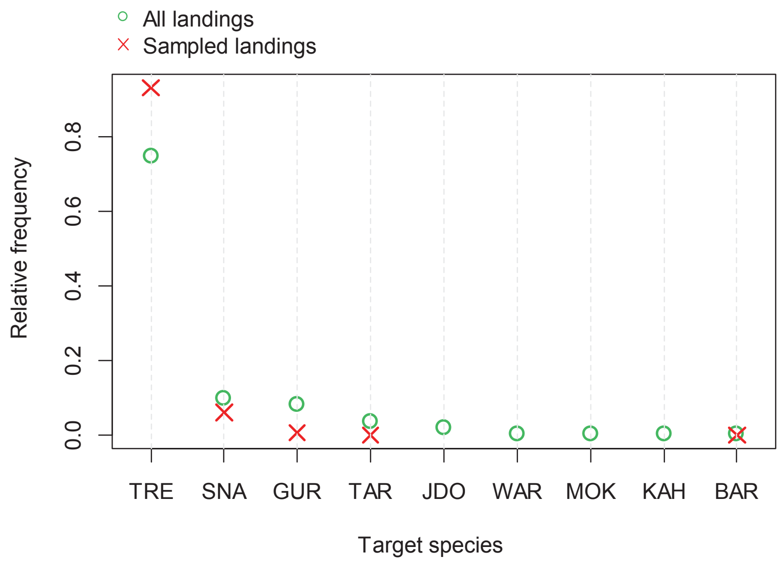

Figure 15: Comparison of the proportional distribution of the estimated bottom trawl catch and the sampled component by target species over the sampling period for the SNA 8 stock in 2015–16.

3.5 Otolith readings

Of the total 586 SNA 8 otolith samples collected in 2015–16, all but one pair of otoliths (being composed of vaterite) were successfully aged. Between-reader tests with graphical comparisons in Figure 16 indicate a high level of consistency between readers with only minor systematic differences (bias) evident in their first counts. The slight positive weighting of the histogram in Figure 16(a), the relative clustering of plotted points about the zero line in Figure 16(b), and the slight deviation from the one-to-one line on the age-bias plot for some of the older age classes (Figure 16(c)) indicate that the second reader slightly undercounted zones relative to the first reader. The overall percentage agreement between readers was 89.6%, and in only nine of the 585 readings (1.5%) did the readers disagree by more than 1 year. The between reader CV and IAPE were less than 1% (Figure 16(c)) and the profiles show that precision was high across almost all age classes (Figure 16(d)). Comparisons of the age-bias plots for reader 1 and 2 with the agreed age show that overall agreement was excellent (99.7 and 89.9%) and precision high with CV and IAPE estimates less than 1% (Figures 16(e) and (f)).

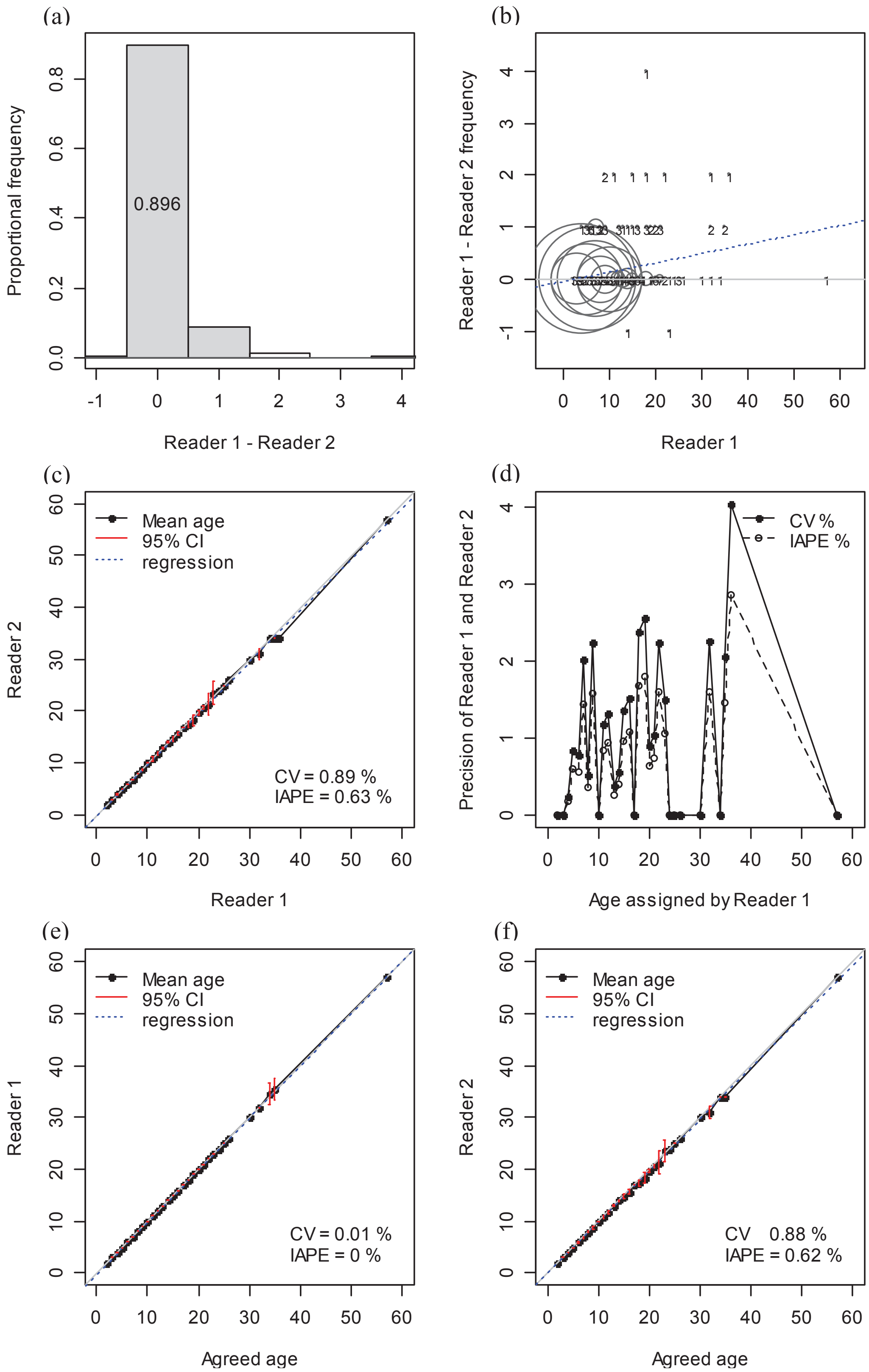

Figure 16: Results of between-reader comparison test (reader 1 and 2) for SNA 8 otoliths collected in 2015–16 (*n* 585): (a) histogram of differences between readings for the same otolith; (b) differences between readers for a given age assigned by reader 1; (c) bias plot between readers; (d) CV and 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).

3.6 Length and age distributions

The 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.

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

Stratifying the length data by season made little difference, as the unstratified and stratified distributions were essentially identical (due to similar proportionality of weighting over spring and summer) characterised by a single mode centred at 35 cm and a tail extending to over 55 cm (Figure 17, Appendix 4). As a result, mean lengths of snapper sampled from the fishery were the same at 36.6 cm, with proportion at length MWCVs differing slightly at 0.17 and 0.15 respectively.

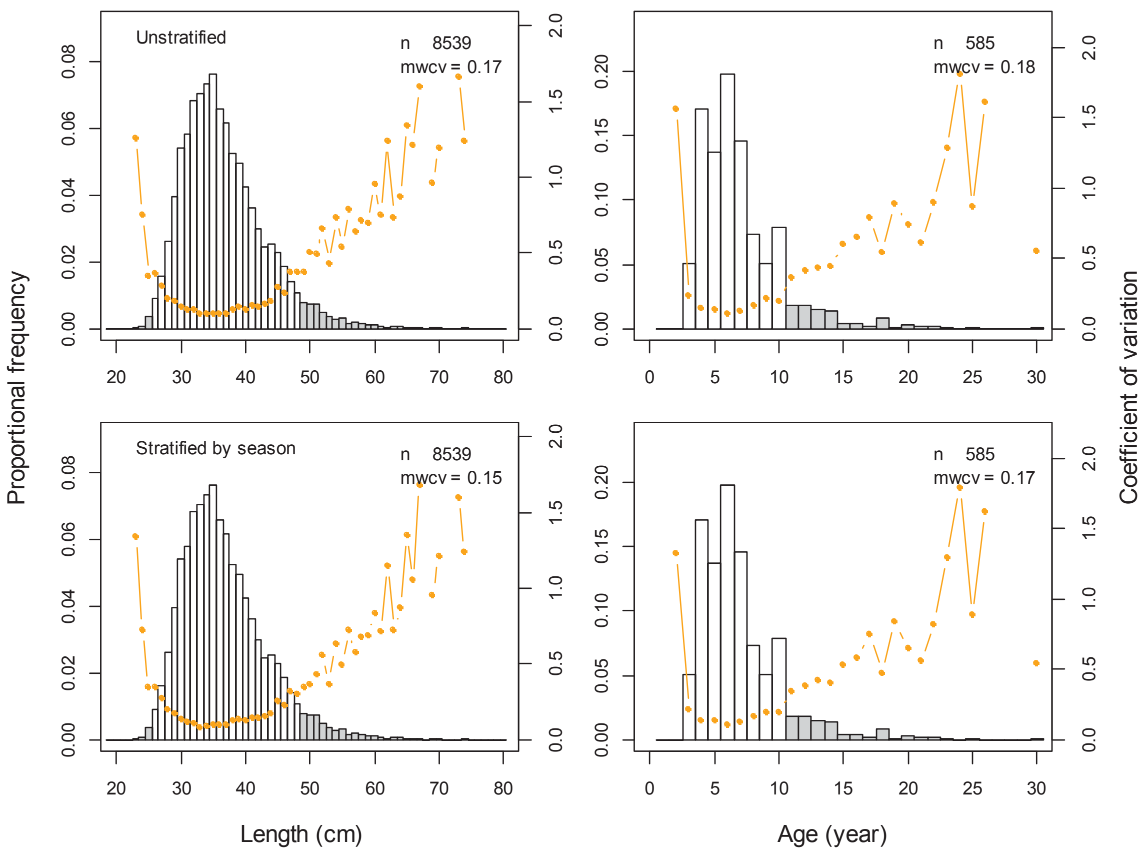

Figure 17: Unstratified (top) and seasonally stratified (bottom) proportions at length and age distributions (histograms) and bootstrap CVs (lines) determined from snapper landings sampled from the SNA 8 bottom trawl fishery in 2015–16 using the length frequency and age-length key approach (*n*, sample size; MWCV, mean weighted CV).

The corresponding unstratified and stratified age distributions were also essentially identical and dominated by young to moderate aged snapper 3 to 10 years, comprising 90% of the total number landed (Figure 17, Appendix 5). The 2010 year class (6-year-olds) was the most dominant in the fishery accounting for one in every five fish landed, followed closely by the 2012 year class (4-year-olds). The 2002 to 2005 year classes (11- to 14-year-olds) of similar relative strength and occupying the mid-age range of the distribution collectively make up around 7% of the catch. Despite representing a total of 38 fish (6.5%) in the age-length key collection, snapper 20 years or older made up just 1% of the overall catch by number in 2015–16, reflecting the low number of fish of this age range (Appendix 6). The oldest fish sampled from the SNA 8 fishery over spring and summer 2015–16 was 57 years (Appendix 3).

The 2011 year class (5-year-olds) appears fully recruited as it contains no fish under 28 cm, unlike the 2013 and 2012 year classes (3- and 4-year-olds) (see Appendix 2). Based on relative proportions in the 2015–16 catch-at-age distribution, the 2013 year class appears to be of average strength making up about 5% of the catch. The mean ages of snapper from the spring-summer bottom trawl fishery were the same (6.9 years) for the unstratified and stratified approaches, respectively, and the catch-at-age MWCVs differed slightly at 0.18 and 0.17 (Figure 17).

Minor temporal differences were evident in seasonal length and age distributions with spring samples comprising a higher proportion of large and old fish compared to summer samples, which contained slightly more small young fish (Figures 18 and 19, Appendices 4 and 5). The mean length and age of snapper landed over the spring period was 37.4 cm and 7.3 years, and during summer, 36.2 cm and 6.7 years. Seasonal catch-at-length and -age MWCVs ranged between 0.16 and 0.33.

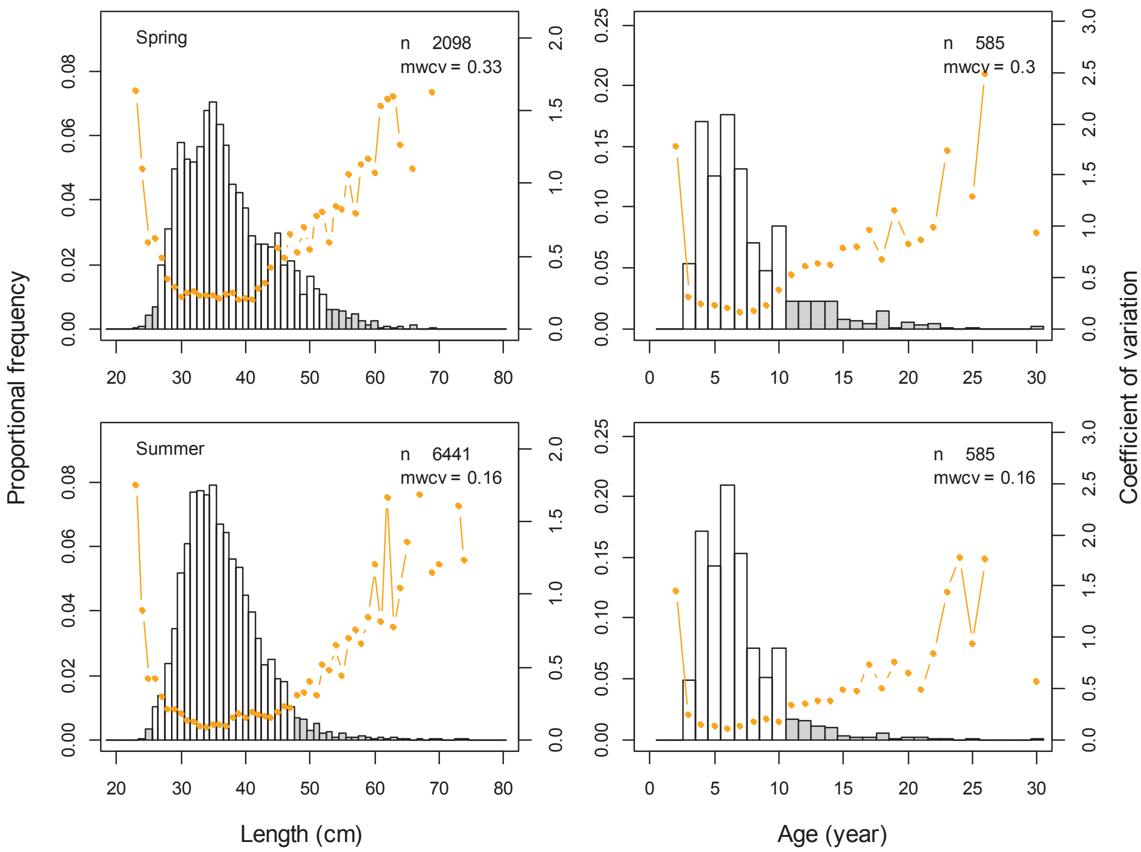

Figure 18: Seasonal proportions at length and age distributions (histograms) and bootstrap CVs (lines) determined from snapper landings sampled from the SNA 8 bottom trawl fishery in spring (top) and summer (bottom) 2015–16 using the length frequency and age-length key approach (*n*, sample size; MWCV, mean weighted CV).

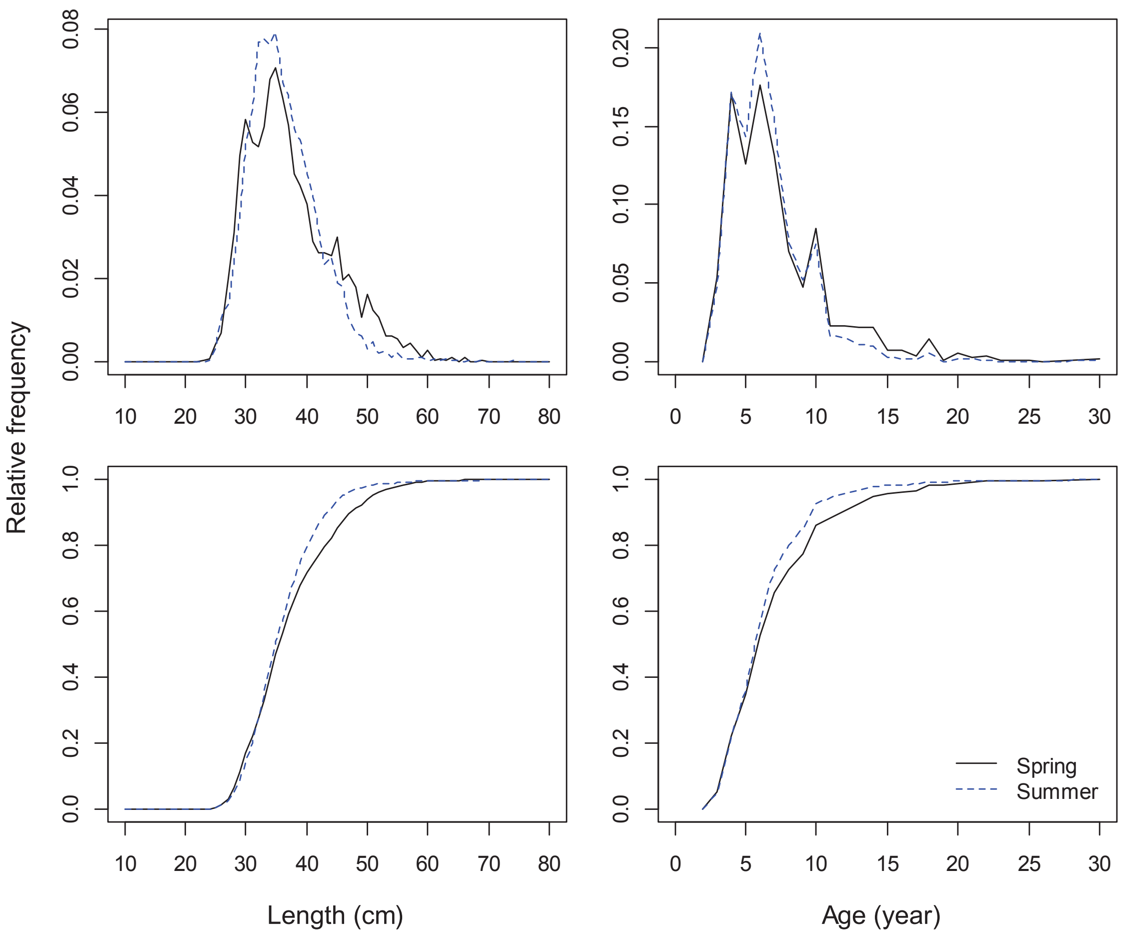

Figure 19: Comparison of the proportion and cumulative proportion at length and age distributions determined from snapper landings sampled over the spring and summer seasons from the SNA 8 bottom trawl fishery in 2015–16.

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

With the exception of a few of the older age groups, a trend of increasing mean length-at-age and mean weight-at-age over successive age classes was generally evident in data collected from the SNA 8 bottom trawl fishery in 2015–16 (Figure 20, Appendices 7 and 8). For 2–4 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.

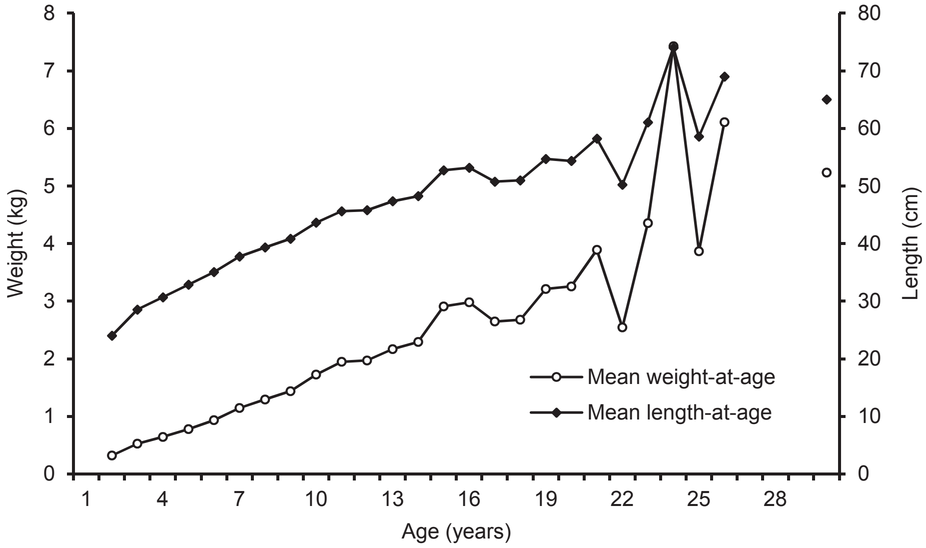

Figure 20: Observed mean weight-at-age and mean length-at-age estimates from snapper landings sampled from the SNA 8 bottom trawl fishery in 2015–16.

Mean length and mean age

Estimates of mean length and mean age for snapper sampled from the SNA 8 bottom trawl fishery between 1974–75 and 2015–16 are given in Figure 21 with estimates for the bottom pair trawl method collected over a similar period included for comparison. The bottom trawl mean length for snapper in 2015–16 was 36.6 cm and equal to the long-term mean estimated over the previous 27 years (since 1989–90), while mean age (6.9 years) was the highest estimate determined over the same period, where the long-term mean was one year less at 5.9 years (Figure 21).

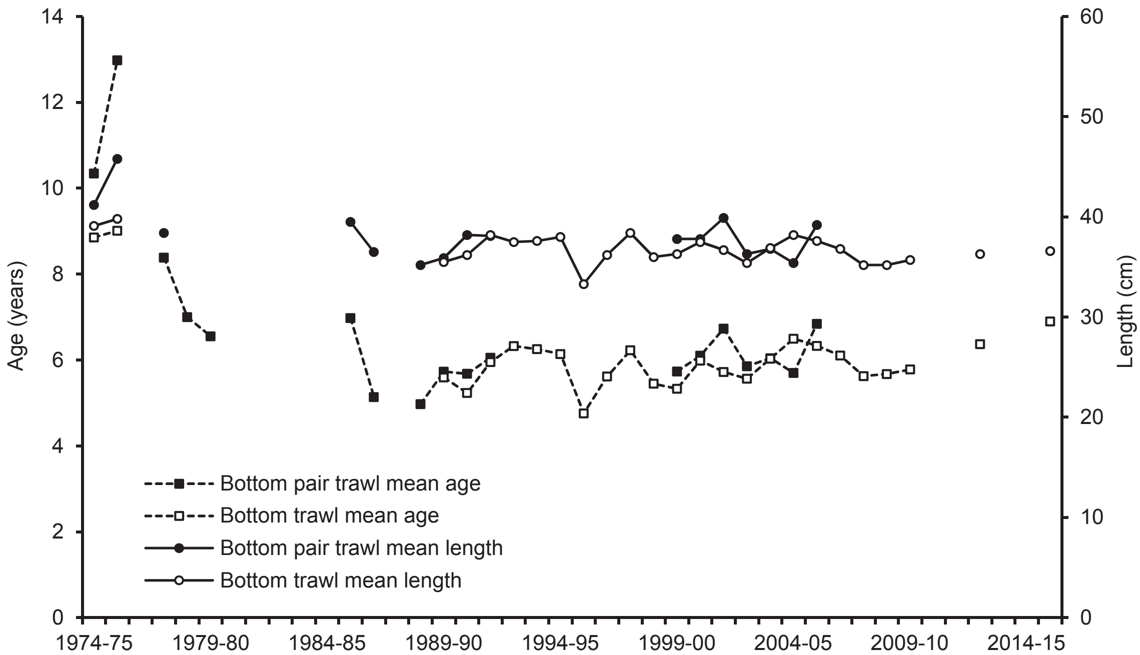

Figure 21: Time series of mean length and mean age estimates from the SNA 8 bottom trawl fishery (1974–75 to 2015–16). The 2012–13 and 2015–16 length and age estimates lie to the right hand side of the figure detached from the time series. Note: Mean estimates from the bottom pair trawl method (1974–75 to 2005–06) have been included for comparison purposes.

Mean weight-at-age time series

A time series comparison of mean weight-at-age estimates derived from sampling the SNA 8 bottom trawl fishery between 1990–91 and 2015–16 shows that although inter-annual variations may exist for snapper for the common age classes (i.e., 6–13 years old), the most recent estimates from 2012–13 and 2015–16 are some of the lowest recorded and indicative of a decline in growth rate since sampling began in 1990–91 (Figures 22 and 23). Annual mean weight-at-age estimates for many of the older age classes (i.e., over 13 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 22).

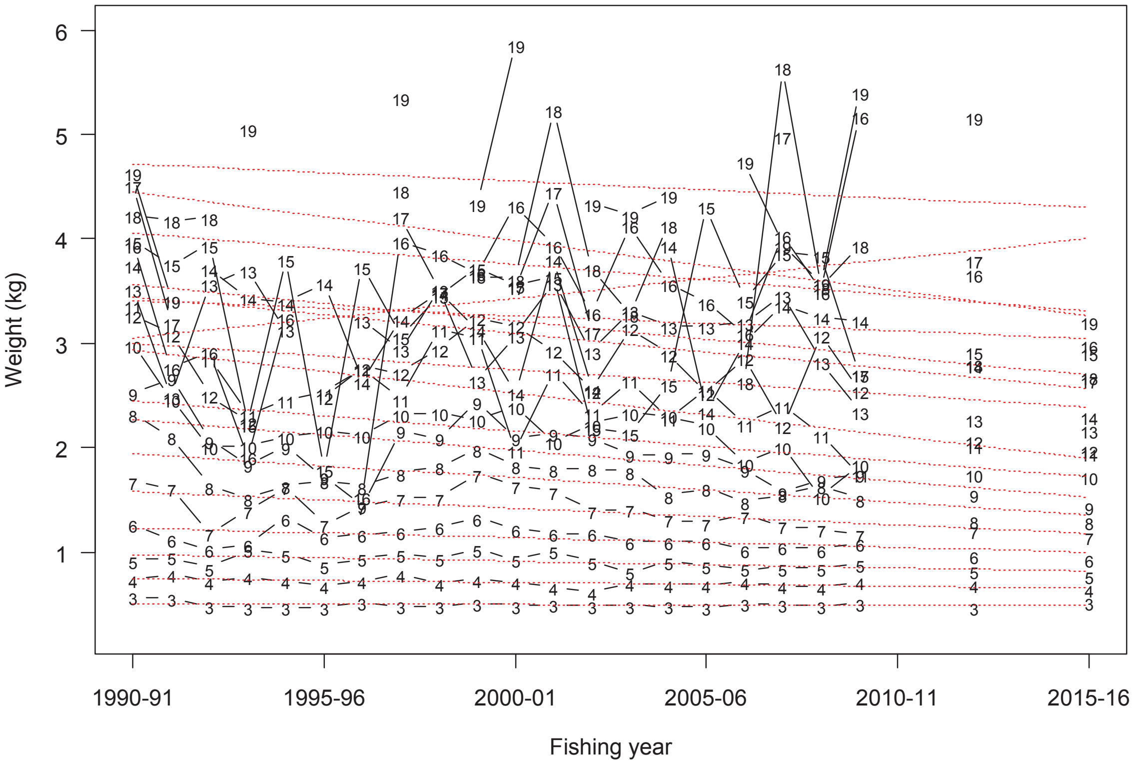

Figure 22: Mean weight-at-age estimates for 3 to >19 year old snapper sampled from the SNA 8 bottom trawl fishery between 1990–91 and 2015–16 with fitted trend lines (dotted red) for each age class depicting long-term changes in growth rates over the 26 year period. Note: No estimates were available for 2010–11 to 2011–12 and 2013–14 to 2014–15 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 2015–16, show the decrease in mean weight-at-age to be considerable in recent years, and most apparent for the common age classes, 4–14 years old. The difference in mean weight-at-age between the first and last time periods (1990s, 2015–16) indicates the overall net weight loss/gain to the fishery, estimated at around -20% to -30% for most of the common age classes in SNA 8 (Figure 23).

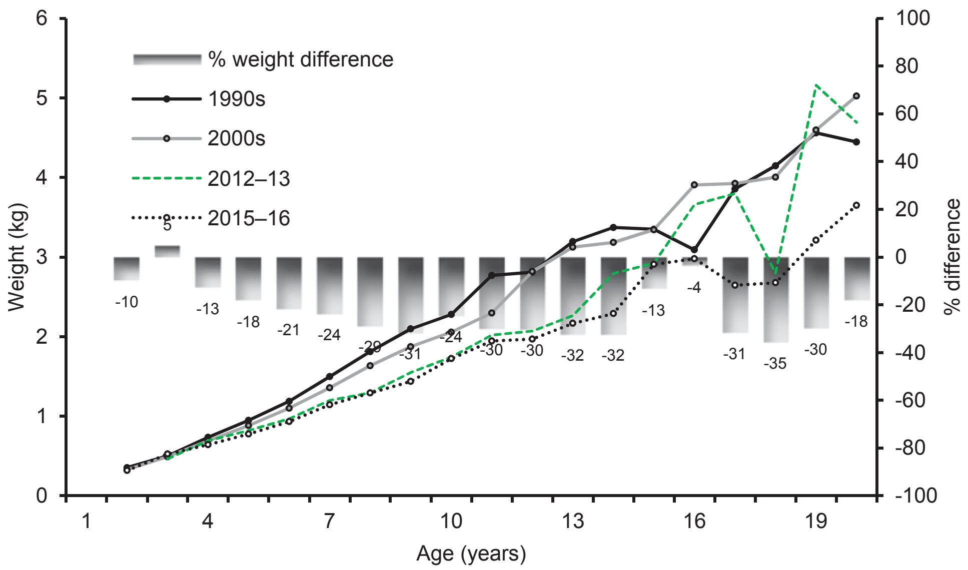

Figure 23: Mean weight-at-age estimates for snapper sampled from the SNA 8 bottom trawl fishery from two distinct time periods (1990s and 2000s) and from the current sampling year 2015–16, and where each period reflects the average mean weight-at-age for those years. The percentage weight difference for each age class (positive or negative) is the difference between the first time period, 1990, and 2015–16, and indicative of a net weight gain or loss in mean weight-at-age through time. For comparison purposes, mean weight-at-age estimates from 2012–13, are also included.

4. DISCUSSION

In recent years, comparisons of SNA 8 age compositions (Walsh et al. 2006a, 2009a, 2011b) have suggested that only moderate change had occurred in the fishery since the introduction of the Quota Management System (QMS) in 1986, the age structure 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), indicating the stock to be between 8% and 12% of the unfished equilibrium biomass, B_0. In October 2005, the SNA 8 TACC was reduced from 1500 t to 1300 t to rebuild the stock (Ministry for Primary Industries 2016), and recent catch sampling in 2012–13 (Walsh et al. 2014c) indicated a slow but consistent rebuild may be underway as a direct result (e.g. broadening age composition, increasing mean age, and slowing growth rate). Three years later, in the current study, 2015–16, these same effects were again evident. 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 reliable and should be interpreted with caution. Only a tagging programme to estimate stock biomass would ultimately clarify this uncertainty.

Catch samples from 2015–16 provide the second opportunity to view the age composition of the SNA 8 fishery since 2009–10, when triennial sampling was first adopted. Bottom trawl landings in spring-summer 2015–16 were dominated by young to moderate aged snapper 3 to 10 years, and collectively make up over 90% of the total number landed. The age composition has continued to broaden slightly from that last described in 2012–13 (Walsh et al. 2014c) with the progression of a number of strong year classes (i.e., 2010, 2009, 2006) still evident the in 2015–16 catch, now at an age of 6, 7 and 10 years respectively (see Appendices 9 and 10). As a result, the mean age of snapper landed by bottom trawl in 2015–16 has increased to 6.9 years, the highest recorded estimate since 1989–90, a period spanning 27 years (see Figure 21, Appendix 9), suggesting continued improvement in the status of the fishery from that seen three years ago. Nevertheless, the combined total of old fish in SNA 8 (i.e., those 15 years and older) has continued to remain low over the same period and is unlikely to improve until the strong year classes grow older and broaden the right hand limb of the age distribution (see Appendices 9 and 10).

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. For example, 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 it was confirmed to be one of the strongest year classes to recruit into the SNA 8 fishery in that decade and important for the short term sustainability and rebuild of the stock (Walsh et al. 2011b). By 2012–13, the 2006 year class (7-year-olds) accounted for one in every five fish landed (Walsh et al. 2014c) and over subsequent years has remained above average strength, not only broadening the age composition but contributing to about 8% of the catch by number as 10-year-olds in 2015–16 (see Appendices 9 and 10). Most important, however, is the contribution it now makes to the fishery in terms of weight. With an average individual size of about 44 cm and weight of about 1.7 kg (see Appendices 7 and 8), snapper from the 2006 year class are about half as heavy again as the average fish (36.6 cm, 1.1 kg) caught by bottom trawl in 2015–16. Although the dominance of other strong year classes that have been identified 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

Using the time series of catch sampling data available from SNA 8, Walsh et al. (2014c) documented temporal trends in the growth rates of snapper by comparing changes in mean weight-at-age for the common age classes over time. They found growth rates for snapper sampled during the 1990s to be some of the fastest in New Zealand, which steadily declined during the mid-2000s. However, it was catch sampling data from 2012–13 that indicated that the most obvious decline in growth rate in SNA 8 had occurred, attributed to compensatory density dependence (Rose et al. 2001) as the SNA 8 stock biomass increased, rather than temperature related effects or bias associated with sampling design or fishing method selectivity (Walsh et al. 2014c).

Catch sample collections from 2015–16 have continued to demonstrate the same trends that were evident in 2012–13 (Walsh et al. 2014c). The mean age (6.9 years) of snapper in SNA 8 is the now the highest estimate since 1989–90, while mean length (36.6 cm) remains relatively unchanged and equal to the long term mean, indicating a slowing in growth (see Figure 21). A slower rate of recruitment of younger age classes into the fishery because of slow growth, coupled with a lower exploitation rate compared to past years (due to a TACC reduction in 2005) may have enabled west coast snapper to attain a greater average age, albeit at a relatively constant size. Although variation in mean weight-at-age can occur over time, estimates for the common age classes (i.e., 4–14 years) in 2015–16 are now consistently some of the lowest ever recorded (see Figures 22 and 23). Furthermore, although the difference may be marginal in comparison to estimates determined in 2012–13, they are consistently lower across all age classes, meaning that growth rates have continued to decline over the past three years. Lastly, just as a slowing in snapper growth rates was evident in the incremental deposition of otoliths aged in 2012–13, the same noticeable narrowing of zones close to the otolith margin was common in otolith samples collected in 2015–16, meaning that somatic growth in some fish had obviously slowed.

Walsh et al. (2014c) postulated that 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 would suggest that there had been a decrease in productivity in the stock, correlated with a gradual increase in stock size. This would mean that the fishery was likely to land more snapper now than it did 10–20 years ago to achieve the same catch weight, an effect unlikely to improve, given that growth rates in 2015–16 appear to be the slowest documented for SNA 8 in almost three decades. Similar density dependent growth trends in relation to changes in biomass have been recently documented for the Hauraki Gulf and Bay of Plenty sub-stocks of SNA 1 (Walsh et al. 2011a, 2011c, 2014b).

Vessel selectivity or spatiotemporal heterogeneous effects?

In the most recent stock assessment of the TRE 7 fishery, principally the same area as SNA 8, Langley et al. (2015) found that one bottom trawl vessel, VesselX, had increasingly dominated the annual TRE 7 catch since 1999–2000 and caught larger (and older) trevally than the other core vessels in the fleet, suggesting different selectivity patterns for length and age. Following similar recommendations for future sampling of TRE 7 by Langley et al. (2015), the sampling design for SNA 8 ensured that VesselX was allocated landings roughly in proportion to its recent historical SNA 8 catch, with a total of seven landings being sampled during spring-summer 2015–16. A comparison of the combined length distributions from VesselX samples with those sampled from other SNA 8 vessels in 2015–16 found that VesselX landings comprised proportionally more large fish, suggesting that slight differences in selectivity for snapper may exist for VesselX (Appendix 12). The mean length of snapper landed by VesselX over the spring-summer period was larger (37.3 cm) than the mean of all other vessels (35.8 cm). Nevertheless, past research has also indicated that spatiotemporal heterogeneity in the stock length composition (and therefore age) may also be a contributing factor, where the broadest length distributions and highest estimates of mean length often come from large catches made off the Kaipara and Manukau Harbours during spring (Reid 1969, Walsh et al. 2006c, 2009a, 2009b, 2011b, 2014c). In 2015–16, VesselX contributed to three of the four sampled spring landings, which were individually the first, second and fourth largest over all landings sampled. Spring samples comprised proportionally more large snapper than summer samples (see Figure 19) with mean length estimates (37.4 and 36.2 cm respectively) closely aligned with the means outlined above for VesselX and all other vessels. It therefore remains unclear whether the reason why VesselX tended to catch larger fish, was because of its selectivity, or due to spatiotemporal heterogeneity in the length composition of the fishery, or a combination of both.

Previous catch sampling data from SNA 8 (Sullivan Gilbert 1978) and SNA 2 (Walsh et al. 2012) clearly indicates that bottom trawling 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 2015–16. Given current average fish size over spring-summer (36.6 cm, 1.1 kg) coupled with a diminishing growth rate, and the paucity of large and old snapper in the commercial fishery, or at least spatially where it operates, this is unlikely to change for some years. In the absence of large fish, snapper may be equally vulnerable to the selectivity of all vessels in the fleet, including VesselX. This finding would be similar to that in past years, when comparisons were made between the length and age compositions of sampled bottom trawl and bottom pair trawl landings (Walsh et al. 2001, 2002, 2004, 2006b, Walsh & Davies 2004).

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, and when fish aggregate for spawning (Davies et al. 2013). In 2015–16 approximately 59% of the TACC was taken during spring-summer. The decline in SNA 8 landings in recent years during spring-summer was 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 in 2015–16, with snapper the principal target in 10% of fishing events, likely to be the lowest recorded estimate since the introduction of the Quota Management System in 1986 (see Figure 15). Bottom trawl remains the dominant fishing method, as it has been for over a decade, and the fact that three-quarters of the total landed SNA 8 catch in 2015–16 was taken by bottom trawl from the northern half of the stock, suggests that a good proportion of the stock biomass continues to reside there. This area was the most heavily fished in the past (Reid 1969) and is still considered the main area to catch snapper commercially today. Nevertheless, in 2012–13, Walsh et al. (2014c) reported that anecdotal information from the commercial and recreational sectors suggested considerable improvement throughout the entire SNA 8 fishery in recent years and postulated that greater spatial dispersion of the stock had occurred due to increased abundance, particularly the lower half of SNA 8 (Statistical Areas 037–041). 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 larger and older fish should commercial fishing pressure continue to remain low and recreational fishing effort stable. Again, a tagging programme to estimate stock biomass would ultimately clarify such uncertainties.

Precision in catch-at-age

It is expected that samples used here to derive proportional length and age distributions are adequate and representative descriptions of commercial bottom trawl landings from SNA 8 in 2015–16, and should therefore be comparable to those collections from past years. The MWCV (bootstrap estimates) for the combined spring-summer length and age distributions sampled from the SNA 8 bottom trawl fishery in 2015–16 ranged between 0.15 and 0.18. 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

We thank Dave Fisher, Colin Sutton, Fred Wei at NIWA for their prompt and efficient handling and storage of data and the Ministry for Primary Industries for the provision of data from the catch effort return system. Funding for this project, SNA2015/01, was provided by the Ministry for Primary Industries. Trident Systems coordinated and arranged the catch sampling events and managed sample collections. Thanks also to Keren Spong who helped out at short notice with otolith preparation and to Bruce Hartill (NIWA) for reviewing the report and providing some helpful comments.

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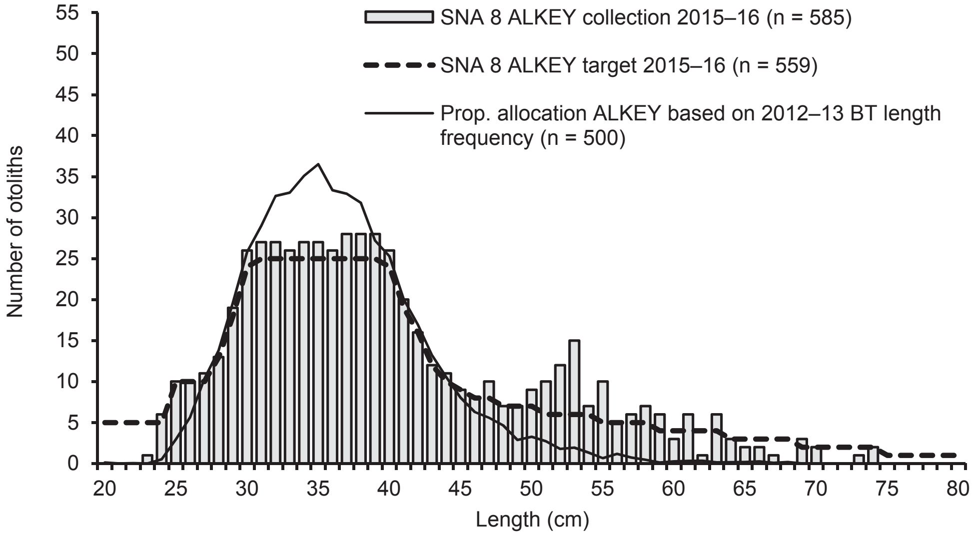
7. APPENDICES

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 2015–16. For comparison, the proportional allocation otolith sample of 500 fish based on the bottom trawl length distribution from 2012–13, the previous fishing year in which catch sampling was undertaken in SNA 8, is also given (solid line).

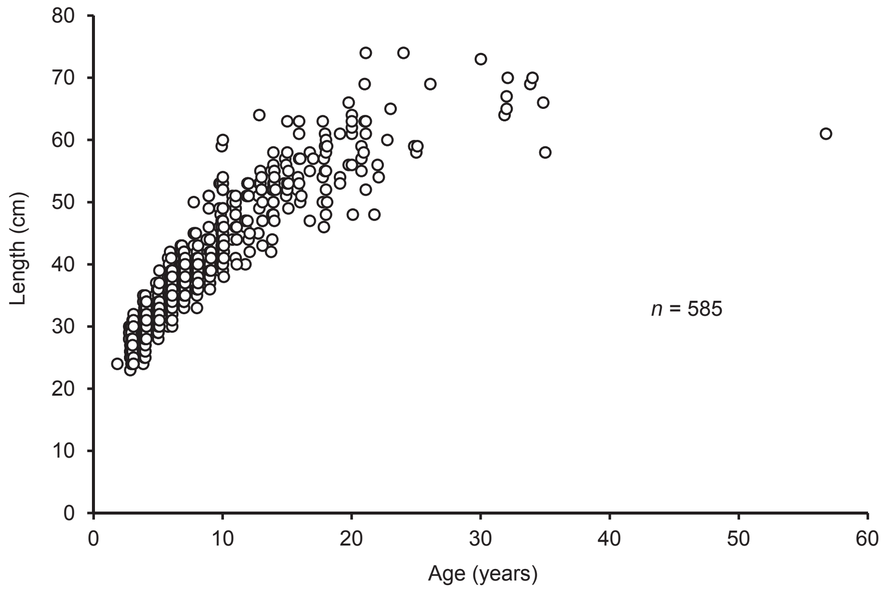


Appendix 2: Age-length key derived from snapper otolith samples collected from SNA 8 in 2015–16.

Estimates of proportion of age at length for snapper sampled from SNA 8, spring and summer 2015–16 (Note: Aged to 01/01/2016).

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	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
24	0	0.17	0.67	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
25	0	0	0.60	0.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
26	0	0	0.70	0.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
27	0	0	0.45	0.55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
28	0	0	0.31	0.62	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
29	0	0	0.16	0.63	0.21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19
30	0	0	0.19	0.54	0.19	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26
31	0	0	0.11	0.37	0.33	0.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27
32	0	0	0.04	0.41	0.22	0.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27
33	0	0	0	0.27	0.38	0.27	0.04	0.04	0	0	0	0	0	0	0	0	0	0	0	0	26
34	0	0	0	0.19	0.37	0.30	0.15	0	0	0	0	0	0	0	0	0	0	0	0	0	27
35	0	0	0	0.07	0.15	0.52	0.22	0.04	0	0	0	0	0	0	0	0	0	0	0	0	27
36	0	0	0	0	0.15	0.35	0.27	0.19	0.04	0	0	0	0	0	0	0	0	0	0	0	26
37	0	0	0	0	0.07	0.39	0.32	0.07	0.14	0	0	0	0	0	0	0	0	0	0	0	28
38	0	0	0	0	0.00	0.32	0.46	0.14	0.04	0.04	0	0	0	0	0	0	0	0	0	0	28
39	0	0	0	0	0.04	0.18	0.39	0.14	0.18	0.07	0	0	0	0	0	0	0	0	0	0	28
40	0	0	0	0	0	0.04	0.35	0.35	0.08	0.12	0.04	0.04	0	0	0	0	0	0	0	0	26
41	0	0	0	0	0	0.10	0.15	0.20	0.15	0.35	0.05	0	0	0	0	0	0	0	0	0	20
42	0	0	0	0	0	0.06	0.25	0.06	0.19	0.31	0	0.06	0	0.06	0	0	0	0	0	0	16
43	0	0	0	0	0	0	0.25	0.17	0.08	0.42	0	0	0.08	0	0	0	0	0	0	0	12
44	0	0	0	0	0	0	0	0	0.27	0.36	0.18	0.09	0	0.09	0	0	0	0	0	0	11
45	0	0	0	0	0	0	0	0.33	0	0.33	0	0.11	0.22	0	0	0	0	0	0	0	9
46	0	0	0	0	0	0	0	0	0.13	0.38	0.25	0.13	0	0	0	0	0	0.13	0	0	8
47	0	0	0	0	0	0	0	0	0	0.30	0	0.30	0.20	0.10	0	0	0.10	0	0	0	10
48	0	0	0	0	0	0	0	0	0	0.14	0.14	0	0	0.29	0	0	0	0.14	0	0.29	7
49	0	0	0	0	0	0	0	0	0.14	0.43	0.14	0	0.14	0	0.14	0	0	0	0	0	7
50	0	0	0	0	0	0	0	0.11	0	0	0.22	0	0.11	0.22	0	0.11	0	0.22	0	0	9
51	0	0	0	0	0	0	0	0	0.20	0	0.20	0.30	0.10	0	0.10	0.10	0	0	0	0	10
52	0	0	0	0	0	0	0	0	0	0.25	0	0	0.17	0.25	0.08	0.08	0	0.08	0	0.08	12
53	0	0	0	0	0	0	0	0	0	0.20	0	0.20	0.13	0.13	0.20	0.07	0	0	0.07	0	15
54	0	0	0	0	0	0	0	0	0	0.14	0	0	0.14	0.14	0	0.14	0	0.14	0.14	0.14	7
55	0	0	0	0	0	0	0	0	0	0	0	0	0.10	0.30	0.10	0	0.10	0.30	0	0.10	10
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0.20	0.20	0	0	0	0	0.60	5
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.17	0.33	0.17	0.17	0	0.17	6
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0.14	0.14	0	0.14	0.14	0	0.43	7
59	0	0	0	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0	0.33	0	0.50	6
60	0	0	0	0	0	0	0	0	0	0.33	0	0	0	0	0	0	0	0.33	0	0.33	3
61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.17	0	0.17	0.17	0.50	6
62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	1
63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.17	0.17	0	0.17	0	0.50	6
64	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0	0	0	0	0	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	2
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	2
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	3
70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	2
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	1.00	2
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																					585

Appendix 3: Scatterplot of age-at-length data for snapper sampled from the SNA 8 bottom trawl fishery in 2015–16 (*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 2015–16.

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

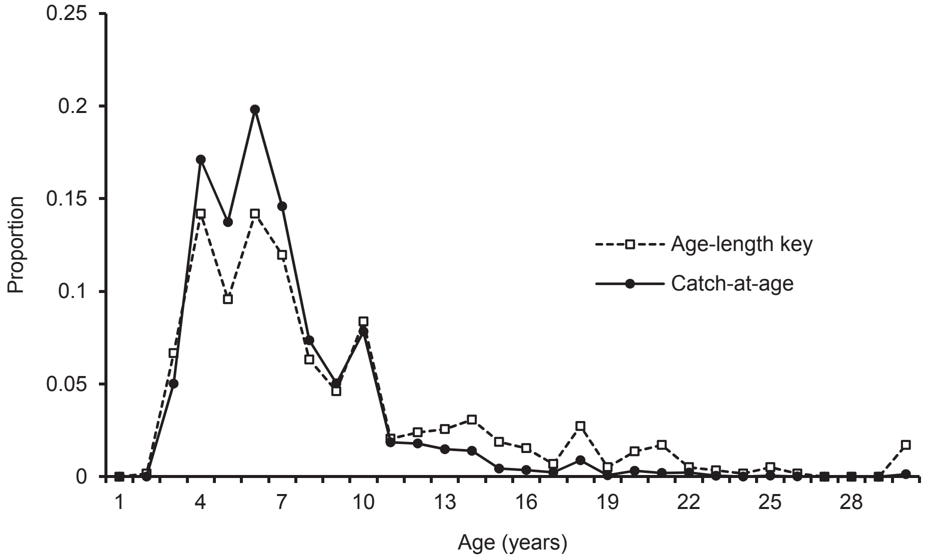
Length	Spring		Summer		Spr-sum (unstratified)		Spr-sum (stratified)	
(cm)	*P.i.*	CV	*P.i.*	CV	*P.i.*	CV	*P.i.*	CV
20	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
21	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
22	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
23	0.0005	1.63	0.0001	1.75	0.0002	1.31	0.0002	1.34
24	0.0008	1.10	0.0004	0.89	0.0005	0.72	0.0005	0.72
25	0.0042	0.59	0.0035	0.42	0.0037	0.35	0.0037	0.35
26	0.0068	0.62	0.0104	0.42	0.0092	0.36	0.0092	0.35
27	0.0200	0.49	0.0138	0.30	0.0159	0.27	0.0160	0.27
28	0.0311	0.34	0.0238	0.21	0.0263	0.20	0.0263	0.20
29	0.0495	0.29	0.0346	0.21	0.0397	0.18	0.0398	0.18
30	0.0582	0.21	0.0519	0.18	0.0540	0.14	0.0541	0.14
31	0.0529	0.24	0.0609	0.14	0.0582	0.12	0.0581	0.12
32	0.0518	0.26	0.0770	0.12	0.0684	0.12	0.0683	0.11
33	0.0568	0.23	0.0777	0.09	0.0706	0.10	0.0705	0.08
34	0.0679	0.23	0.0762	0.08	0.0734	0.10	0.0733	0.09
35	0.0706	0.23	0.0793	0.10	0.0763	0.10	0.0763	0.10
36	0.0635	0.21	0.0673	0.11	0.0660	0.10	0.0660	0.10
37	0.0571	0.24	0.0644	0.09	0.0619	0.10	0.0619	0.09
38	0.0451	0.24	0.0563	0.15	0.0525	0.13	0.0524	0.12
39	0.0423	0.20	0.0536	0.18	0.0498	0.15	0.0497	0.14
40	0.0378	0.21	0.0452	0.15	0.0427	0.13	0.0427	0.12
41	0.0289	0.19	0.0398	0.19	0.0361	0.15	0.0361	0.14
42	0.0264	0.27	0.0317	0.17	0.0299	0.14	0.0299	0.14
43	0.0263	0.32	0.0234	0.16	0.0244	0.15	0.0244	0.15
44	0.0256	0.42	0.0251	0.15	0.0253	0.17	0.0253	0.17
45	0.0300	0.55	0.0190	0.19	0.0227	0.28	0.0228	0.26
46	0.0197	0.49	0.0181	0.23	0.0186	0.24	0.0186	0.22
47	0.0211	0.65	0.0105	0.22	0.0141	0.37	0.0141	0.32
48	0.0180	0.53	0.0069	0.30	0.0107	0.37	0.0107	0.30
49	0.0108	0.70	0.0064	0.32	0.0079	0.37	0.0079	0.35
50	0.0164	0.54	0.0030	0.40	0.0075	0.49	0.0076	0.37
51	0.0126	0.77	0.0050	0.30	0.0076	0.49	0.0076	0.43
52	0.0108	0.80	0.0020	0.51	0.0050	0.66	0.0050	0.55
53	0.0062	0.59	0.0024	0.48	0.0037	0.41	0.0037	0.37
54	0.0062	0.84	0.0010	0.65	0.0027	0.73	0.0027	0.63
55	0.0057	0.83	0.0021	0.44	0.0033	0.53	0.0033	0.49
56	0.0033	1.06	0.0008	0.70	0.0017	0.79	0.0017	0.73
57	0.0046	0.79	0.0008	0.75	0.0021	0.66	0.0021	0.57
58	0.0027	1.12	0.0011	0.65	0.0016	0.69	0.0016	0.67
59	0.0010	1.17	0.0009	0.84	0.0009	0.67	0.0009	0.68
60	0.0027	1.07	0.0004	1.20	0.0012	0.95	0.0012	0.84
61	0.0005	1.53	0.0007	0.81	0.0007	0.74	0.0007	0.72
62	0.0007	1.58	0.0002	1.67	0.0004	1.18	0.0004	1.15
63	0.0005	1.60	0.0006	0.77	0.0006	0.73	0.0006	0.72
64	0.0010	1.27	0.0003	1.04	0.0005	0.90	0.0005	0.87
65	0.0000	0.00	0.0003	1.36	0.0002	1.32	0.0002	1.35
66	0.0011	1.10	0.0000	0.00	0.0004	1.19	0.0004	1.06
67	0.0000	0.00	0.0002	1.68	0.0002	1.65	0.0002	1.68
68	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00
69	0.0003	1.63	0.0004	1.15	0.0004	1.01	0.0004	0.96
70	0.0000	0.00	0.0002	1.21	0.0001	1.20	0.0001	1.21
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	0.0001	1.61	0.0001	1.62	0.0001	1.60
74	0.0000	0.00	0.0003	1.23	0.0002	1.20	0.0002	1.24
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	212 306		405 363		617 701			
n	2 098		6 441		8 539			

Appendix 5: Estimates of proportion at age with CVs (bootstrap estimates) for snapper from the SNA 8 bottom trawl fishery in 2015–16.

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

Age	Spring		Summer		Spr-sum (unstratified)		Spr-sum (stratified)		
(years)	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV	*P.j.*	CV	*n*
1	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	–
2	0.0001	1.78	0.0001	1.46	0.0001	1.46	0.0001	1.33	1
3	0.0538	0.31	0.0484	0.24	0.0502	0.22	0.0502	0.22	39
4	0.1703	0.24	0.1714	0.14	0.1710	0.14	0.1710	0.14	83
5	0.1259	0.23	0.1432	0.14	0.1374	0.14	0.1373	0.14	56
6	0.1760	0.20	0.2094	0.10	0.1981	0.11	0.1979	0.11	83
7	0.1316	0.16	0.1532	0.13	0.1459	0.13	0.1458	0.12	70
8	0.0703	0.18	0.0753	0.18	0.0736	0.17	0.0736	0.17	37
9	0.0477	0.23	0.0517	0.21	0.0504	0.21	0.0503	0.20	27
10	0.0844	0.37	0.0752	0.17	0.0783	0.19	0.0783	0.19	49
11	0.0228	0.53	0.0164	0.33	0.0185	0.37	0.0186	0.34	12
12	0.0226	0.60	0.0155	0.35	0.0179	0.40	0.0179	0.38	14
13	0.0221	0.64	0.0111	0.38	0.0148	0.43	0.0149	0.42	15
14	0.0220	0.62	0.0098	0.38	0.0140	0.42	0.0140	0.41	18
15	0.0074	0.79	0.0028	0.49	0.0044	0.58	0.0044	0.54	11
16	0.0070	0.80	0.0018	0.47	0.0036	0.63	0.0036	0.58	9
17	0.0038	0.96	0.0015	0.73	0.0023	0.80	0.0023	0.74	4
18	0.0147	0.67	0.0058	0.50	0.0088	0.53	0.0089	0.48	16
19	0.0014	1.15	0.0004	0.76	0.0007	0.90	0.0008	0.84	3
20	0.0056	0.82	0.0019	0.65	0.0032	0.68	0.0032	0.65	8
21	0.0032	0.86	0.0014	0.49	0.0020	0.54	0.0020	0.56	10
22	0.0041	0.99	0.0013	0.84	0.0022	0.95	0.0023	0.82	3
23	0.0009	1.73	0.0003	1.44	0.0005	1.38	0.0005	1.29	2
24	0.0000	0.00	0.0001	1.78	0.0001	1.73	0.0001	1.79	1
25	0.0007	1.29	0.0005	0.93	0.0005	0.86	0.0005	0.89	3
26	0.0001	2.49	0.0001	1.76	0.0001	1.64	0.0001	1.62	1
27	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	–
28	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	–
29	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	–
>29	0.0015	0.93	0.0012	0.57	0.0013	0.57	0.0013	0.54	10

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 2015–16.



Appendix 7: Estimates of mean length-at-age (cm) with CVs for snapper from the SNA 8 bottom trawl fishery in 2015–16.
CV, coefficient of variation

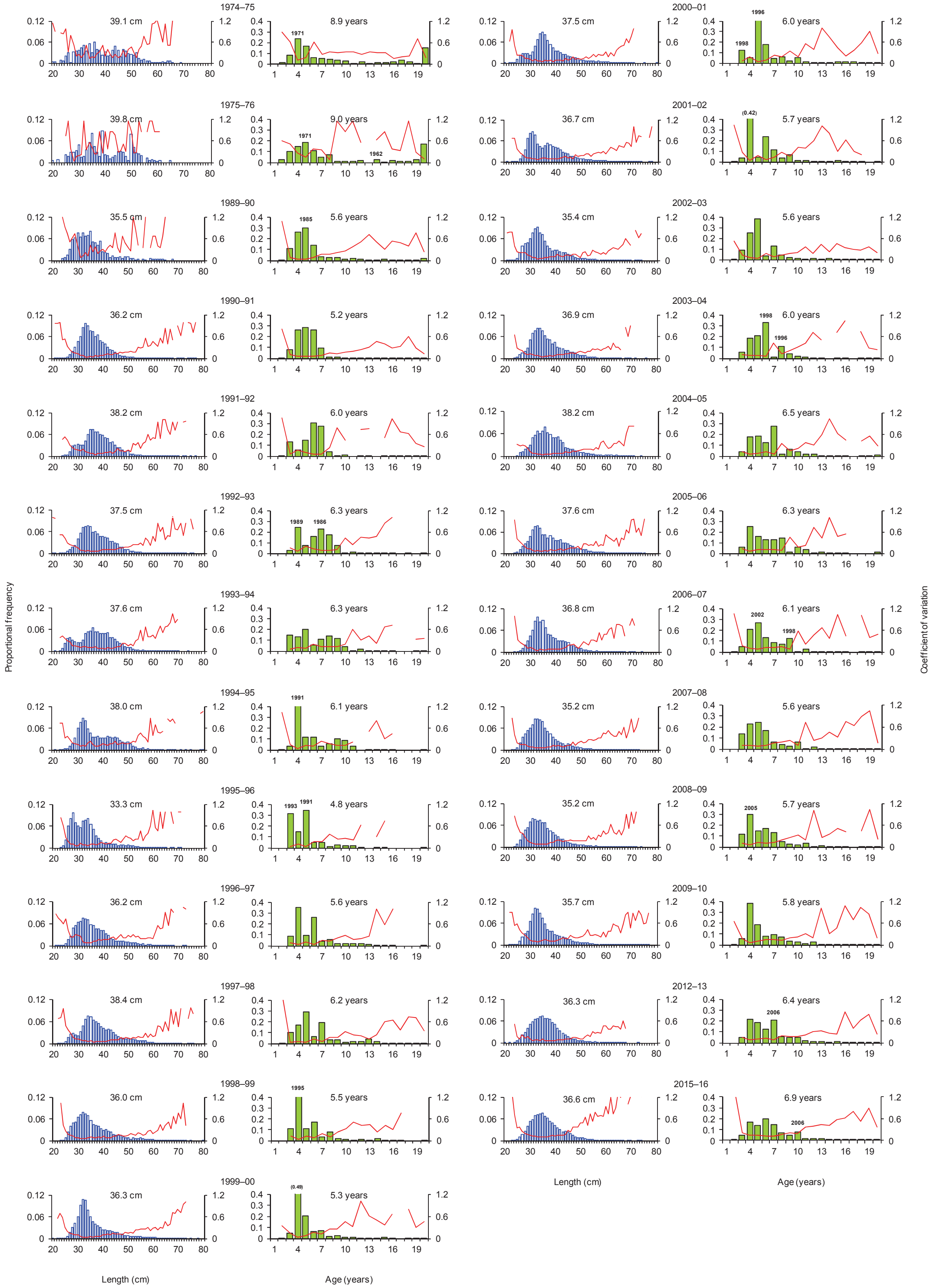
Length	Spring		Summer		Spr-sum (unstratified)		Spr-sum (stratified)	
(cm)	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	–	–	–	–	–	–	–	–
2	24.00	1.15	24.00	0.88	24.00	0.80	24.00	0.80
3	28.46	0.02	28.59	0.01	28.54	0.01	28.54	0.01
4	30.38	0.01	30.82	0.01	30.67	0.01	30.67	0.01
5	32.74	0.01	32.91	0.01	32.85	0.01	32.85	0.01
6	35.07	0.01	35.03	0.01	35.04	0.01	35.04	0.01
7	37.73	0.01	37.75	0.01	37.74	0.01	37.74	0.01
8	39.75	0.03	39.12	0.01	39.32	0.02	39.33	0.02
9	41.26	0.03	40.63	0.02	40.83	0.02	40.83	0.02
10	44.42	0.02	43.17	0.01	43.63	0.01	43.63	0.01
11	46.51	0.03	44.95	0.02	45.60	0.02	45.61	0.02
12	46.47	0.03	45.29	0.02	45.79	0.02	45.80	0.02
13	47.98	0.03	46.70	0.02	47.34	0.02	47.35	0.03
14	49.23	0.03	47.08	0.03	48.23	0.03	48.24	0.03
15	52.92	0.04	52.45	0.03	52.72	0.03	52.72	0.03
16	52.96	0.06	53.61	0.04	53.17	0.04	53.17	0.03
17	51.29	0.22	50.05	0.16	50.75	0.15	50.75	0.15
18	51.44	0.04	50.34	0.05	50.96	0.04	50.97	0.04
19	54.13	0.35	55.65	0.26	54.70	0.25	54.69	0.25
20	54.70	0.19	53.78	0.11	54.34	0.08	54.34	0.08
21	56.31	0.10	60.44	0.05	58.24	0.05	58.22	0.04
22	50.57	0.31	49.65	0.25	50.22	0.24	50.23	0.24
23	60.00	1.09	62.72	0.77	61.08	0.59	61.06	0.61
24	–	–	74.00	1.21	74.00	1.19	74.00	1.21
25	58.47	0.60	58.66	0.31	58.57	0.25	58.57	0.26
26	69.00	1.71	69.00	1.06	69.00	0.94	69.00	0.94
27	–	–	–	–	–	–	–	–
28	–	–	–	–	–	–	–	–
29	–	–	–	–	–	–	–	–
>29	63.45	0.26	66.01	0.06	65.04	0.06	65.02	0.06

Appendix 8: Estimates of mean weight-at-age (kg) with CVs for snapper from the SNA 8 bottom trawl fishery in 2015–16.

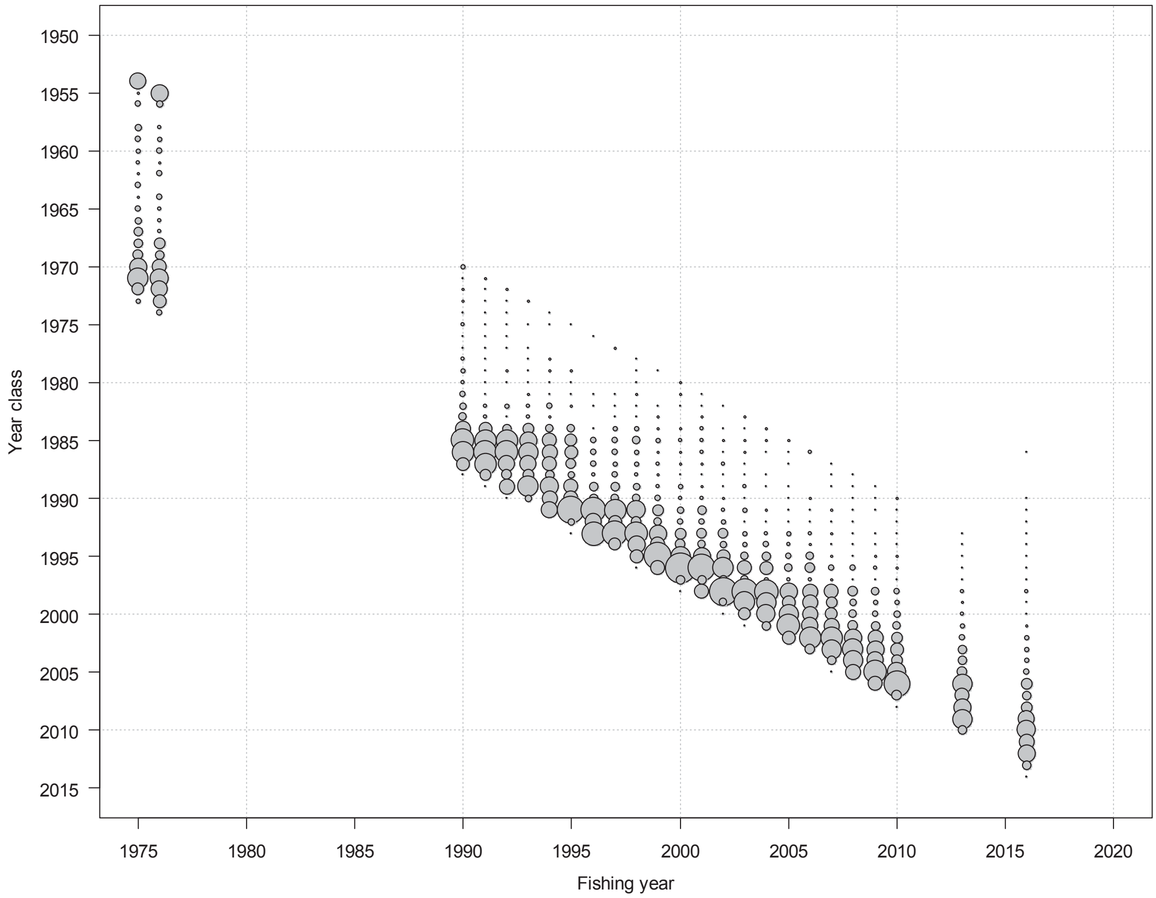
CV, coefficient of variation

Age	Spring		Summer		Spr-sum (unstratified)		Spr-sum (stratified)	
(years)	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	–	–	–	–	–	–	–	–
2	0.32	1.15	0.32	0.88	0.32	0.80	0.32	0.80
3	0.52	0.04	0.53	0.04	0.53	0.04	0.53	0.03
4	0.63	0.03	0.65	0.02	0.64	0.02	0.64	0.02
5	0.77	0.03	0.78	0.02	0.78	0.02	0.78	0.02
6	0.93	0.02	0.93	0.02	0.93	0.02	0.93	0.02
7	1.14	0.03	1.14	0.02	1.14	0.02	1.14	0.02
8	1.34	0.08	1.27	0.04	1.29	0.04	1.29	0.04
9	1.49	0.09	1.41	0.05	1.44	0.05	1.44	0.05
10	1.82	0.06	1.67	0.02	1.72	0.04	1.72	0.03
11	2.06	0.07	1.87	0.06	1.95	0.06	1.95	0.06
12	2.05	0.07	1.91	0.06	1.97	0.06	1.97	0.06
13	2.25	0.09	2.08	0.07	2.17	0.07	2.17	0.07
14	2.42	0.08	2.14	0.09	2.29	0.08	2.29	0.08
15	2.94	0.08	2.87	0.09	2.91	0.07	2.91	0.07
16	2.94	0.11	3.06	0.11	2.98	0.09	2.98	0.09
17	2.73	0.28	2.54	0.24	2.65	0.23	2.65	0.23
18	2.74	0.10	2.60	0.14	2.68	0.11	2.68	0.11
19	3.11	0.37	3.38	0.29	3.21	0.28	3.21	0.28
20	3.32	0.30	3.15	0.22	3.25	0.22	3.26	0.21
21	3.51	0.17	4.34	0.14	3.89	0.14	3.89	0.12
22	2.59	0.34	2.46	0.30	2.54	0.28	2.54	0.28
23	4.13	1.09	4.70	0.78	4.36	0.60	4.35	0.62
24	–	–	7.43	1.21	7.43	1.19	7.43	1.21
25	3.85	0.60	3.88	0.31	3.87	0.25	3.87	0.26
26	6.11	1.71	6.11	1.07	6.11	0.94	6.11	0.94
27	–	–	–	–	–	–	–	–
28	–	–	–	–	–	–	–	–
29	–	–	–	–	–	–	–	–
>29	4.87	0.28	5.46	0.11	5.23	0.10	5.23	0.10

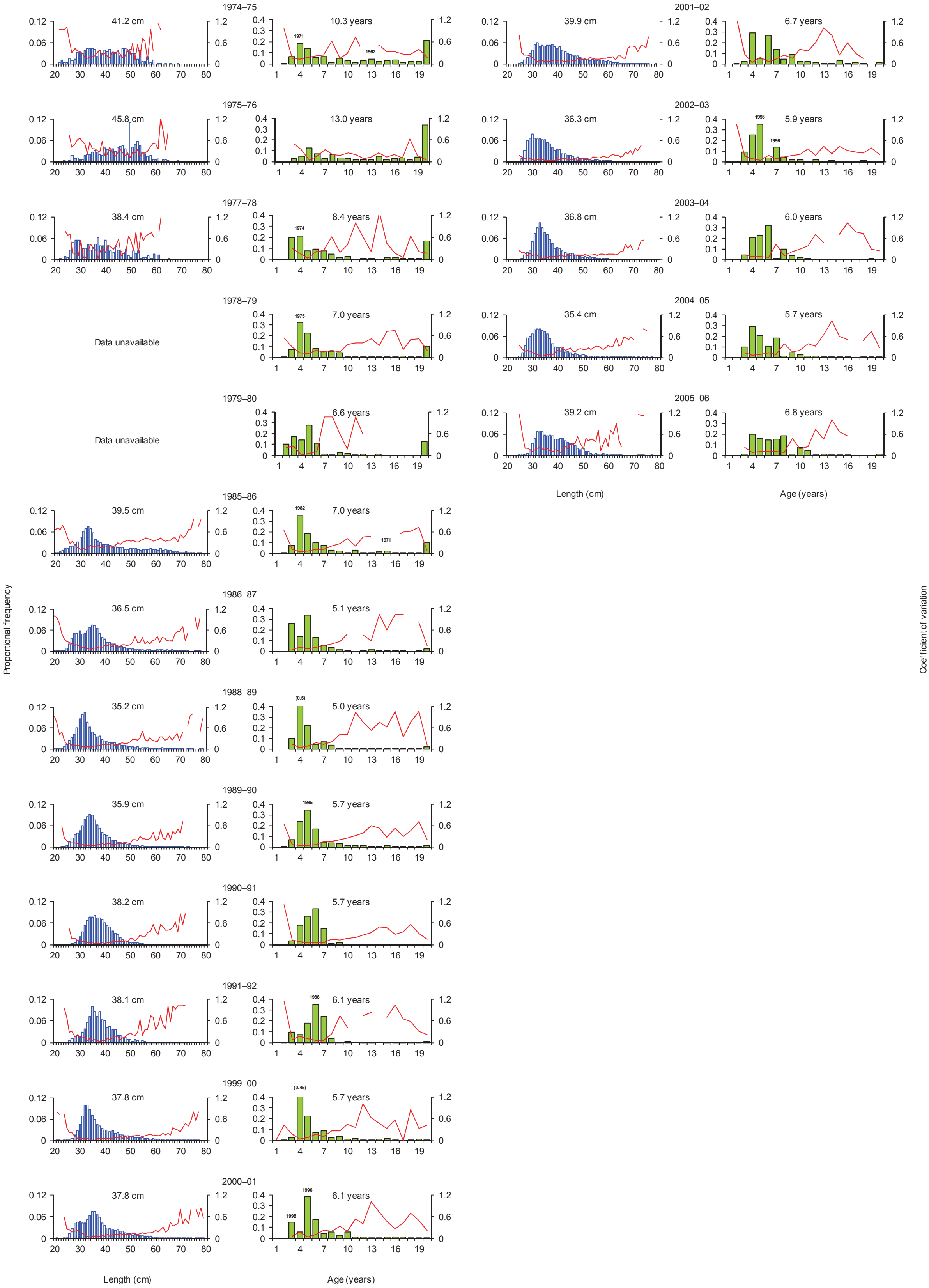
Appendix 9: Time series of proportion at length and age distributions and CVs for snapper from the SNA 8 bottom trawl fishery from 1974–75 to 1975–76, 1989–90 to 2009–10, 2012–13 and 2015–16. Data are from spring-summer and plots are annotated with estimates of mean length or age.



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 2015–16. 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: Comparison of the proportion and cumulative proportion at length distributions determined from snapper landings sampled over the spring and summer seasons from VesselX and "other" bottom trawl vessels in the SNA 8 fishery in 2015–16.