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Determining acceptable *c.v.*s on proportions of the three *Trachurus* species in the JMA 7 catch

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Final Research Report

Report Title	Determining acceptable *c.v.*s on proportions of *Trachurus* species in the JMA 7 catch
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7. Executive Summary

Data from the deepwater trawl fishery for jack mackerel in JMA 7 were extracted from the MFish catch and effort database and the MFish observer database.

Spatial stratification of the data was based on an examination of species proportions from the observer data, and an understanding of how the species composition varied between shallow and deeper water. Five spatial strata were defined. Because of the patchiness of the observer data temporal stratification was limited to annual aggregations.

A simulation method was developed to investigate aspects of a recent research results where standardised stock indices based on catch per unit effort (CPUE) were used as inputs to a stock reduction model to estimate virgin biomass for the two New Zealand species of jack mackerel (*Trachurus declivis* and *T. novaezelandiae*) in Fishstock JMA 7. CPUE was estimated for each species by applying species proportions estimated from observer data to the total jack mackerel catch and effort data. Development of the simulation method included the following activities:

- Automation of the original method.
- Determination of an appropriate distribution for drawing the simulated observer samples.

- Definition of a diagnostic measure of the variability in the synthetic observer species proportions.

Simulation runs based on a set sample weight of 300 kg showed a reduction in the variability of the estimated virgin recruitment with increasing observer coverage for both species, although the result was marked for *T. declivis* but less well defined for *T. novaezelandiae*. This result supported the working hypothesis underlying the research — that the species proportions estimated from the observer samples are a major source of uncertainty in biomass estimates from stock reduction model.

The stock reduction model may not be suitable for assessing this Fishstock. The suitability of other age-structured models should be investigated before further steps are taken in this work. However, this is secondary to continued work examining the required level of observer coverage to provide species proportions with acceptable *c.v.*s, which will benefit from some years of data collection in the fishery. In the meantime work should continue by investigating several aspects of the simulation method. Of particular importance are the following activities:

- Compare and contrast the use of separate stock indices with the use of stratum as a predictor variable.
- Investigate the use of distributions other than the negative binomial for the synthetic sample weights.
- Investigate improvement to the CPUE standardisation model (log normal) by comparing and contrasting the use of other models.

8. Scope of the document and objectives of the project

The scope of this report is to document research carried out under MOF1999/04F. The objectives for MOF1999/04F are closely associated with those of MOF1999/04E. Outputs from MOF1999/04F feed directly into MOF1999/04E. The two activities, summarising spatial and temporal strata and determining acceptable CVs, are fundamental to determining the required level of observer coverage as part of MOF1999/04E. The following were the objectives for MOF1999/04F:

- To investigate how the high level of uncertainty associated with estimates of species proportions of jack mackerel from the JMA 7 TCEPR fishery might be reduced.
- To make recommendations on the future of the current stock assessment approach.

9. Background

Species proportions were identified as the greatest potential source of uncertainty in a recent feasibility study using a stock reduction model to assess *T. declivis* and *T. novaezelandiae* in JMA 7 (Taylor 1999). Reliable estimates of species proportions are fundamental to jack mackerel stock assessments because the three species (including *T. s. murphyi*) are recorded in catch reports as the single species "jack mackerel". The estimates are used to determine individual catch histories for the three species and to adjust jack mackerel catches for use in catch per unit effort (CPUE) analyses.

The observer data used to produce species proportions for the study were patchy (Taylor 1999). The best time series estimate would be on a tow-by-tow basis which could then be applied to the tow catch before CPUE was estimated. Because of the sparse nature of the data, the best time series that could be produced was on quarterly basis, with data aggregated over three month periods. However, the variance was high between individual samples, and CVs on the quarterly mean values were unacceptable.

Little is known about the targeting strategy employed in the fishery. Information from Taylor (1999) showed a complex distribution of trawl shots in time and space, with targeting occurring in a number of sub-areas of the Fishstock and proceeding throughout the year, rather than being restricted to the summer months as had been previously described (Jones 1990). Because of the probability that species distributions vary in time and space (Taylor 1999), features of the temporal and spatial variation must be clearly defined to summarise strata in the fishery.

The simulation method for determining acceptable CVs for species composition estimates should produce useful guidelines to the amount of sampling necessary. It will also be used to investigate the sensitivity of the model abundance estimate to the method of temporal aggregation for the species proportions. Results of this work will provide insight into whether inadequate estimations of species proportions can be fixed easily by increasing observer coverage. High variance in species proportions estimates is the most likely cause of uncertainty in the biomass model but there may be other factors which need to be examined. For example, determining the combination of CPUE stock indices that best represents the JMA 7 fishery may need further work.

10. Methods

10.1 The data

The dataset compiled by Taylor (1999) was used as a basis for the present work and updated where necessary. The original data covered the period July 1989 to September 1997. Extracts were made to update the dataset to December 1999. Data were extracted from two sources: the MFish catch and effort database and the MFish observer database, which are referred to as "real-time" data below to distinguish them from simulated "observer" data. The selected catch and effort data were from the TCEPR trawl fishery for jack mackerel in JMA 7 and included the following fields for each tow:

- the date at the start of the tow,
- a vessel identification code,
- target species,
- the total jack mackerel catch in kilograms,
- speed of the vessel at the beginning of the tow,
- the tow duration in minutes,
- latitude and longitude,
- nationality of the vessel.

The date at the start of the tow was used to provide the year, month, and day of the tow, and CPUE was estimated as follows:

$$CPUE = \frac{\left(\frac{C}{1000}\right)}{\left(\frac{v * t}{60}\right)}$$

where C is the total jack mackerel catch in the tow (kg), v is the speed of the vessel at the beginning of the tow, and t is tow duration in minutes.

The selected observer data included the following fields for each tow:
- the date at the start of the tow,
- a trip identification code,
- a tow identification code,
- target species,
- latitude and longitude,
- the number of each species in the observer sample,
- the weight of each species in the observer sample.

Once spatial stratification was complete, a stratum identification code was added to each tow in the two datasets. Time variables based on date (year, month, and day) were also added to enable selection by time intervals specified below.

Extensive exploratory data analysis (*EDA*) had been carried out by Taylor (1999). In the present case initial exploration was restricted to the more simple approach of identifying any outliers, and either adjusting them where there was an obvious error, or deleting the record where an adjustment could not be made. A total of 153 tows with a speed that lay outside the range of 3.5–6.5 kn were discarded. The distribution of total jack mackerel catch varied between 1 and 130 t, with 81% of catches being 11.5 t or less.

Catch (t)	0.5	1.5	2.5	3.5	4.5	6.5	7.5	8.5	9.5	10.5	11.5	>11.5
Percentage of data	27	14	9	7	6	6	4	3	3	2	3	16

All tonnages seemed reasonable and were included in the dataset, although only five catches were greater than 75 t (i.e., 78, 82, 83, 116, and 130 t). Maximum capacity of the trawls was not available to test the validity of these values.

Some *EDA* was carried out in conjunction with preliminary runs of the simulation method. As a consequence the following criteria were set:
- Mean jack mackerel weights less than 0.2 kg and greater than 1.8 kg were excluded (based on known distributions of jack mackerel weights — Taylor, unpublished data).
- Data were only included where the number of one of the species was greater than 36 fish.

10.2 Stratifying the data

The need for stratification arose from information on temporal and spatial patterns in the data shown by Taylor (1999). The data were examined for patterns or consistent features to determine how they might be stratified in time and space. Stratification was based primarily on the distribution of estimated species proportions from the observer data. To identify spatial patterns, the estimates for each observed tow were plotted by position onto a map of JMA 7. Three plots were produced, one for each species. Temporal patterns were identified by examining tabulated species proportions by year, month, and species.

The spatial strata so determined were then overlaid onto a map plot of tow positions for the catch and effort data. Some modification of the stratum boundaries were made based on how well the tow positions fell within them.

10.3 The simulation method

A simulation method was developed to investigate aspects of the method described by Taylor (1999) where standardised stock indices based on CPUE were used as inputs to a stock reduction model to estimate virgin biomass for the two New Zealand species of jack mackerel (*Trachurus declivis* and *T. novaezelandiae*) in Fishstock JMA 7 (Appendix 1). Development of the simulation method was based on an outline formulated from discussions with members of the pelagic working group (Appendix 2) and included the following activties:

1. Automation of a modified version of Taylor's (1999) method.
2. Determination of an appropriate distribution for drawing the simulated observer samples.
3. Definition of a diagnostic measure of the variability in the synthetic observer species proportions.

Taylor's (1999) method was characterised by CPUE series derived using quarterly species proportions, catch histories based on annual means of species proportions, and summer/winter stratification of the catch and effort data. Key differences in the simulation method were that the CPUE series was based on species proportions averaged by year and the summer/winter stratification was not applied. A flow chart of the simulation method is shown in Appendix 3.

10.3.1 Inputs to the model

There were three input variables whose values could be fixed for individual model runs. Their influence was examined by comparing runs where different fixed values of the particular input had been used.

1. *Observer coverage* was defined as the proportion of tows "observed". The number of tows to be "observed" was calculated by multiplying observer coverage by the number of tows in each year. Tows were distributed among the strata by sampling randomly from 4 strata with a probability given by the historic proportion of tows in each year:stratum combination. This allowed some (random) variation in the number of "observed" tows amongst the strata around the average distribution of

tows. However, any change in the pattern of fishing over time is not accounted for by this procedure.

2. *Observer coverage* was fixed over all years.

3. *Sample weight* was defined as the weight of an "observer" sample (kg). Species sample weights in a year,stratum bin were drawn from a negative binomial population with a mean given by the mean species weight for that bin. The negative binomial shape parameter (θ), which relates the mean (μ) to the variance according to $\sigma^2 = \mu + \mu^2 / \theta$, was constant for each species and simulation.

4. The negative binomial distribution was chosen above the Poisson distribution to provide greater flexibility. The maximum likelihood estimates from the observer data were relatively small (0.88, 0.72 and 0.26 for *T. declivis*, *T. novaezelandiae*, and *T. s. murphyi* respectively) — i.e., all were less than 1 — suggesting the Poisson could not adequately describe the data. However, it is unlikely that the observer data are representative enough to provide reliable estimates of θ. Therefore, larger values of θ (9, 7 and 3 for *T. declivis*, *T. novaezelandiae*, and *T. s. murphyi* respectively) were also tried.

5. *Sample weight* was fixed for all "observed" tows.

6. The *time interval* for averaging "observed" species proportions was fixed at 1, 2, or 3 months.

10.3.2 Generating the simulated "observer" database

This consisted of the following five steps.

1. The level of observer coverage was selected and fixed, and, based on this value, a subset of the catch and effort data was selected as a basis for the simulated "observer" database.

2. Using the real-time observer data, species proportions were calculated from the ratio of species sample weight observed in each stratum to the total sample weight for that year. Interpolation and smoothing were required for bins (year, stratum) with no observer coverage or where sharp changes in species proportions caused problems in the simulation.

3. The input value for sample weight was selected and fixed.

4. The mean species proportion was multiplied by the sample weight to provide a table of mean species weights by year and stratum. These means were used to define the negative binomial distributions (one for each species) from which the synthetic samples were drawn.

5. For each tow in the simulated "observer" dataset (derived in step 1 above) a synthetic sample was drawn from the negative binomial populations defined by the species means for the tow's year-stratum bin, using the S-plus function *rnegbin*

(Venables & Ripley 1999). These samples comprised a set of three species weights (one for each species) which were converted to species proportions as the ratio of the individual species weight to the sum of the three species weights. These were added to the simulated "observer" dataset and provided the complete simulated "observer" database.

10.3.3 Computing species simulated catch and CPUE

"Observer" species proportions that were used to determine species CPUE were averaged over year, stratum, and the time interval specified. A varying bin time interval enabled an investigation of the effect of the averaging process described in Taylor (1999). Yearly averages were also calculated to estimate annual species catch which were required by the stock reduction model. Averages were calculated from the ratio of species catch observed in each bin to the total catch for that bin. Since the bin sample weights were different, standard deviations were estimated using a weighted mean square of the deviations in each bin (Snedecor, 1967). This is slightly different to the approach used by Taylor (1999) who computed the mean and standard deviations directly from observed sample proportions.

CPUE for each tow in the catch and effort database was computed by multiplying total CPUE by the averaged simulated species proportion of the (year, stratum, time interval) bin to which the tow belongs. Species total catch for the years in the "observer" database was obtained similarly, except that annual simulated species proportions were used.

10.3.4 Generating simulated species abundance indices

Simulated abundance indices for *T. declivis* and *T. novaezelandiae* were standardised using a log-normal CPUE model similar to that described in Taylor (1999) and including the predictor variables determined as significant in that study. Rather than develop indices for each stratum, however, the simulation model included stratum as a predictor variable. This simplification was used mainly to increase simulation speed. It should be noted that the model only allows for an average stratum effect (over all years). Variability in the strata between years was therefore excluded. Thus, standardisation of the simulated abundance indices was performed using the following model:

$$\log CPUE = year + month + nation + stratum + latitude + longitude + \varepsilon$$

10.3.5 Estimating species virgin recruitment from stock reduction models

A modified version of the stock reduction model described in Taylor (1999) used simulated catch histories and abundance indices for *T. declivis* and *T. novaezelandiae* to estimate virgin recruitment for those species. Separate stock reduction models were used for each species, whereas the Taylor (1999) model utilised a combined sums-of-squares approach. The sums of squares attributable to each abundance index is equally weighted in a combined model, so the simplification achieved by using two stock reduction models in the simulation is probably justified.

Virgin recruitment was chosen as the parameter of interest because it was easily accessible as an output from the stock reduction model. While there are other parameters, such as current biomass, maximum exploitation rate, or virgin biomass, which are more widely used and probably more interesting, absolute output values from the simulation are meaningless in a fishery context at this time. Virgin recruitment provided a measure by which simulation runs could be compared, and is perhaps more useful because there is less tendency for the reader to attach importance to it in a fishery context. Once a method is fully developed and reliable data are available, output parameters will be chosen according to the needs of the current stock assessment method.

10.3.6 Simulation outputs

The simulation method comprised 1000 iterations in each "simulation run". For each iteration two outputs were produced and stored for further analysis: the *c.v.*s estimated from the set of species proportions for the iteration; and the virgin recruitment parameter from the stock reduction model for each species.

10.3.7 Expressing uncertainty in the species proportions

a) Examining variations in observer coverage

Observer coverage was set as a fixed proportion of tows in each of the simulation runs. Choice of the "best" observer coverage was required for MFish Project MOF1999/04E and was based on interpretation of the test statistic, given the fixed inputs: the shape parameter (θ) of the negative binomial distribution chosen for each species; sample weight; and observer coverage.

The test statistic is somewhat obscure and requires careful description. It was named the *diagnostic "noise" figure* and is a measure of how well we know the *c.v.*s on the synthetic species proportions. It is itself a *c.v.*, and features of its estimation are as follows:

- The simulation method comprised 1000 iterations in each "model run". For each of the iterations a set of species proportions was produced, which was accompanied by a set of *c.v.*s. These are the *c.v.*s on the species proportions, and there were 1000 sets of them, one for each iteration of the "model run".

- The diagnostic "noise" figure can be referred to as the *c.v.* on the *c.v.*s. It is the *c.v.* based on the mean of the *c.v.*s from the 1000 iterations of a "model run". It is therefore a measure of the variability in the *c.v.*s of the synthetic species proportions and can be referred to as a measure of how well we know the *c.v.*s on the synthetic species proportions.

b) Examining performance of the stock reduction model

For each of the 1000 iterations of the "simulation run" a set of species virgin recruitment parameters was produced. To investigate the effect of observer coverage on performance of the stock reduction model, 95% confidence intervals (*CI*s) were constructed for the virgin recruitment parameters and used to compare uncertainty in the different simulation runs.

10.4 Species proportions from FAO data for area 81

FAO data were examined for their potential use in estimating the proportions of *Trachurus declivis, T. s. murphyi*, and *T. novaezelandiae* in the southwestern Pacific Ocean (FAO Area 81). The following sources were used.

- The 1995 FAO Yearbook of fishery statistics on catches and landings.
- The database at http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp.

These sources were unable to provide appropriate data for estimating species composition. Although landings data are provided by species in many areas, the three jack mackerel are not individually listed for area 81.

10.5 Time series of data required for a viable stock assessment for JMA 7

It is too early in the development of this work to make reliable predictions about the length of the time-series of data that would produce a viable result from the stock reduction model. Predictions about the number of data points constituting an acceptable stock index can be based on experience from other studies, but the multi-species aspect of the present work and the requirement for reliable species proportions, confound any attempts at definition at this time.

10.6 Identifying uncertainty in the model

In developing the simulation method some sources of uncertainty could not be addressed, either because they fell outside the scope of the objective for the present work, or because they required some years of reliable data. These were recorded as requiring attention at a later time.

11. Results

11.1 Stratifying the data

Based on initial examination of species proportions from the observer data, and an understanding of how the species composition varied between shallow and deeper water (Horn 1991), eight spatial strata were defined (Figure 1). Summaries of the catch and effort data by year, month, and these strata, showed some consistent annual patterns of fishing by month and stratum from 1989 until the mid-1990s that changed somewhat in the most recent years. Re-examination of observer data showed poor coverage in some strata and the number of strata were reduced to five as follows:

- Strata 1 and 3 were combined to give stratum 1.
- Strata 2 and 4 were combined to give stratum 2.
- Stratum 5 was renamed as stratum 3.
- Strata 6 and 8 were combined to give stratum 4.
- Strata 7 was renamed as stratum 5 but took no further part in the simulation.

Because of the patchiness of the observer data, temporal stratification was limited to annual aggregation.

11.2 Determining the influence of uncertainty in the species proportions

a) Examining variations in observer coverage

The simulation was run with the maximum likelihood estimates of θ (0.88, 0.72, and 0.26 for *T. declivis*, *T. novaezelandiae*, and *T. s. murphyi* respectively) from the "real-time" observer coverage. An initial run, based on extreme input values for observer coverage and sample weight (100% and 1000 kg respectively), provided a baseline measure for the test statistic of 14%. This was a measure of the least amount of variability in the *c.v.* of the species proportions that could be attained reasonably at the specified values of θ, and provided a comparison for the test statistic's output by the simulations.

The simulation was run using five levels of observer coverage — 5, 10, 20, 35, and 50% (the current level is about 7%) — and several levels of sample weight (30, 65, and 300 kg). Because initial results showed that sample weight had little effect on the test statistic, only results for 300 kg are considered here. Plots of absolute values of the test statistic for *T. declivis* and *T. novaezelandiae* against observer coverage for a sample weight of 300 kg (Figure 2) suggests that at an observer coverage of 50% the variability is very similar to the baseline measure and that most of the reduction in the variability occurs at low values of observer coverage.

The simulation was rerun using values of θ that were greater by a factor of 10 (9, 7, and 3 for *T. declivis*, *T. novaezelandiae*, and *T. s. murphyi* respectively) to investigate the difference in response between "low" and "high" values of θ (Figure 3). In this case the test statistic was normalised to 100% observer coverage. There is little difference in the response to the two levels of θ.

From the plots it is clear that uncertainty about the synthetic species proportions is almost halved, with an increase of observer coverage from current levels to 20%. By increasing observer coverage still further, to 35%, uncertainty about the synthetic species proportions is reduced to about 15% of its value at current levels of observer coverage. After this there are only small reductions for relatively large increases in observer coverage. A reasonable target for observer coverage would therefore be about 30% coverage of tows.

b) Examining performance of the stock reduction model

The simulation was run to investigate variability in the virgin recruitment from the stock reduction model, using three levels of observer coverage (5, 20, and 35% — the current level is about 7%), several levels of sample weight (30, 65, and 300 kg), and the maximum likelihood estimates of the negative binomial shape parameter θ from the observer coverage (*see* previous section).

Results for *T. declivis* and *T. novaezelandiae* from the runs with a sample weight of 300 kg are shown in Figure 4 as plots of the log of virgin recruitment (log R_0) with 95% *CI*s. For *T. declivis*, the width of the *CI* is reduced markedly with an increase in observer coverage. The result for *T. novaezelandiae* is not so well defined.

11.3 Identifying uncertainty in the model

Several potential sources of uncertainty were identified that require investigation in the future.

a) Investigate improvement to the log normal CPUE standardisation model by comparing and contrasting the use of other models and investigating the use of other predictor variables.

   The distribution of catch data suggests that there may be problems arising from the high number of small catches. There is no readily available model that is satisfactory for this case — the Poisson is generally too overdispersed, the negative binomial often does not converge, and the log-normal does not include a distribution for negative values.

b) Compare and contrast the use of separate stock indices for each stratum with the use of stratum as a predictor variable. Taylor (1999) included several stock indices, one for each stratum, but time constraints in the present study prompted the use of stratum as a predictor variable.

c) Investigate the use of other distributions for the sample weights.

d) Investigate the sensitivity of the stock reduction model to the input parameters.

12. Conclusions and discussion of future stock assessment

Progress has been made in identifying a level of observer coverage that almost halves the uncertainty in the *c.v.*s of the species proportions. The results of the simulation suggest that most of the reduction in the diagnostic "noise" figure occurs at an observer coverage somewhere between the minimum value included in the simulation (5%) and a level of 25 to 35%. Setting a target level of 30% based on this result seems reasonable and allows some flexibility, given that there is little difference in the test statistic between 25 and 35%. Future work should concentrate on examining this issue more thoroughly, and include those sources of uncertainty directly relevant in this context (a, b, and c in Section 11.3 above).

Reducing uncertainty in the species proportions by increasing the level of observer coverage appears to improve the performance of the stock reduction model by decreasing the width of the 75% *CI* for both species. This is more pronounced for *T. declivis* than *T. novaezelandiae*. The cause of the difference for the two species is unknown, although a preliminary examination of the likelihood surfaces from the results of Taylor (1999) indicate that there is no well defined minimum for *T. novaezelandiae* (Ken Richardson unpublished data).

The inverse relationship between the width of the 75% *CI* and the level of observer coverage supports the conclusion by Taylor (1999) that species proportions are a major source of the uncertainty in biomass estimates using a stock reduction method for *T. declivis* and *T. novaezelandiae* in this Fishstock. Taylor (1999) investigated the feasibility of using an age-structured model to estimate biomass and produce yield estimates for *T. declivis* and *T. novaezelandiae* with mixed results. Development of a stock assessment model for this Fishstock is currently in its early stages and the stock reduction model was used as an example of an age-structured model for the purposes of the exercise, but failed to provide reliable biomass (and therefore yield) estimates for the Fishstock.

It is possible that a stock reduction model is unsuitable for this Fishstock. Its use in examining the feasibility of using an age-structured model has highlighted a number of areas of uncertainty, and it may be fruitful to examine its suitability in more detail and investigate the use of other possible models. The underlying cause of the model's continued inability to significantly reduce the width of the 95% *CI*s for *T. novaezelandiae* may be an absence of any reduction in the stock of this species.

However, it is more likely that CPUE, in its present form at least, is an inadequate abundance index for this fishery. Taylor (1999) showed temporal and spatial patterns in the data, and spatial stratification was included as a predictor variable in the present standardisation as a strategy to incorporate this variability. Systematic examination may determine whether this is the best approach, or whether individual stratum abundance indices should be used. Further definition of stratum boundaries using data from more extensive observer coverage could further reduce uncertainty in the simulation. Ultimately, however, a fishery-independent index is the most desirable. Acoustic surveys may provide more reliable abundance indices, and these could be compared with CPUE indices for the same year to help determine the relative merits of each method.

The results of this work were used in MFish Project MOF1999/04E to propose a more extensive level of observer coverage, which could provide more extensive data from the fishery. Uncertainty in the value of shape parameter of the negative binomial distribution (θ) is probably a result of the patchiness of the observer data. More complete coverage will help to provide better estimates of θ for the three species, and consequently, a better estimate of the required observer coverage.

The complexities of jack mackerel stock assessments are further complicated by our present inability to age the third species, *T. s. murphyi*. This is currently being addressed under MFish project JMA2000/02, Age and growth of the Peruvian jack mackerel. Once this has been achieved, *T. s. murphyi* can be included in the stock assessment.

13. Publications

Nil.

14. Data Storage

Nil.

15. References

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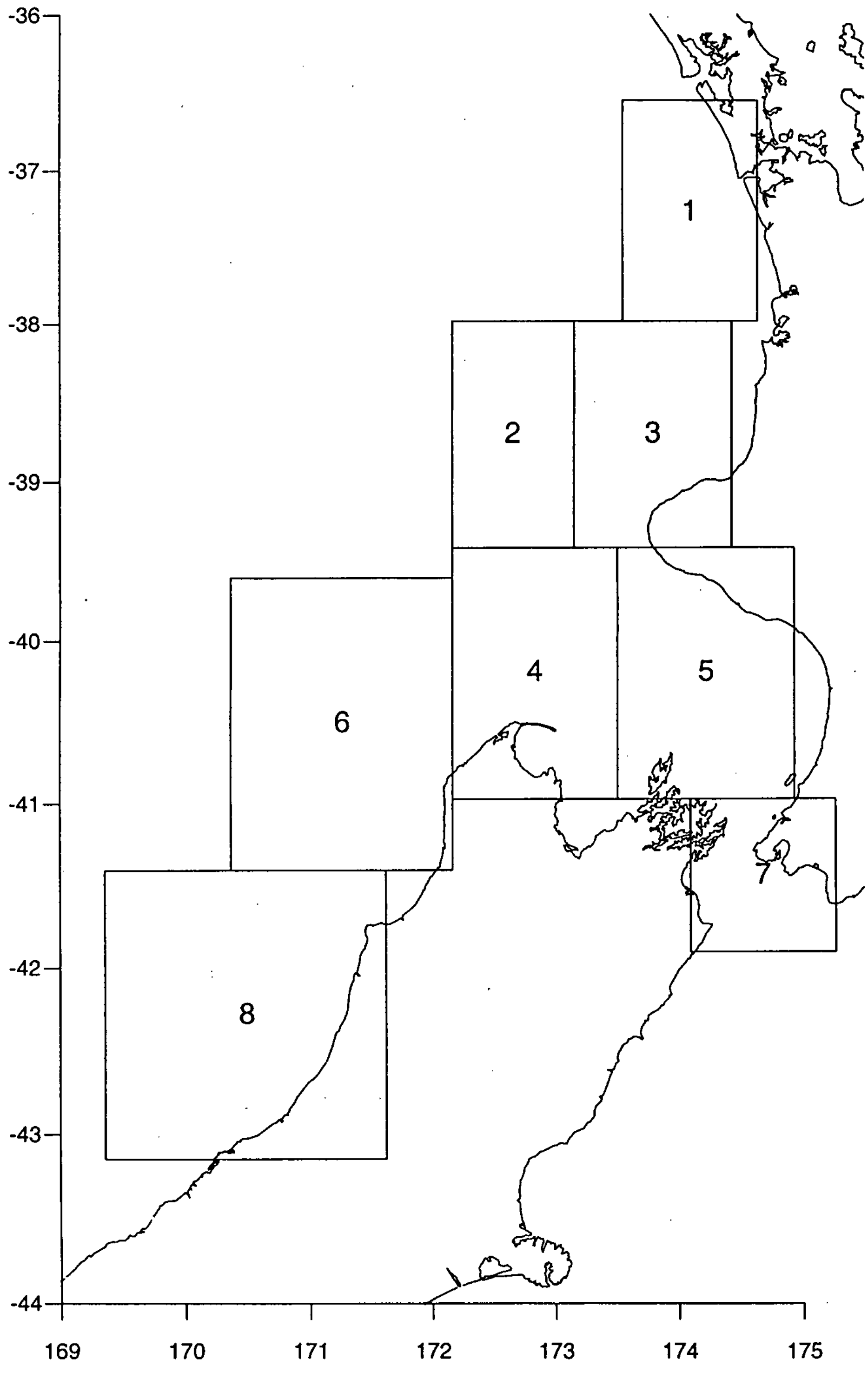
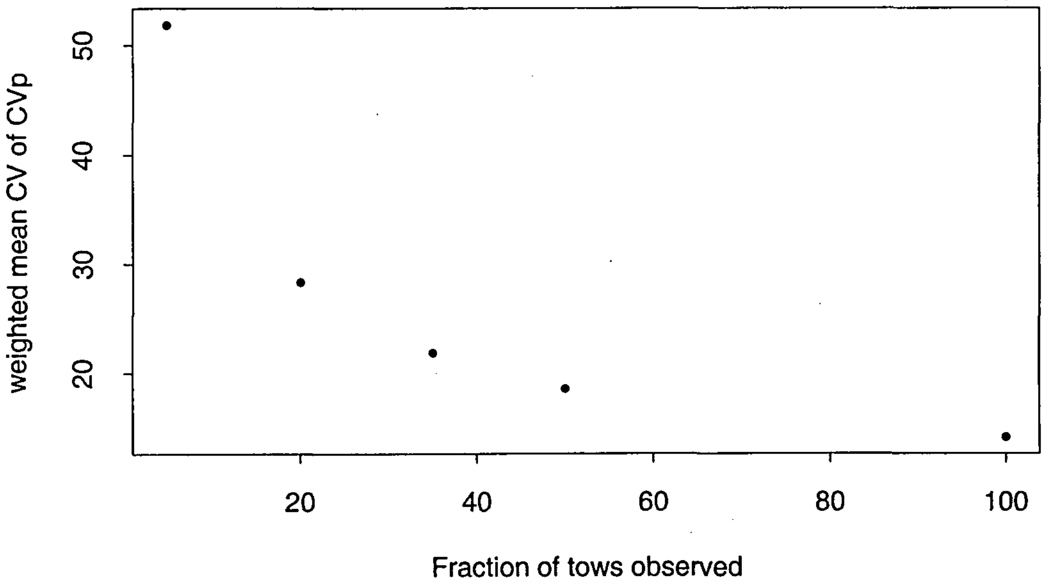


Figure 1: Boundaries of initial strata in JMA 7.



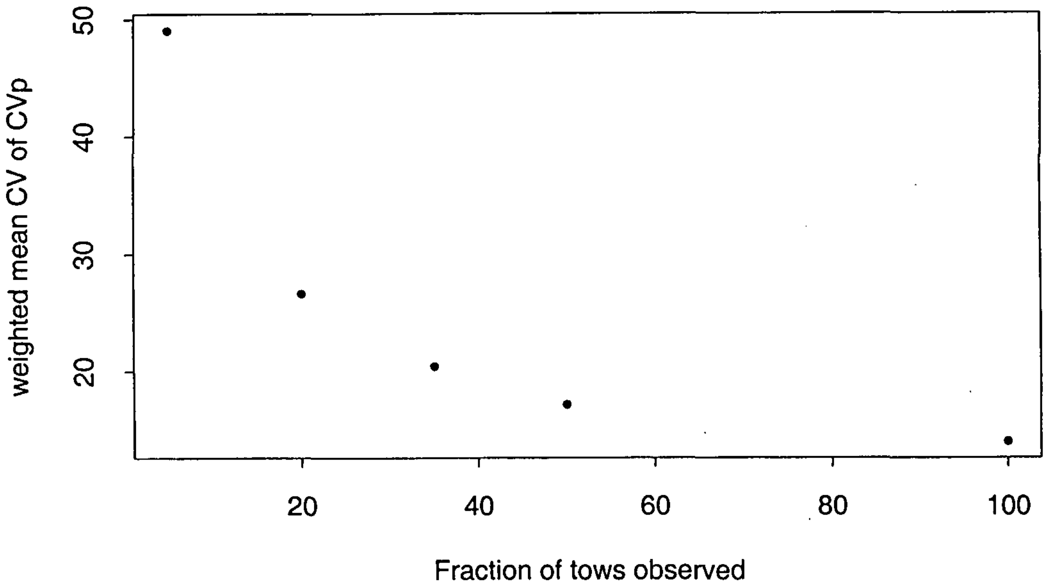


Figure 2: Plots of absolute values of the diagnostic "noise" value (weighted mean *CV* of the *CV*s of the species proportions p — CV_p) from the 1000 iterations of the simulation "model run", against the proportion of observer coverage as fraction of tows observed for *Trachurus declivis* above and *T. novaezelandiae* below; simulation runs were for sample weight fixed at 300 kg.

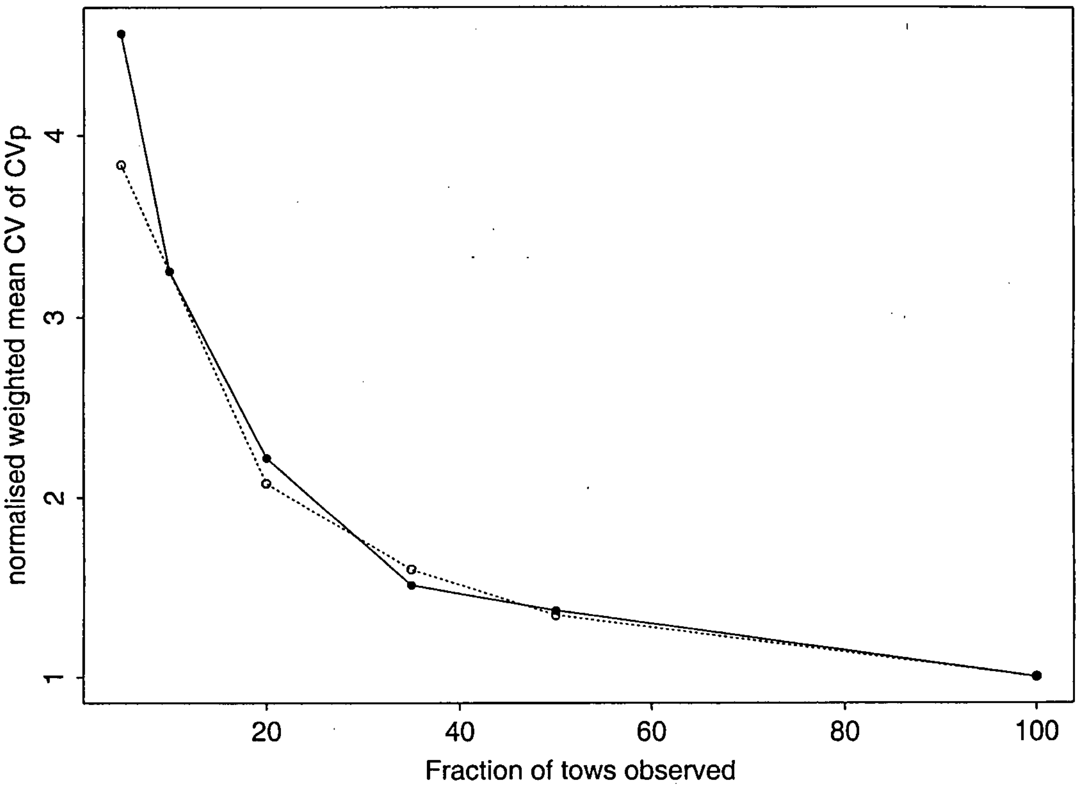


Figure 3: Plots for two series of θ of the diagnostic "noise" figure (CV of the CVs of the species proportions p — CV_p) from the 1000 iterations of the simulation "model run" normalised to 100%, against the proportion of observer coverage as fraction of tows observed for *Trachurus declivis*. Closed circles indicate "low" values of θ (0.88, 0.72, and 0.26 for *T. declivis*, *T. novaezelandiae*, and *T. s. murphyi* respectively; simulation runs were for sample weight fixed at 300 kg.

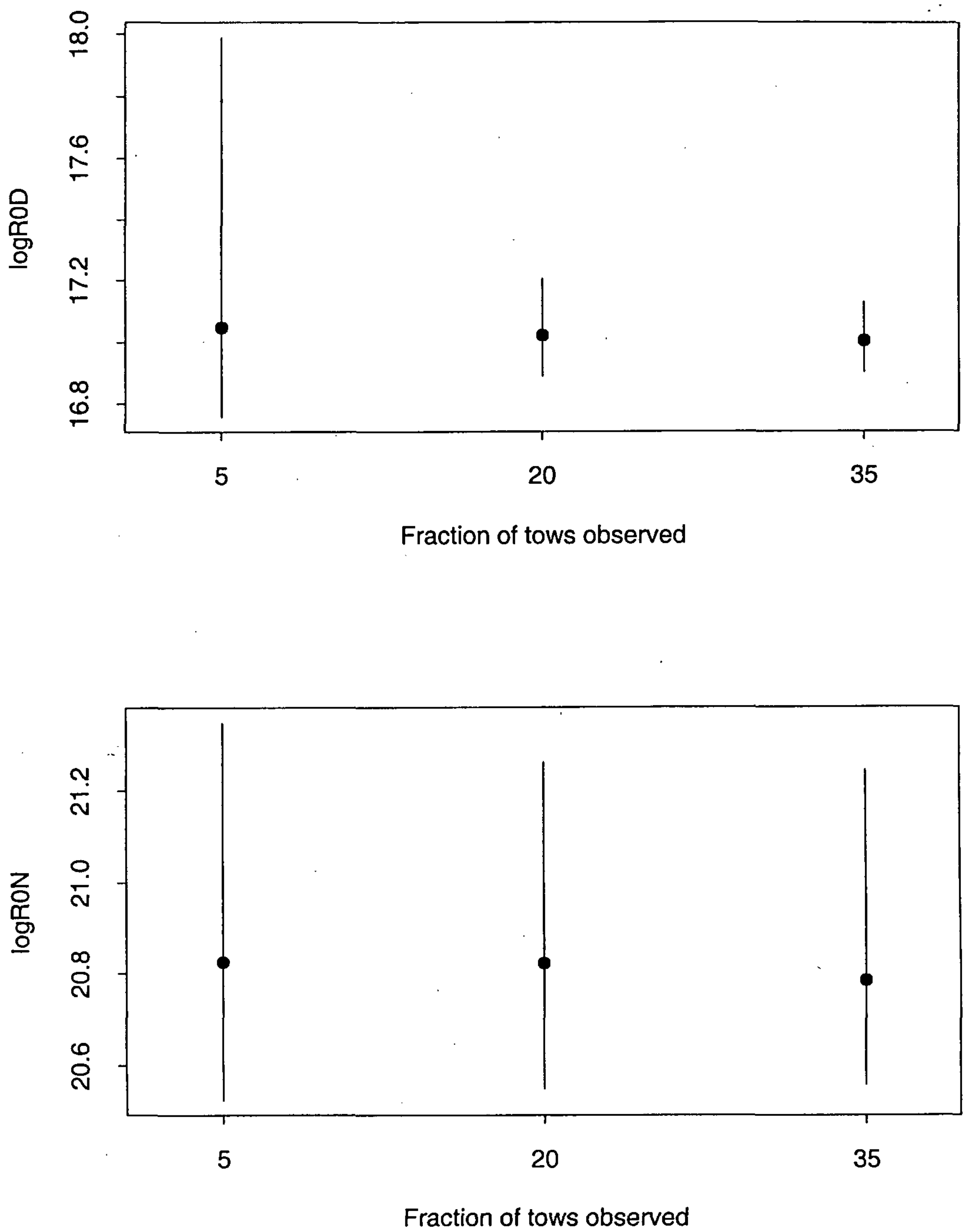
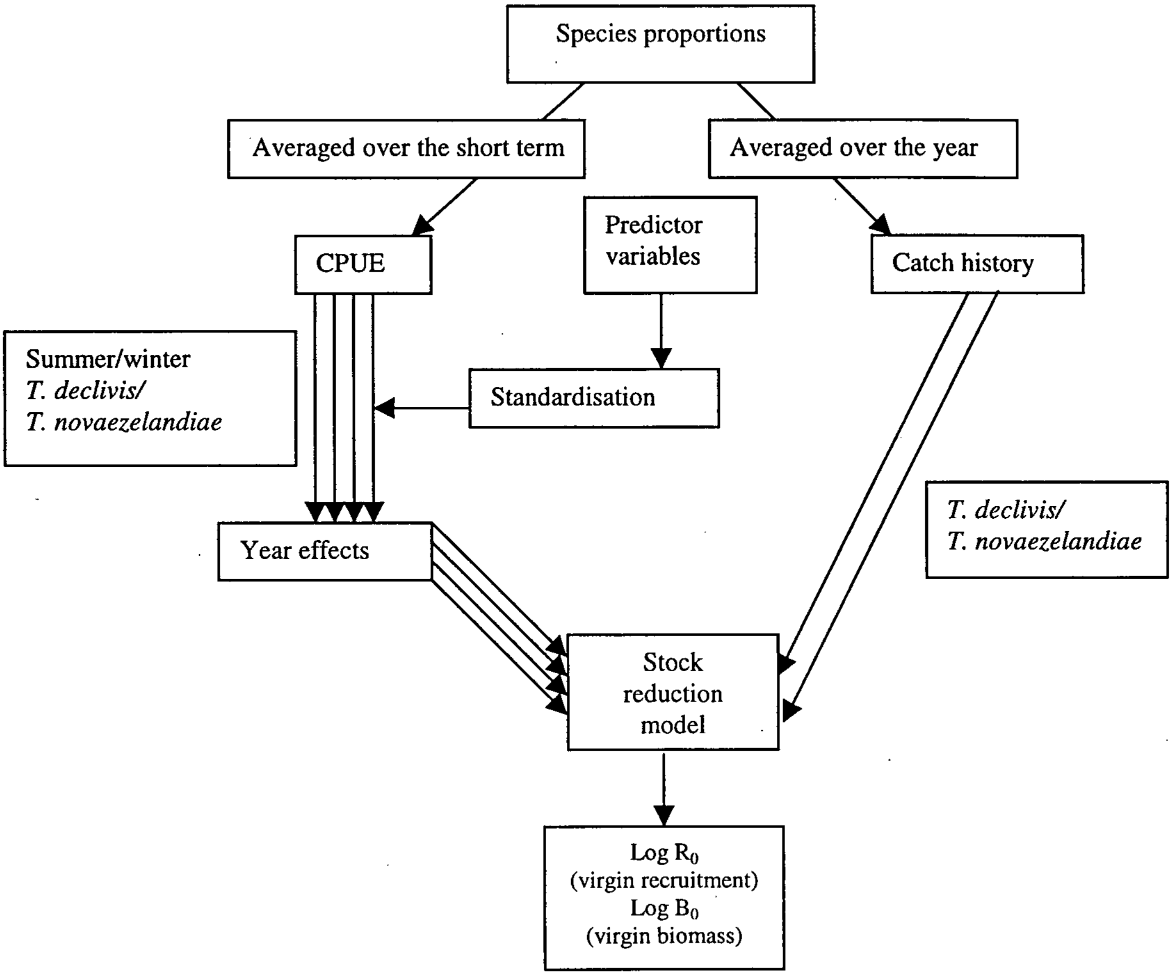


Figure 4: Plots of estimated values for log virgin recruitment (R0) with 95% confidence intervals (*CI*) from the stock reduction model, against proportion of observer coverage as fraction of tows observed for *Trachurus declivis* (D) above and *T. novaezelandiae* (N) below; to illustrate reduction in the width of the 95% *CI* achieved by increasing the level of observer coverage; simulation runs were for sample weight fixed at 300 kg.

Appendix 1: Taylor's (1999) method.

Taylor's (1999) method can be represented by the following flowchart.



Appendix 2: The proposed method.

This was based on the following outline which had been formulated as a result of discussions with pelagic working group members.

- Produce 1000 sets of synthetic species proportions data at each of several CV levels (e.g., 10%, 15%, 20%).
- Determine year effects by standardising the CPUE series generated by each of the 1000 datasets at each CV level.
- Rerun the stock reduction model for each stock index (i.e., for each set of year effects) to produce CVs on the abundance estimate from the model for each of the species proportion CV levels.
- Set an acceptable CV for the abundance estimate, and plot CV(*model abundance estimate*) against CV(*species proportion*) to determine a suitable CV(*species proportion*).
- Levels other than the original 10%, 15%, 20% can be examined as the analysis proceeds and the approximate target value is identified.
- The effect of applying temporally aggregated species proportion estimates to catches can also be examined as the analysis proceeds.

Appendix 3: Main features of the simulation method