GETTING THE RIGHT INFORMATION FOR AGE-STRUCTURED MODELS

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Introduction

There are many uses for ageing data in fisheries modelling. Age-based models range in complexity from the relatively simple (eg. growth curves, catch curves for estimating total mortality, and the estimation of relative year class strength) to Virtual Population Analysis (often refered to as cohort analysis) and similar models. For a comprehensive review of age-structured assessment models see Megrey (1989).

VPAs are powerful tools for estimating fishing mortality, population size and recruitment. They are, however, very data intensive. The minimum requirements are a catch-at-age matrix from the commercial fishery, and an estimate of natural mortality. To obtain the age composition of catches requires estimates of the total catch, the size composition of the catch and an age-length key (see for example Kimura 1977). Independent measures, such as abundance indices and estimates of fishing mortality in the most recent year (the terminal assumption), allow tuning of the model.

In this paper we do not concern ourselves with errors, particularly of input parameters, and their effect on VPAs and cohort analyses. These have been well documented, and recently reviewed and extended by Rivard (1989). Rather, methods to determine sampling requirements for VPAs and age-length keys are described. Given that these methods are data intensive and require commitment to data collection over a long time period, optimising sampling is very important.

Two examples are used:

- the New Zealand hoki (blue grenadier) fishery
- the Central Ageing Facility

The New Zealand Hoki (*Macruronus novaezelandiae*) Fishery

Hoki is one of New Zealand's most important commercially exploited fish species. In 1990-91, the total catch was about 215,000 t valued in excess of $NZ200 million. The NZ fishery is described in Annala (1992) and details of hoki/blue grenadier biology are given in Annala (1992) and Smith (in press).

The main fishery for hoki is on spawning aggregations on the west coast of the South Island (WCSI) during winter, which contributes over 70% of total landings (Figure 1). A characteristic of the fishery is that mean lengths of both males and females decline during the season as smaller fish enter the fishery. This has implications for the sampling strategy to provide a representative size composition of the catch.

In 1988, a pilot program of at-sea sampling was carried out to collect length frequencies and otoliths from this fishery. The program was simulated by bootstrap techniques to optimise the sampling regime in terms of:

a) sample size - the number of fish to measure for length within a sample

b) sample frequency - the number of samples to take from each strata (week) throughout the season

c) age/length key - the number of fish to be aged for each sex.

These data were to be used for a VPA analysis of the fishery.

Precision of VPA

Simulation modelling was used to assess the precision of the catch-at-age matrix and the tuning data, required to achieve a target level of precision of the population estimate (derived from the VPA). A 15 age class population was modelled over 10 years with increasing effort (F) and a pattern of varying recruitment.. Perfect catch-at-age data were generated. The catch-at-age matrix and effort data were then subjected to various levels of variability using a Monte Carlo simulation. The variability in the estimate of biomass in the last year was calculated, suggesting CVs of no greater than 10% were required for catch-at-age matrix if precise estimates of population size were to be obtained (Table 1). This was set as target level of precision. For hoki, tuning data were to be derived from fishery independent and CPUE measures of abundance.

Age and Length Frequencies

Minimum sample sizes for age-length keys for each were based on simulation results (Figure 2). Otolith readings from at least 400 fish of each sex were made for each year.

A bootstrap simulation exercise was used to determine sample sizes and numbers for length frequencies. The mean weighted coefficients of variation (MWCV) for males are shown in Figure 3. Based on these results, a minimum number of 400 length frequency samples was targetted for each spawning season with a sample size of 150 fish (males and females combined) recommended for at-sea sampling.

Problems with Ageing - The Best Laid Plans

In 1990 a strong year class entered the fishery. It was possible to follow this cohort through from 1989 to 1992 by which time it dominated catches (Figure 4). However, it was not reflected in the age composition of catches determined from ageing using otoliths. This indicated that there were problems with ageing young hoki which up until then was regarded as "routine". Obviously this had significant implications for the usefulness and robustness of the analysis, particularly as one of the main aims of the VPA was to provide quantitative estimates of recruitment.

Recently, similar problems with ageing young blue grenadier were identified in Australia (D Smith, J Lyle unpublished data). An otolith exchange program between New Zealand and Australia is being used to resolve this problem.

The Central Ageing Facility

The Central Ageing Facility (CAF) is based at the Victorian Fisheries Research Institute's Marine Science Laboratories in Queenscliff. It was established primarily to provide a long-term database on the age composition of fish caught in key Australian fisheries. Prior to the establishment of the CAF, fish ageing studies in Australia tended to be of short-term duration.

Production ("routine") ageing of 8 species taken in the South East Fishery (SEF) is undertaken by the CAF. To date, sample sizes for age determination of these species are empirically based: determined from the published literature and the expertise of scientists involved in the fishery. We are using simulation techniques to examine how robust these sample sizes are, ie. do they provide accurate age-length keys?. At this stage we have not considered regional differences but this will be undertaken in the future.

Mean weighted coefficients of variation of the mean age-at-length for each sample were estimated as follows:.

1. Monte Carlo simulations were used to create a population and sample age-length distributions
   - input mean and standard deviation of length for each age class;
   - assuming a normal distribution of each length-at-age, create a population of 10,000 fish from this data set;
   - randomly select sets of 30 samples each of sizes= 50, 100, 250, 1000, 1500, 2000 fish;
   - calculate the mean age and proportion by length for each sample.
2. The mean weighted coefficient of variation was calculated as follows:
   - calculate the mean proportion and coefficient of variation of mean age for each length within sample sets of each sample size;
   - weight coefficient of variation by mean proportion of each length;
   - calculate the mean of weighted coefficient of variation for each sample size.

Results for two species are presented in Figure 5. Blue grenadier live to about 25 years whereas school whiting *(Sillago bassensis flindersi)* are short-lived with a maximum age of about 7 years. Sample sizes to give a MWCV of 10% or less are 1000-1500 for blue grenadier and 500-1000 for school whiting. Current sample sizes for spawning blue grenadier (upon which the simulations were based) and school whiting are 1000 and 750, respectively. Thus it appears that sampling for school whiting is about right but the sample size for spawning blue grenadier could be increased slightly. Note the optimum sample size determined for blue grenadier is higher than that for the same species (hoki) in New Zealand. This reflects the greater number of age classes present in Australian catches.

In addition, it should be possible to generalise the results of these simulations. Optimum sample sizes will be broadly dependent on longevity or number of age classes in the fishery and differences between sexes.

Conclusions

There are a number of sources of errors associated with population age estimates used in age-based models. By taking into account the type of population, one source of error can be reduced by choosing an appropriate sample size. Up to a certain sample size, the error about the estimate of population ages can be minimised but beyond this there is no real gain in precision. The latter is particularly important because of the costs of monitoring and ageing. The importance of repeatable and validated age estimates is also stressed.

References

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Table 1. Results of simulation modelling to assess the precision of the population biomass estimated from the catch-at-age matrix and tuning data under different levels of precision.

Precision is expressed as the CV of the estimate

	CV of catch-at-age matrix		
	10%	20%	50%
CV of tuning data			
Perfect	0.043	0.089	0.297
10%	0.153	2.440	
20%	0.180		
50%	2.240		

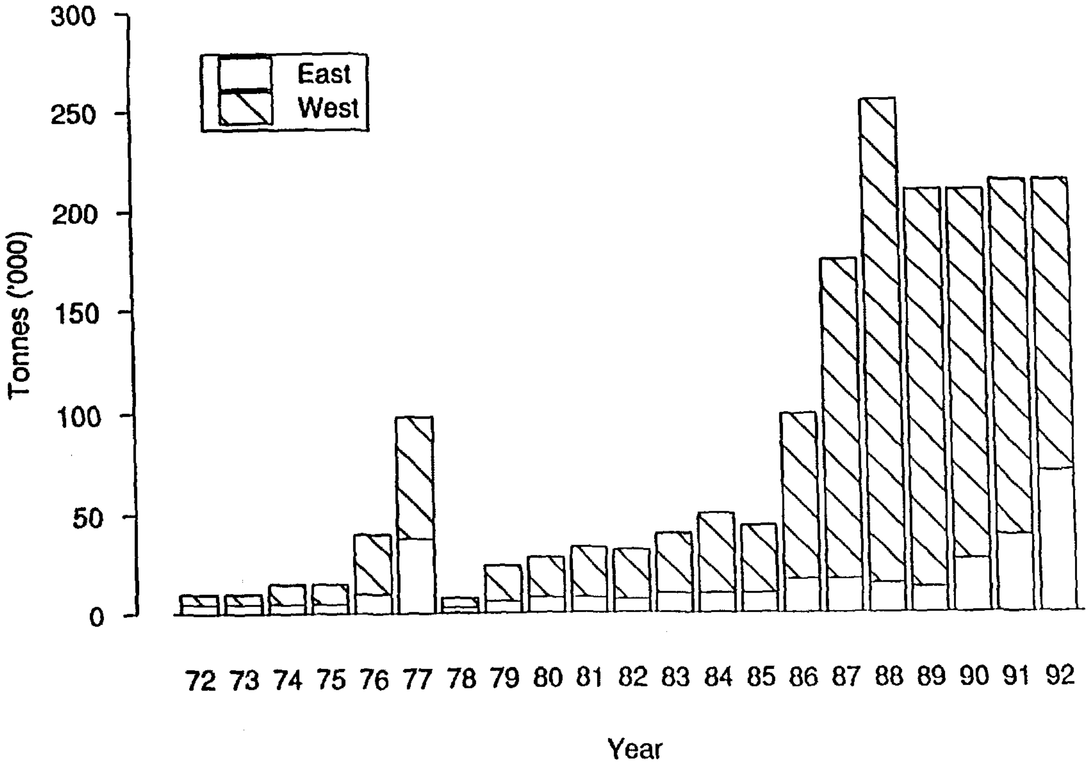


Figure 1. Annual landings of hoki (*Macruronus novaezelandiae*), east and west coast of New Zealand 1972 to 1992.

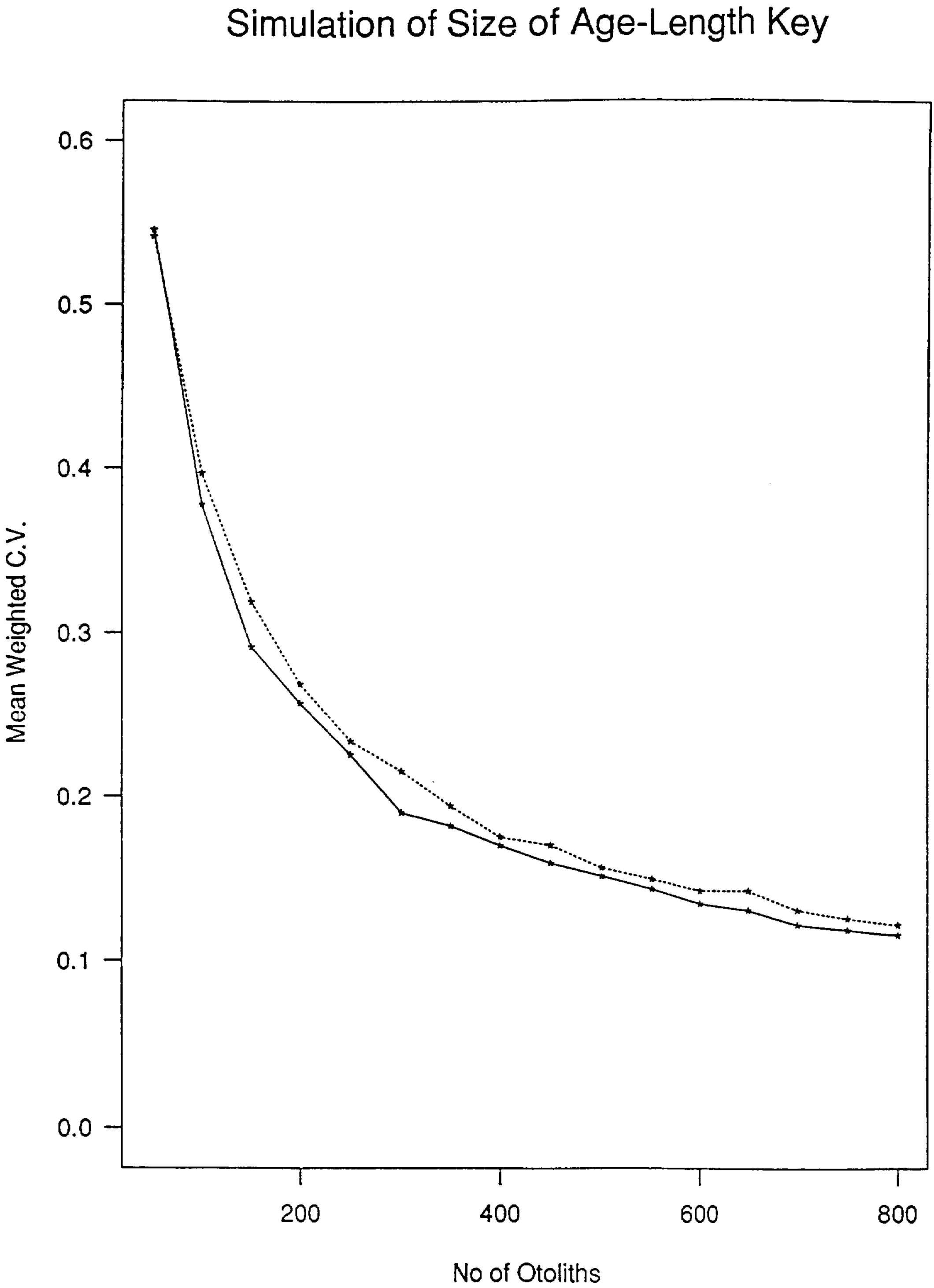


Figure 2. The mean weighted coefficient of variation (MWCV) for all age classes plotted against age-length key sample size determined by simulation for hoki, west coast South Island (females dotted line; males solid line).

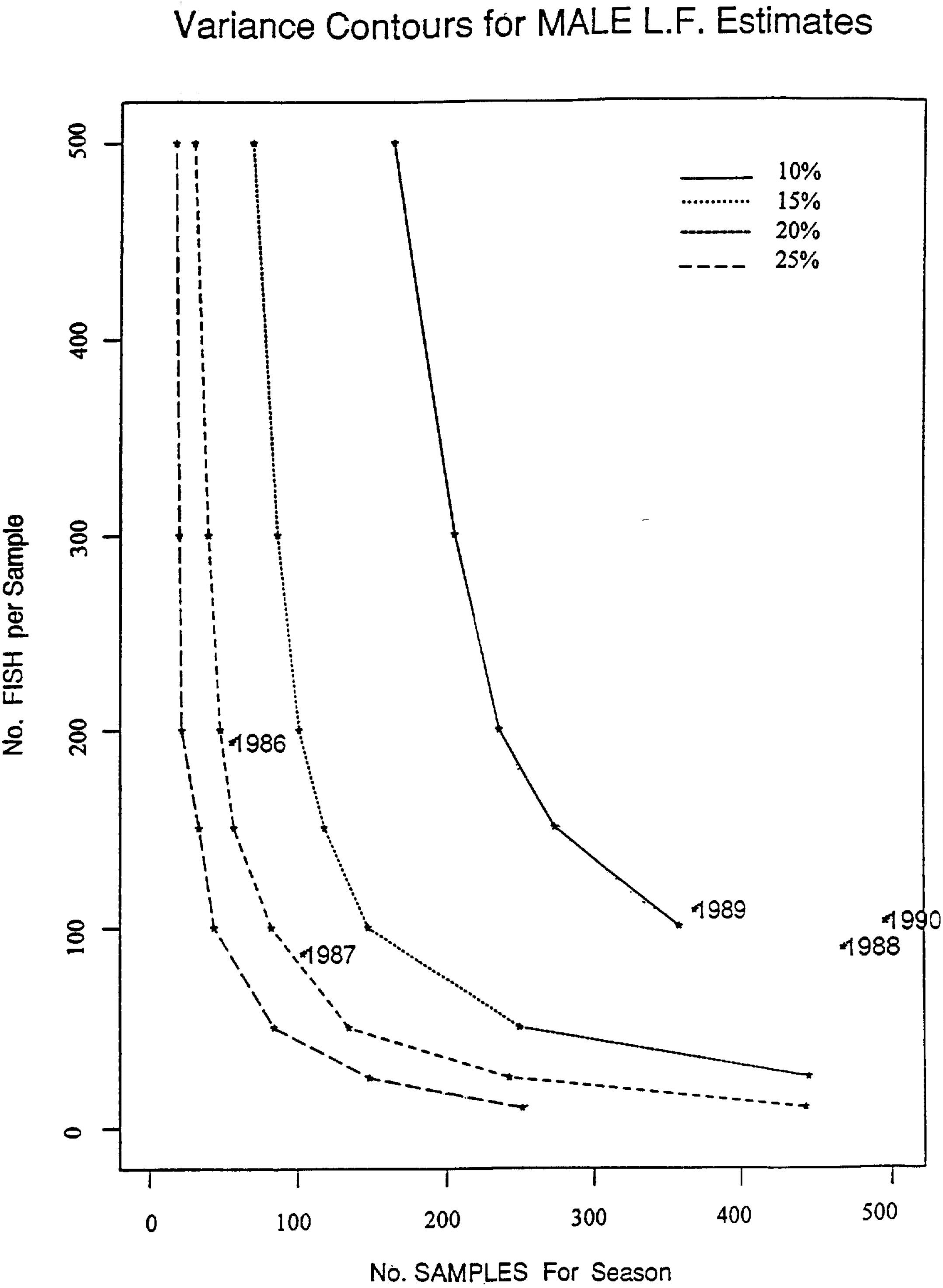


Figure 3. Variance contours of MWCV (all length classes) for male hoki determined by bootstrap simulations. Actual sampling regime for each year indicated by dates.

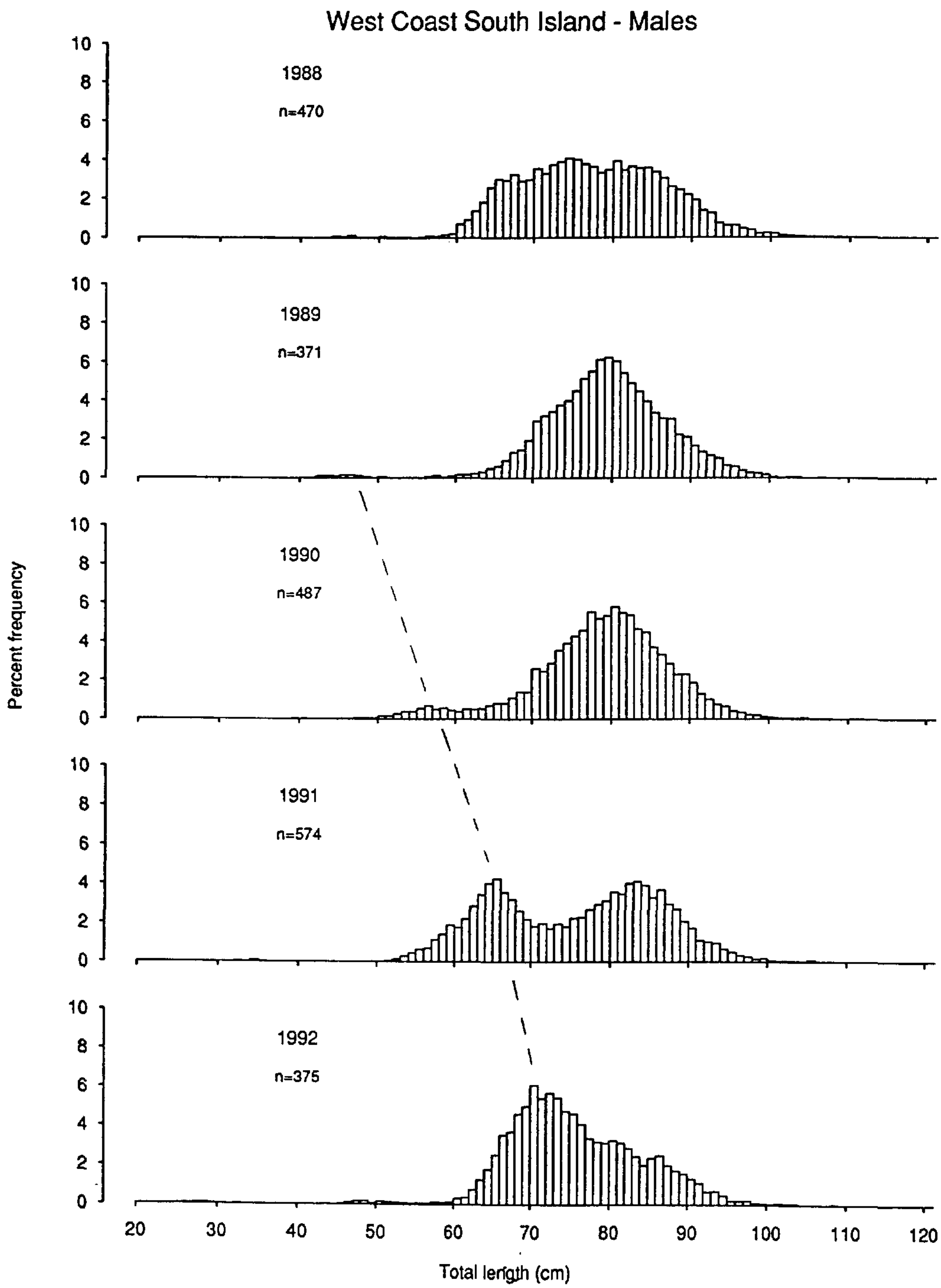
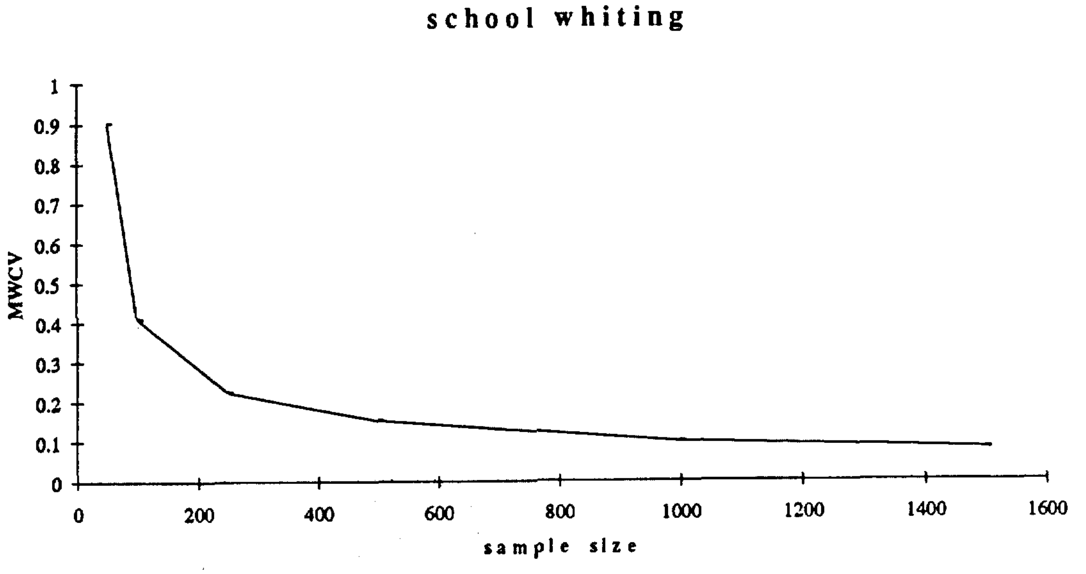


Figure 4. Percentage length frequency distributions for male hoki, west coast South Island, 1988 to 1992. The progress of the 1987 cohort is shown by the broken line.



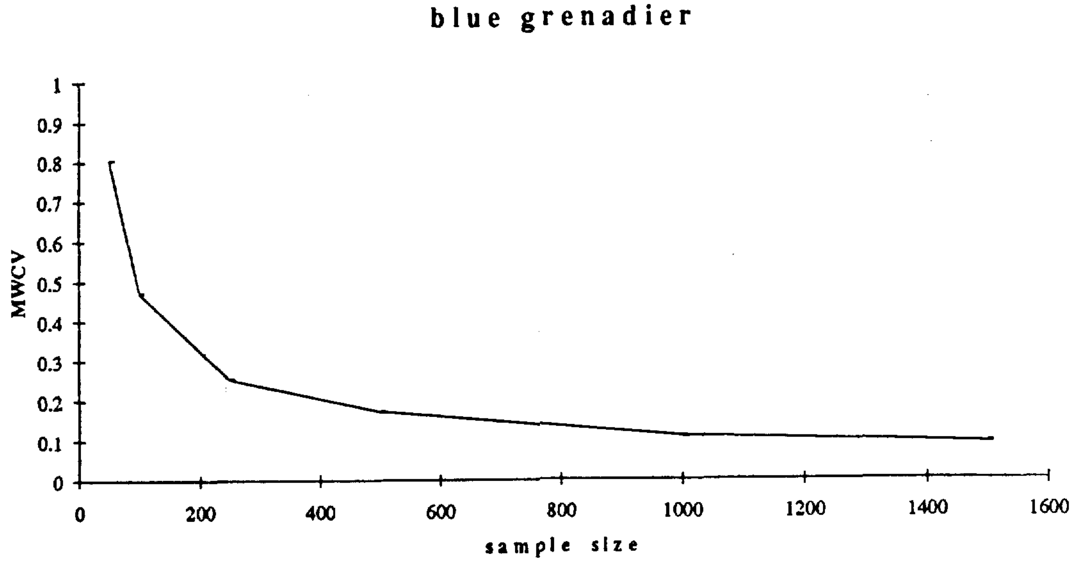


Figure 5. Mean weighted coefficients of variation (MWCV) for blue grenadier (hoki) and school whiting *(Sillago bassensis flindersi)* against the sample size of the age-length key determined from Monte Carlo simulations.