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Snapper catch-at-length and -age heterogeneity within and between strata in East Northland longline landings

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Variation to contract (Objective 3)

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7. Executive Summary

The purpose of this investigation is to determine whether spatial heterogeneity in East Northland longline landings considerably affect the precision of catch-at-length and catch-at-age estimates. This may influence sampling designs currently used. The design proposed for 2001–02 (Ministry of Fisheries project SNA2001/02) involves the collection of length frequency samples from 40–50 landings with random otolith subsamples of approximately 25 per landing. This design is expected to satisfy the desired precision of a target mean weighted coefficient of variation (MWCV) equal to 0.2. A review of this design by the Ministry suggested the design could be improved by considering catch at age heterogeneity between strata within East Northland. Consequently a variation was made to the project SNA2000/02 to include an objective titled: East Northland substratum analyses.

To address the objective, historical length and age data from two statistical areas (East Northland stratified on the finest possible spatial scale) were used for two separate analyses. Firstly, to derive stratum estimates of catch at length, catch at age, and variances from 1995–96 to 1999–2000; and secondly, simulations of alternative sampling strategies between strata using the most recent length and age data. These analyses were done for both the length frequency plus age-length key (LF+ALK) and random age frequency (RAF) sampling methods.

Some differences in the age composition of landings between strata were evident for particular year classes, that suggest some heterogeneity in catch at age within East Northland. The time series of catch at age estimates and the simulation results indicate no considerable heterogeneity in between-landing variability in the East Northland strata. Consequently, using the current sampling designs, similar, and acceptable, levels of precision may be obtained from either stratum.

The current sampling design proposed for 2001–02 is likely to produce target levels of precision irrespective of the proportion sampled in either stratum. The random selection of landings from the entire fishery, and from all processing sectors, is likely to ensure sampling is proportional between strata relative to landings from the fishery, and therefore representative.

8. Objectives

1. To determine whether sub-stratification of the East Northland longline snapper catch-at-length and catch-at-age data by statistical area reduces the heterogeneity of current estimates.

9. Methods

To address the objective, an appropriate stratification of the East Northland region was determined according to the finest spatial scale of commercial catch records and catch at age sample collection. This scale was the commercial fishing statistical reporting area used for the collection of Catch Effort Landing Returns (CELR) by the Ministry of Fisheries. Two statistical areas, 002 and 003, constitute the East Northland region and defined its spatial stratification applied in this study. Historical length and age data from the commercial longline fishery operating in the two statistical areas (strata) of East Northland were used for two separate analyses. Firstly, to derive stratum catch at age and variance estimates for 1995–96 to 1999–2000; and secondly to investigate alternative sampling strategies within and between the strata using simulations.

1. Catch at age estimates 1995–96 to 1999–2000

A full description of the collection and analysis of snapper catch at length and age samples from East Northland is given in a series of reports by Walsh et al. (1997, 1998, 1999, 2000a, 2000b). A brief overview follows to provide a background for the treatment of this data in this study.

Snapper length and age samples collected during spring and summer from 1995–96 to 1999–2000 were analysed for each stratum to calculate proportion caught at age and estimates of variance expressed as mean weighted coefficient of variation (MWCV). Length and age data, and the corresponding CELR records stored on the Ministry of Fisheries databases, were extracted for each stratum. Data from individual landings originating from both strata were excluded from the analysis, however these instances were few. Catch information for longline landings over the entire fishery (weight and numbers of landings) by stratum was requested from the Ministry of Fisheries.

Two different sampling methods were employed during the period 1995–96 to 1999–2000. The first method was the length frequency and age-length key approach (LF+ALK) that was used in 1995–96, 1996–97, and 1999–2000. This involved the collection of approximately 40–50 length frequency samples, with a total of around 600 otolith samples collected as a subsample from the length frequency samples. The otoliths were collected by proportional allocation according to the length frequency distribution as estimated for the previous year. Estimates of stratum proportion caught at length and age, and analytical variances (expressed as coefficients of variation, c.v.) followed that of Davies & Walsh (1995). Bootstrap mean and c.v. estimates were not determined because the difference between bootstrap and analytical estimates has been found to be negligible (Davies et al. unpublished results). Estimates were calculated for the recruited age classes with the maximum age being an aggregate of 19 years and older.

The second approach used was the random age frequency (RAF) sampling method (Davies et al. unpublished results) and was used from 1996–97 to 1999–2000. RAF samples were collected from an individual landing by taking random otolith samples from each grade of fish making up the landing. No length frequency sample was therefore required. A random sample of bins from each landing was taken with the systematic selection of every n^{th} fish counted in a continuous sequence from the sampled bins. The optimum selection interval, n, was determined from simulations using data from historical length and age samples that achieved a desired level of precision. This range took account of the expected mean number of fish in a bin and the total number of bins in landings. Sample sizes typically ranged from 15 fish being collected from landings of 10 bins, to 45 fish collected from landings of above 100 bins. A total sample size of 1000 otoliths was targeted for collection from each fishery. Estimates of proportion caught at age and c.v.s (analytical and bootstrap) for the two East Northland strata were calculated from the RAF samples. Bootstrap mean estimates are not presented as the difference between analytical and bootstrap means in proportion at age estimates have been found to be negligible (Davies et al. unpublished results).

2. Alternative sampling strategies

A range of alternative sampling strategies within and between strata was investigated by simulation using length and age data collected during spring and summer 1999–2000. Catch at age MWCV was estimated for alternative sample sizes in each stratum and for both strata combined using data collected by both the LF+ALK and RAF sampling methods. To investigate a range of sampling proportions between strata, simulation estimates of catch at age MWCV were calculated at each proportion.

The most recent available data were used (1999–2000) to include current variability in length and age compositions between landings, and the patterns in relative year class strengths. Both these factors will determine catch-at-age precision derived from particular sampling strategies and will differ from year to year. The number of landings sampled was 32 and 15, and the otolith sample sizes were 651 and 321 for strata 002 and 003 respectively. These data comprise both LF+ALK and RAF samples.

Length frequency and otolith data was used to calculate the MWCV associated with different combinations of landing and otolith sample sizes using the LF+ALK method. The landing sample size is the total number of landings selected at random from the fishery and the otolith sample size is the total number of otoliths comprising the age-length key. Sampling strategies within the ranges of 10 to 60 landings, and 200 to 1200 otoliths were investigated. For each option investigated, 500 bootstraps were carried out. In each bootstrap, both landings, and bins within landings, were randomly resampled with replacement to derive a landing length frequency. Similarly, otoliths within each length class interval of the age-length key were randomly resampled with replacement to produce an age-length key for the specified total sample size. The variance and MWCV of the 500 bootstrap catch at age estimates was calculated.

Simulations of the RAF sampling strategy were undertaken within a range of 10 to 60 landings, and with 10 to 60 otoliths being sampled from each landing. A strategy was a combination of number of landings sampled, and an otolith sample size taken from each landing, e.g. 40 landings with 20 fish randomly sampled from each landing. For each strategy 500 bootstraps were carried out to estimate catch at age MWCV. In each bootstrap, both landings, and individual fish in the sample taken from a landing, were randomly resampled with replacement to derive pseudoreplicate RAF samples.

Using an LF+ALK sampling strategy found to be optimal in terms of desired MWCV, a range of sampling strategies was investigated for the proportion sampled in each stratum. A range of proportions from 0 to 100% in strata 002 and 003 alternatively was used with 10% intervals at each option. For each option, the number of landings and otoliths corresponding to the specified proportion was randomly sampled with replacement from each stratum respectively. The samples were then pooled for the calculation of the East Northland catch at age estimates. For each strategy, 1000 bootstraps were carried out to estimate catch at age and length MWCV.

10. Results

10.1 Catch at age estimates 1995–96 to 1999–2000

10.1.1 Sample collection

Summaries of the sampling method, number of landings and otoliths sampled, total number of landings in the fishery are given by stratum for the period 1995–96 to 1999–2000 in Table 1. The ratio of the proportion of landings in the fishery from stratum 002 compared to 003 ranged from 0.56:0.44 in 1997–98 and 1999–2000, to 0.61:0.39 in 1995–96. The ratio of the proportion of landings sampled in stratum 002 compared to 003 ranged from 0.39:0.61 in 1997–98, to 0.68:0.32 in 1999–2000. In some years the proportion sampled in each stratum was disproportionate to the respective landings in the fishery from each stratum.

The number of otoliths collected by the LF+ALK method in 1995–96 was roughly equally distributed at approximately 300 otoliths for strata 002 and 003 respectively. The stratum otolith sample sizes collected by the RAF method (1996–97 to 1999–2000) was roughly proportional to the number of landings collected in each stratum.

For example, in 1999–00, the ratio of sampled landings from strata 002 and 003 was 0.68:0.32 and the subsampled otolith collection was 651:321.

Table 1: **Summary of the sample number and total number of landings by statistical area from the East Northland longline fishery from 1995–96 to 1999–00.***

			No. of landings sampled			No. of otoliths	No. of landings in fishery		
Year	Sampling method	Stat area	ENLD	Stat. area	Proportion	collected	ENLD	Stat. area	Proportion
1995–96	LF+ALK	002	39	24	0.62	295	1479	896	0.61
		003	39	15	0.38	284	1479	583	0.39
1996–97	LF+ALK	002	52	23	0.44	464	1626	958	0.59
		003	52	29	0.56	522	1626	668	0.41
	RAF	002	49	23	0.47				
		003	49	26	0.53				
1997–98	RAF	002	41	16	0.39	337	1483	827	0.56
		003	41	25	0.61	615	1483	656	0.44
1998–99	RAF	002	43	27	0.63	628	1329	780	0.59
		003	43	16	0.37	393	1329	549	0.41
1999–00	LF+ALK; RAF	002	47	32	0.68	651	1626	916	0.56
		003	47	15	0.32	321	1626	710	0.44

* LF+ALK = Length frequency and age-length key approach; RAF = Random age frequency approach.

The total longline snapper catch and number of landings in strata 002 and 003 from 1995–96 to 1999–2000 are presented in Figure 1. The total catch ranged between 365–565 tonnes. The relative proportions of the catch weight in each stratum were similar in most years except 1997–98, when the catch from stratum 003 exceeded that of 002. The total number of landings from respective strata was similar between years, with the number from stratum 002 almost always exceeding that from 003.

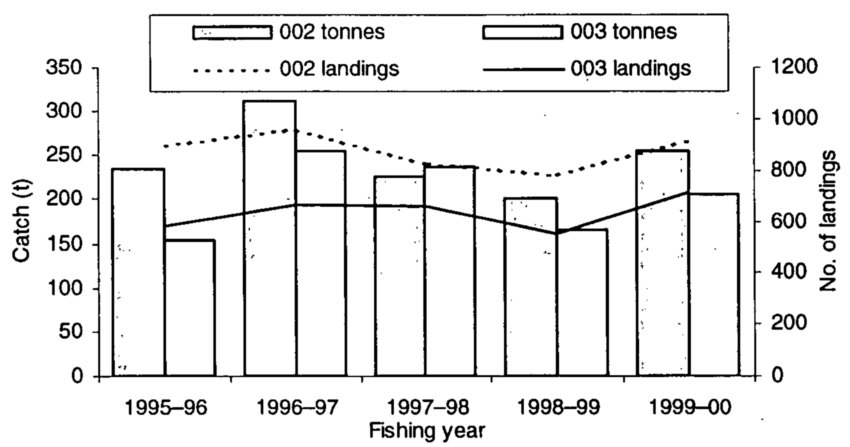


Figure 1: **The total weight of snapper (tonnes) and the total number of landings by stratum (statistical area) for the East Northland longline fishery from 1995–96 to 1999–00.**

10.1.2 Catch at length and age estimates

The existing time series of catch at length and age estimate for the East Northland longline fishery (strata 002 and 003 combined) from 1995–96 to 1999–2000 are presented in Figure 2. Catch at age analytical MWCV estimates for all years ranged from 0.11 to 0.18.

LF+ALK sample estimates of catch at length and age, number of landings sampled, length frequency and otolith sample sizes, mean length, mean age, and MWCV for strata 002 and 003 are presented in Figures 3 and 4 for length and age respectively. Comparisons of the length and age distributions between strata are presented in Figure 5 showing visible differences. Length estimates were similar in 1995–96, but considerably different in 1996–97 and 1999–2000 stratum 002 was comprised of larger fish. Age estimates were generally similar, although some minor differences occur for particular age classes. Catch at age MWCV for both strata and over all years ranged from 0.14 to 0.23.

RAF sample estimates of catch at age, number of landings sampled, otolith sample sizes, mean age, and MWCV from strata 002 and 003 are presented in Figure 6. Catch at age analytical MWCV estimates for both strata and over all years ranged from 0.18 to 0.27. Comparisons of the age distributions between strata are presented in Figure 7 showing differences for some year classes, e.g. 1989 and 1991 visible as 9 and 7 year olds respectively in 1997–98. These year classes from stratum 003 appear of higher relative strength compared to stratum 002.

The variability in catch at age MWCV relative to otolith sample size for the LF+ALK and RAF samples from the East Northland longline fishery (strata 002 and 003 combined) from 1995–96 to 1999–2000 is given in Figure 8. For an otolith sample size of around 1000, lower MWCV estimates are obtained using the LF+ALK compared to the RAF method.

10.2 Sampling strategy

MWCV estimates derived from bootstrap simulations of alternative LF+ALK and RAF sampling strategies in strata 002, 003, and 002/003 combined are presented in Figures 9 and 10 respectively. LF+ALK estimates were comparatively lower than those from RAF samples. For either method, the results indicate that precision is largely determined by the otolith sample size per landing, and that the number of landings determines the relative scale of precision achieved. The relatively high MWCV estimates obtained for strategies with low sample size shows the effects of the typically broad age composition and high between-landing variability. MWCV estimates from stratum 003 were slightly lower than those from 002, which in turn were only slightly lower than those for 002 and 003 combined. This indicates that slightly lower MWCV estimates may be obtained from samples collected within each stratum than from samples from combined strata. This is most likely because between-landing variability is lower within, than between strata.

The optimum LF+ALK sampling strategy was considered to be 50 landings with the collection of 1000 otoliths as this is indicated to produce a MWCV of between 0.1 and 0.15 (Figure 9). This strategy was used to investigate changes in MWCV for catch at age and length estimates from LF+ALK samples relative to the percentage sampled in stratum 002 versus 003 (Figure 11). The slightly lower MWCV for strategies with more than 90% collected in stratum 003 shows that slightly lower between-landing variability exists in stratum 003 than 002. Strategies with between 20 to 80% of samples collected in either strata produce slightly higher MWCV estimates shows that slightly lower MWCV estimates may be obtained from samples collected within strata than from samples from combined strata. However, these differences are slight and the MWCV estimates from samples from combined strata are satisfactory in terms of the desired precision for catch at age estimates (MWCV less than or equal to 0.2).

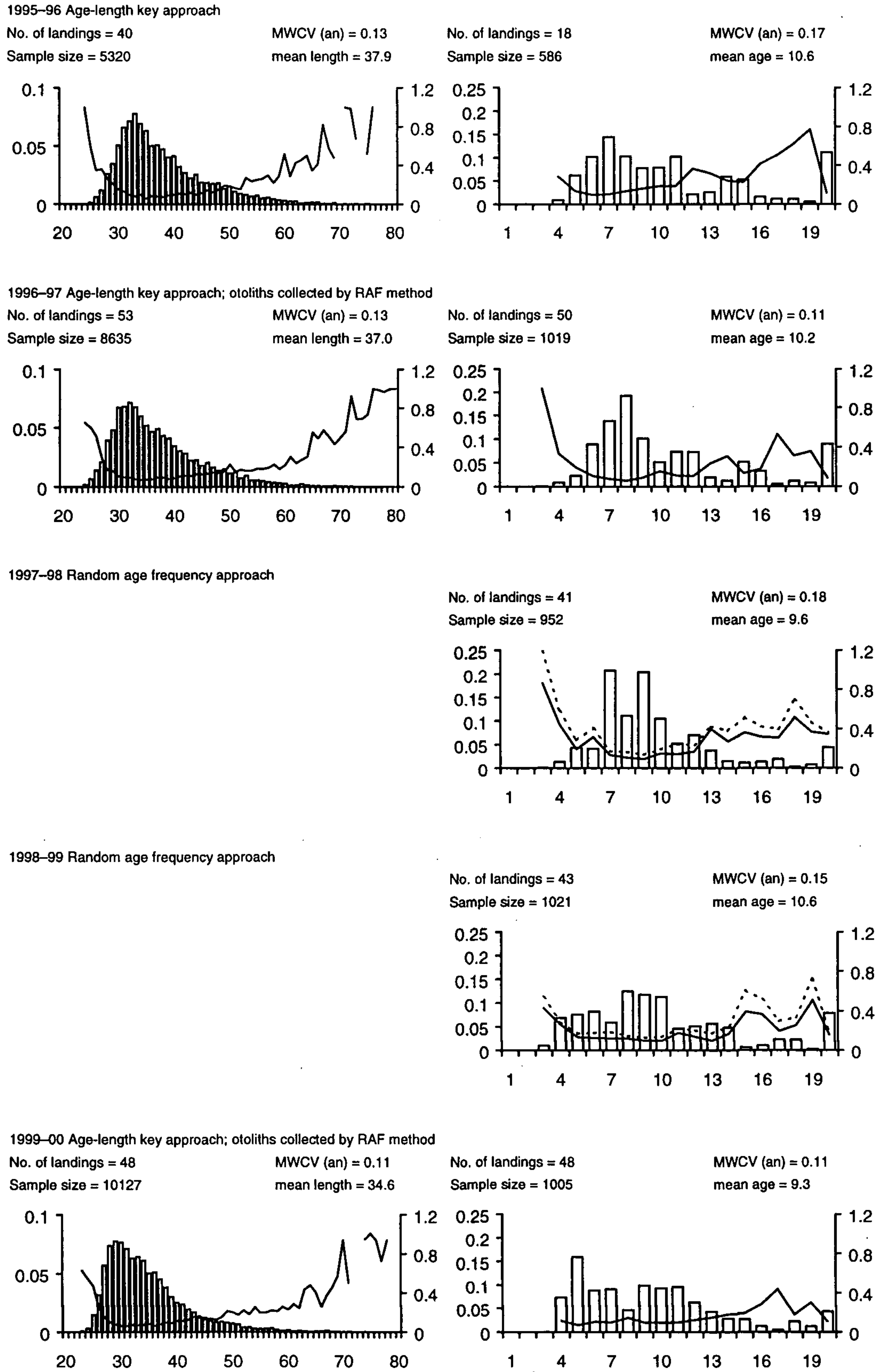


Figure 2 **: Length and age sample estimates for SNA from the East Northland stock from 1995–96 to 1999–00.**

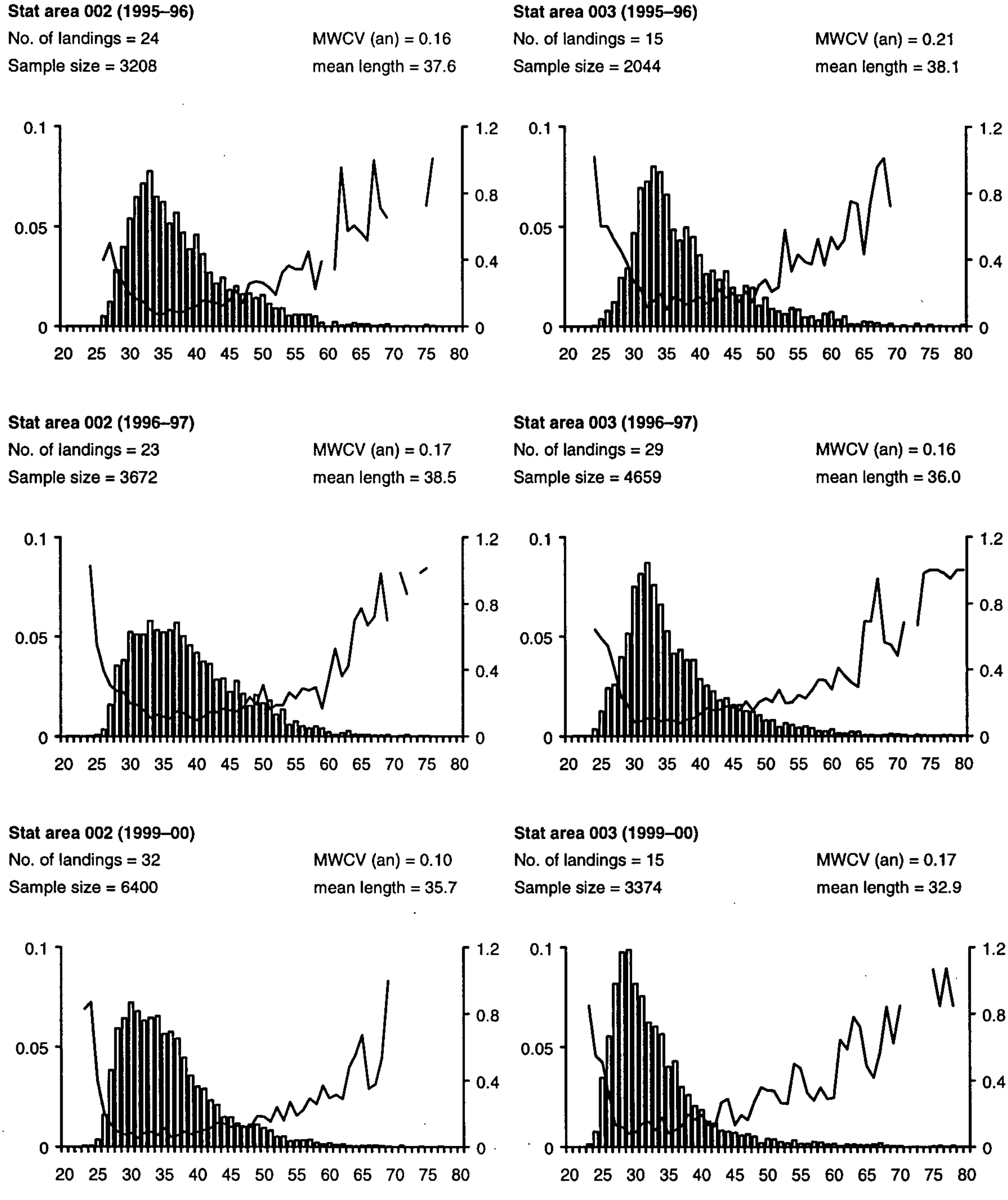


Figure 3 **: Length sample estimates for SNA catch-at-age by statistical area from the East Northland stock from 1995–96, 1996–97 & 1999–00.**

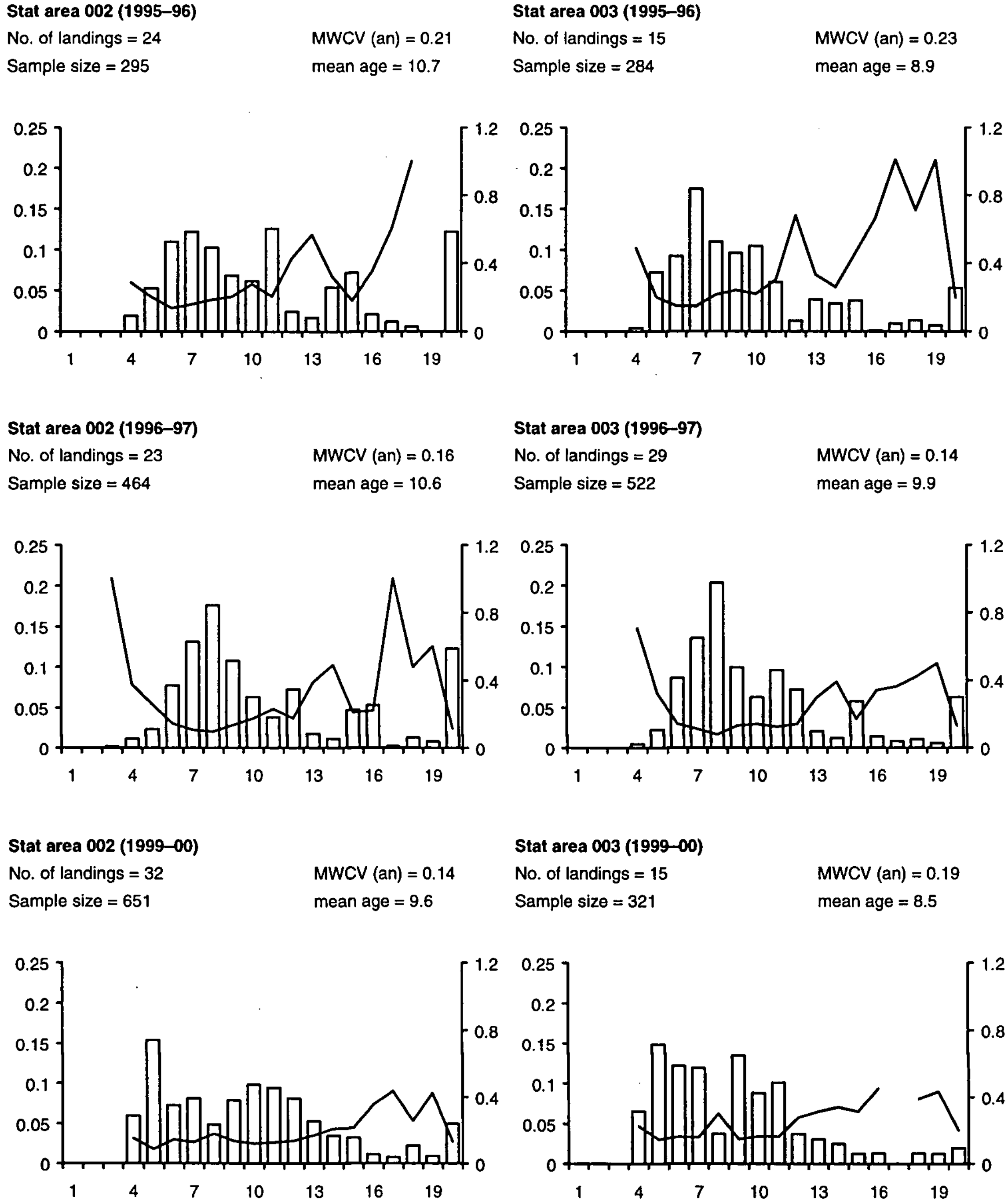


***Figure 4*: Estimates for SNA catch-at-age (from age-length key) by statistical area from the East Northland stock from 1995–96, 1996–97 & 1999–00.**

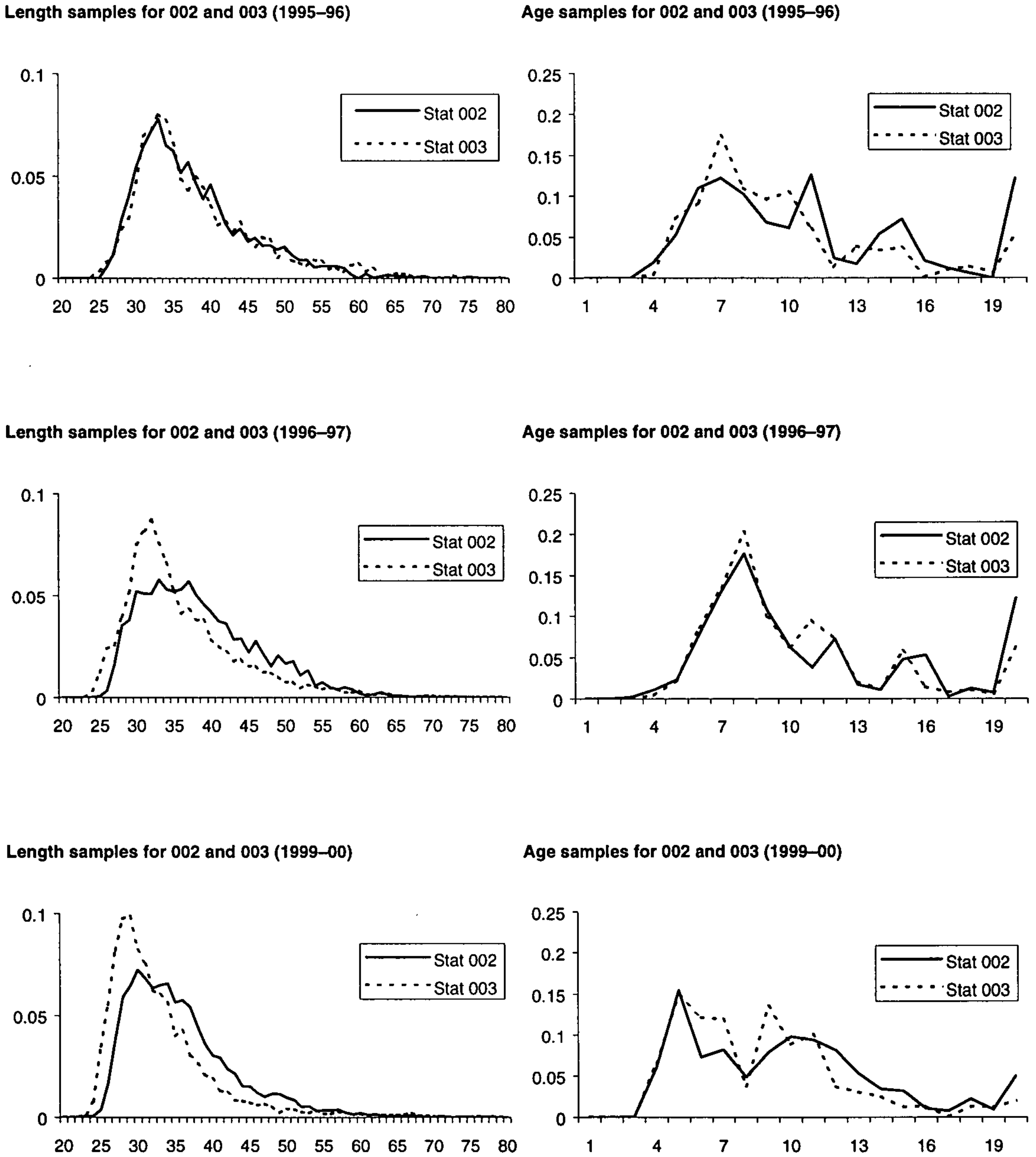


Figure 5: **Length and age sample estimates for SNA catch-at-age by statistical area from the East Northland stock from 1995–96, 1996–97 & 1999–00.**

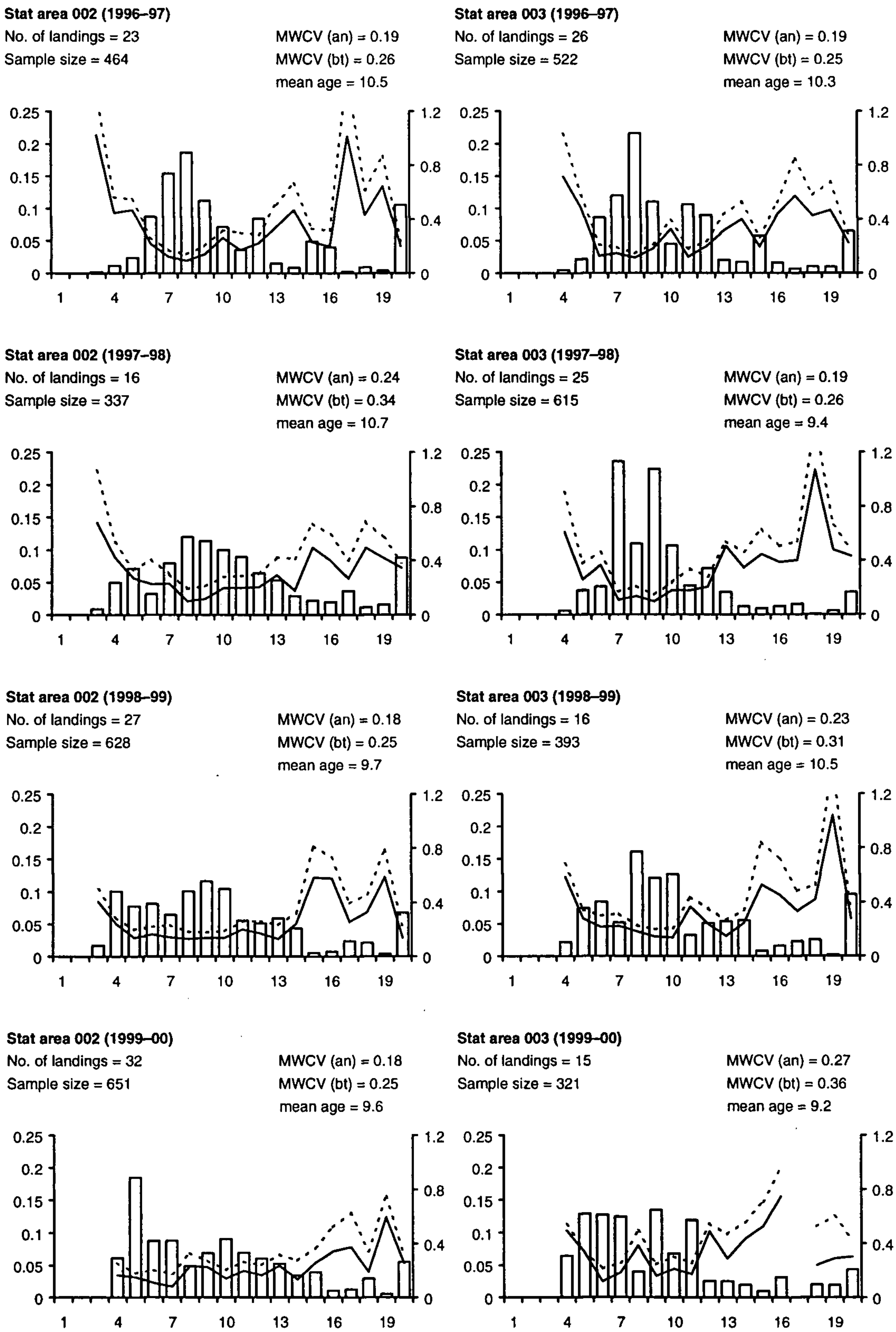
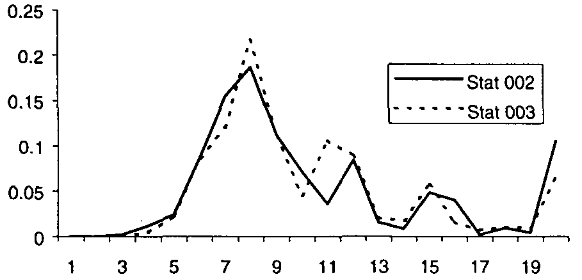
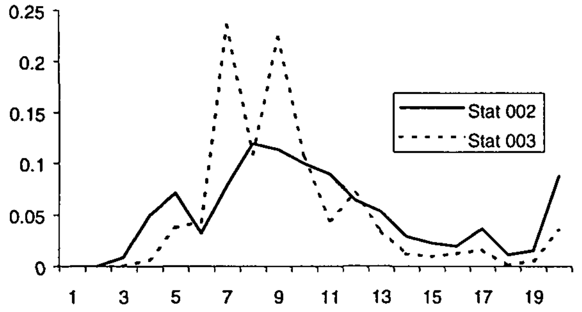


***Figure 6*: Random Age Frequency sample estimates for SNA catch-at-age by statistical area from the East Northland stock from 1996–97 to 1999–00. Note: solid and dashed lines represent analytical and bootstrap c.v.s.**

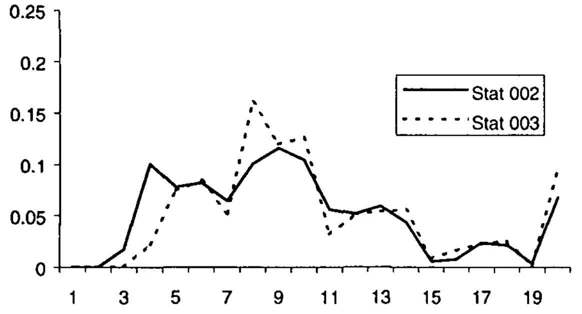
Random age frequency samples for 002 and 003 (1996–97)



Random age frequency samples for 002 and 003 (1997–98)



Random age frequency samples for 002 and 003 (1998–99)



Random age frequency samples for 002 and 003 (1999–00)

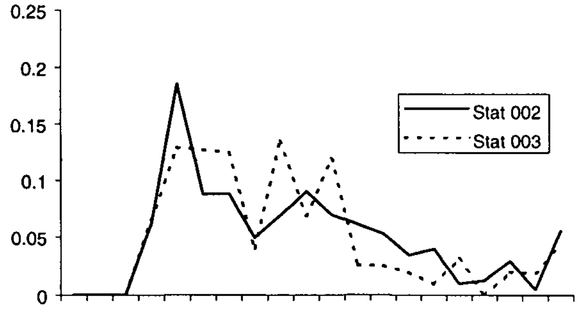


***Figure 7*: Random Age Frequency sample estimates for SNA catch-at-age by statistical area from the East Northland stock from 1996–97 to 1999–00.**

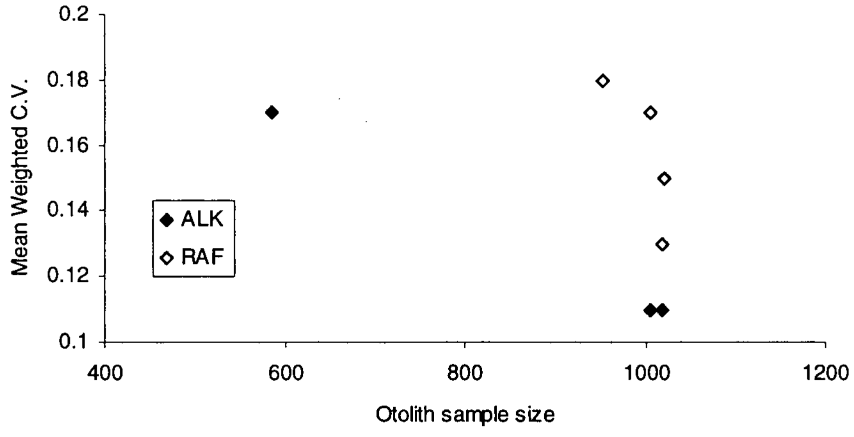
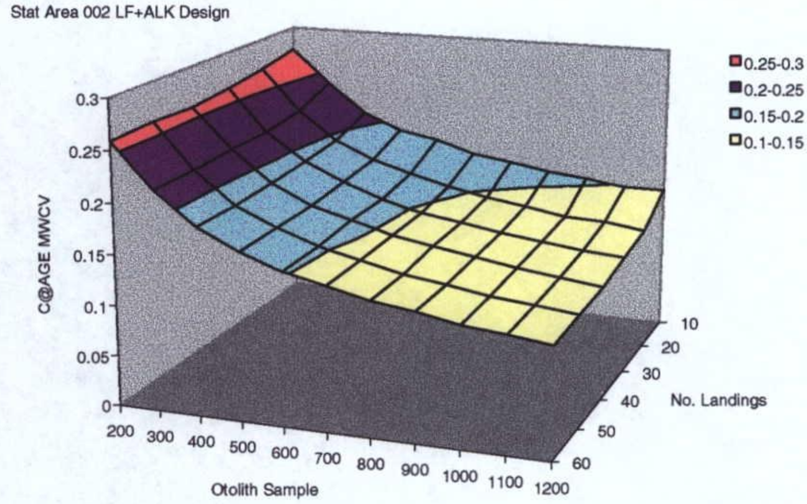
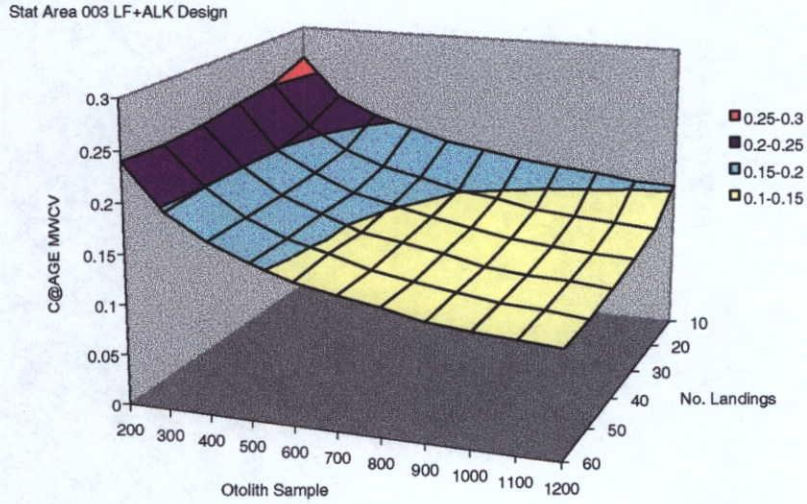


***Figure 8*: The variability in MWCV with otolith sample size for the age-length key and random age frequency approaches sampled from the East Northland longline fishery from 1995–96 to 1999–00.**





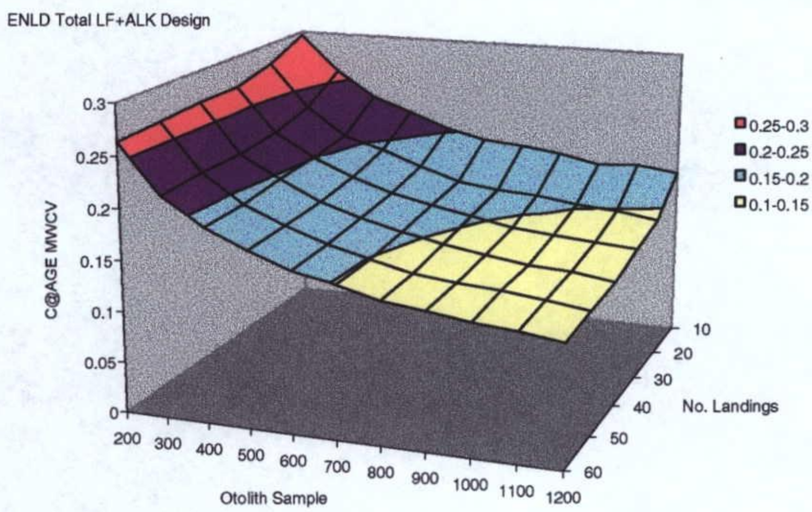


Figure 9 **: Mean weighted coefficient of variation for estimates of proportion at age of snapper in landings from statistical areas 002, 003, and 002/003 combined calculated from 500 bootstraps for each of different combinations of total number of landings, and otolith sample sizes taken in each landing.**
Note: Length frequency and age-length key samples used.

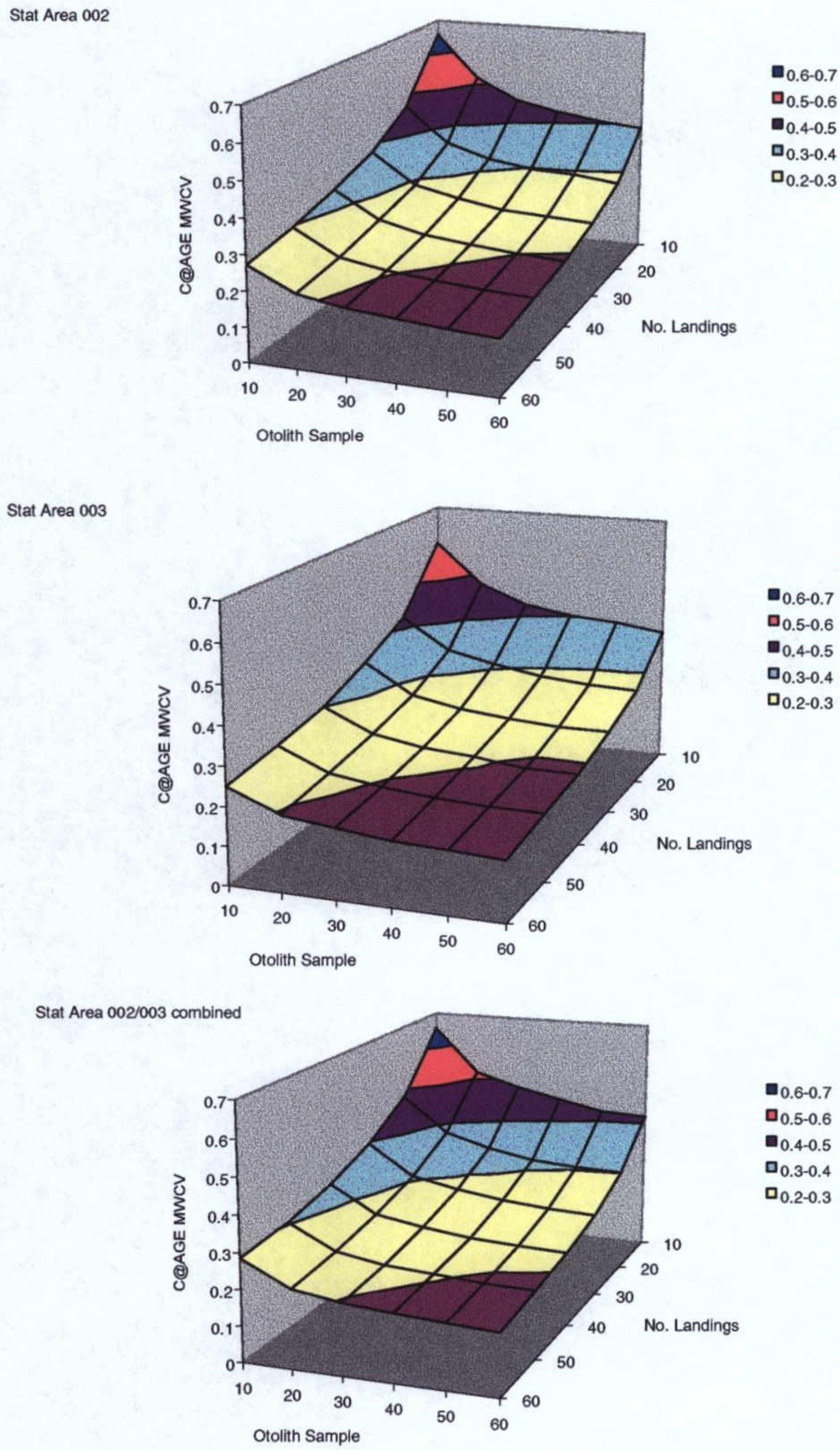


Figure 10 **: Mean weighted coefficient of variation for estimates of proportion at age of snapper in landings from statistical areas 002, 003, and 002/003 combined calculated from 500 bootstraps for each of different combinations of total number of landings, and otolith sample sizes taken in each landing. Note: Random age frequency samples used.**

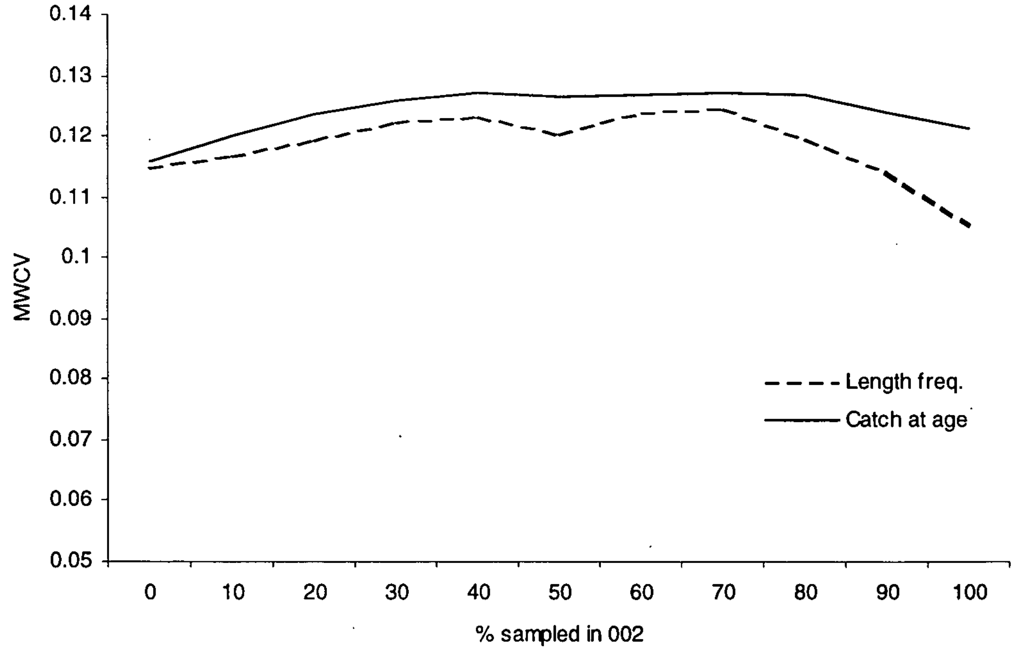


Figure 11: **The change in MWCV of the length frequency and catch at age (for the age-length key approach) relative to the percentage of the sample collected in statistical area 002 versus 003.**

11.0 Discussion

The sampling of commercial landings for catch at age has two requirements for the estimates to be of value as input data for age-structured population models used for snapper stock assessments. Firstly, the samples must be representative of the commercial catch taken from the region during the season surveyed, and secondly, the samples provide a sufficient number of observations to achieve a desired level of precision. The first requirement relates to the accuracy of the sample estimate, and is dependent upon the allocation of sample effort over landings from the fishery. The second requirement relates to a predetermined target level of precision, and is dependent upon sample design in terms of strategy and size.

This investigation relates particularly to the second aim, in that heterogeneity in strata affects precision and may be addressed by appropriate sample designs that optimise the allocation of sampling effort between strata. However, this must be considered in terms of the effects that the sample design may have on the first requirement, because the allocation of sampling effort between strata may influence how representative it is of all strata.

11.1 Stratum catch at age

Some differences are evident between strata in the inferred relative strength of particular year classes. This suggests heterogeneity in the length and age composition of snapper in East Northland landings, with some year classes being more abundant in stratum 003 than 002, and slightly older fish in stratum 002. Despite these differences, the age distributions are broadly similar with a wide range of classes represented, including a dominant aggregate age class. This typifies the East Northland region compared to the other regions of SNA 1.

Catch at age estimates from stratum 003 resemble estimates derived for the adjacent Hauraki Gulf fishery in some years. Many samples collected from 003 are from catches taken in the southern part of the statistical area, i.e. Bream Bay, Hen and Chickens and Tutukaka coastline. Similarly, almost all samples collected from stratum 002 are from the northern half of the statistical area i.e. from Whangaroa, Mangonui, and Houhora. Very few vessels fish the area between and the two fishing grounds can therefore be regarded as quite distinct.

Slight differences in precision between strata were evident in the catch at age time series and in the simulations using recent data. Lower precision was obtained for samples from stratum 002, particularly when applying the RAF method. However, catch at age precision for both strata were generally at levels acceptable using the sample sizes collected within each stratum for both the LF+ALK and RAF methods. Similarly, simulation precision estimates within strata for sampling strategies currently employed were also acceptable (close to, or less than, the target level, MWCV=0.2). The results show between-landing variability in catch at age is similar between strata such that precision of stratum catch at age estimates is generally similar, and of acceptable levels using the current sampling strategies.

11.2 Sampling strategy

Simulations of the LF+ALK and RAF sampling strategies applied within each stratum indicate desired precision is obtained with designs currently used for the East Northland fishery. These are for the LF+ALK method 40-50 landings with a sample of 600-700 otoliths, and for the RAF method 40-50 landings with 25 otoliths from each landing. Application of these designs to both strata combined in the proportions sampled during 1999–2000 (68% in 002) is also indicated to provide target levels of precision.

Simulation results indicate that varying the proportion sampled between strata over the range of 20 to 80% does not appear to influence catch at age precision. This most likely reflects the similarities in between-landing variability and age composition. Consequently, no considerable gains in terms of precision are likely by selectively allocating the proportion of landings sampled between strata.

11.3 Practical considerations

The analyses of catch at age precision between strata suggest that a sampling strategy that allocates samples between strata in proportion to the number of landings typical from the strata is likely to provide acceptable levels of precision. However, some differences in the age-composition between strata are evident. Therefore, the sampling design must address the requirement that samples are representative such that the allocation of samples between strata must be proportional to landings from the fishery. This raises some important practical considerations.

It is not possible at the outset of sampling a fishery to determine where fishers will distribute their fishing effort between strata during the survey period. One can only predict the likely proportion of vessels fishing in a stratum in any given year. For example, in the 1997–98 fishing year, the proportion of the catch from stratum 002 and 003 was roughly equal, which was substantially different to most other years (see Figure 1). This difference was mainly because of unseasonably cold water temperatures in the Hauraki Gulf that resulted in low catch rates, and subsequently fishers moved to southern parts of the East Northland region to improve their catch rates (see Walsh et al. 1999).

A number of factors apparent from sampling of snapper landings in the past make it difficult and cumbersome to determine exactly the catch location of a landing. Firstly, some of the current commercial longline fishers are relatively new to fishing and not familiar with the statistical areas and therefore misreport their catch locations. Secondly, the port of landing is only a broad indication of catch location and only close communication with the fisher at the time of landing determines the catch location. Fishermen do not always land into one port and therefore do not always fish the same fishing grounds. This is usually dependent on changes in catch rates or market demands for particular sized fish or bycatch. Furthermore, all landings are sampled from Licensed Fish Receivers (LFR) the day following the landing of the catch, and information of the port of landing is often not available. One may therefore rely on the CELR information of catch location by statistical area that becomes available some months after sampling. Consequently, exact information of the catch locality is often unavailable prior to sampling the catch, and the sampler must choose the sample on the basis of some confidence of it originating from the East Northland region.

11.4 Proposed strategy

To achieve the aim of a representative sample, the sampling strategy must accommodate the practical considerations mentioned above, i.e. must be flexible to capture shifting trends in fishing effort between strata within a season. The application of random selection of landings from both strata combined will assure that the sample represents each stratum in proportion to the total landings from each stratum. This approach may suffice when sampling effort is applied to all sectors of the fishery and LFRs processing landings from both strata.

The time series of catch at age estimates and the simulation results indicate no considerable heterogeneity in between-landing variability in the East Northland strata. Irrespective of the proportion sampled in either stratum, catch at age precision (MWCV) is within the desired range. It is therefore recommended that the design currently proposed for sampling East Northland longline landings in 2001–02 (tender for SNA2001/02) be retained. This design treats East Northland landings as a single stratum and randomly selects landings from the entire fishery, thus assuring a sample representative of the fishery. The sampling strategy and size is mostly to achieve the desired level of precision.

12. Conclusions

- Some differences in the age composition of landings between strata were evident for particular year classes that suggests some heterogeneity in catch at age within East Northland.
- The time series of catch at age estimates and the simulation results indicate no considerable heterogeneity in between-landing variability in the East Northland strata, with similar, and acceptable, levels of precision being obtained from either stratum.
- The current sampling design proposed for 2001–02 is likely to produce target levels of precision irrespective of the proportion sampled in either stratum.
- The random selection of landings from the entire fishery, and all processing sectors, is likely to ensure sampling is proportional between strata relative to landings from the fishery, and ensure the sample is representative.

13. References

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14. Publications

Nil.

15. Data Storage

Nil.