Standardised CPUE analyses for *Trachurus declivis* and *Trachurus novaezealandiae* in the JMA 7 jack mackerel fishery to 2004–05

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This series continues the informal New Zealand Fisheries Assessment Research Document series which ceased at the end of 1999.
EXECUTIVE SUMMARY


The JMA 7 jack mackerel fishery is located off the west coast of the South and North Islands, with most catch being taken off the North Island. It is a target fishery, with most catch taken by large trawlers.

The jack mackerel catch (recorded as JMA) is actually of three separate species: Trachurus declivis (JMD), Trachurus novaezealandiae (JMN), and an invasive species Trachurus murphyi (JMM). Because the commercial catch and landings are recorded under JMA, observer data are needed to apportion the catch amongst the three species, a complicating factor in analyses of the fishery. A Bayesian analysis for species proportions was applied to the TCEPR fishery in JMA 7 to estimate catch-effort for JMD and JMN. This estimated catch-effort was then used to derive standardised CPUE indices for JMD and JMN from 1989–90 to 2004–05. Based on changes in fleet composition and unstandardised CPUE indices, the JMD and JMN standardisations were split into early period (1990–96) and late period (1997–2005) series, so a total of four standardisations was done.

For early period JMD the standardised CPUE index shows a downward trend from the 1990 fishing year, reaching about 43% of its initial value in 1996.

The late period JMD index is more irregular with a 45% drop from 1997 to 1998, then subsequently an irregular upward trend. In 2005 the index is nearly double its value in 1997.

For the early period JMN the standardised CPUE is essentially flat for 1990–91, and then gradually declines. In 1996 the index is 34% of its value in 1990.

The late period JMN index doubled from 1998 to 1999 (there was no vessel coverage in 1997). Subsequently it remains flat but irregular until a 27% drop in 2003, after which it remains flat. In 2005 the index is nearly double its value in 1998.
1. INTRODUCTION

This document is a report on work carried out as part of the Ministry of Fisheries project JMA200402.

The JMA 7 jack mackerel fishery is located off the west coast of the South and North Islands, with most catch being taken the North Island (Figure 1). Most of the jack mackerel catch is taken by targeted trawling (midwater or bottom) by large boats.

![Figure 1: The location of the JMA 7 management area off the west coast of the South and North Islands (boundary marked by thick solid lines). It is subdivided further into statistical areas, with most of the jack mackerel being taken in 034-037 and 040-042 (i.e., from about midway down the west coast of the South Island, north to Manukau harbour).](image)

The jack mackerel catch (recorded as JMA) is actually of three separate species: *Trachurus declivis* (JMD), *Trachurus novaezelandiae* (JMN), and an invasive species *Trachurus murphyi* (JMM). Because the commercial catch and landings are recorded under JMA, separate observer data are needed to apportion the catch amongst the three species, a complicating factor in analyses of the fishery. Previous analyses of species proportions have concentrated on the temporal aspect, allocating species proportions for catch by year, or sometimes at the more finely detailed level of quarter (Taylor 1999). A recent Bayesian analysis of species proportions in JMA 7 has also incorporated a spatial component, in addition to a seasonal component, and was applied to the TCEPR catch-effort for JMA 7 to estimate catch-effort for JMD and JMN (Rohan et al. 2006). This estimated catch-effort was then used to derive standardised CPUE indices for JMD and JMN.
Standardised catch per unit effort (CPUE) analyses were carried out using Generalised Linear Models (GLMs), based on the procedure explained by Vignaux (1994) and as modified by Francis (2001). The aim behind this type of analysis is to remove the effect of changes in fishing patterns and conditions (e.g., the type of vessel used, when fishing was done, fishing techniques used) on the catch rate, leaving a component that is presumed to be proportional to the biomass of fish present.

Four standardised analyses were carried out based on jack mackerel TCEPR data: (1) using tows for which the derived JMD catch was non-zero (early and late period), and (2) using tows for which the derived JMN catch was non-zero (early and late period).

2. THE INITIAL JMD AND JMN DATA SETS

The initial data extract consisted of all TCEPR catch-effort records from the jack mackerel bottom trawl and midwater fisheries from vessels operating within JMA 7 from 1990 to 2005. This data set contained 48,139 tows for which jack mackerel was either targeted or caught. Only tows that targeted and caught jack mackerel were retained (29,020 tows), these tows accounting for 93% of the weight of jack mackerel caught. About 6% of the tows that targeted jack mackerel recorded no jack mackerel catch.

Tows were then excluded for which quantities fell outside reasonable bounds (Table 1) leaving 60% of the tows from the initial data set and retaining 86% of the jack mackerel catch.

Table 1: Range checks performed on the initial data set. The range checks for speed, headline height, and wingspread are the same as those used by Taylor (1999). Ambiguous bottom trawls are those for which the ratio of wingspread to headline height ratio is close to one, a value more typical for midwater trawls (Taylor 1999). The range checks for catch, duration, and depth are conservative values mainly based upon inspection of the boxplots for the variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Range</th>
<th>Number outside range</th>
<th>Contained NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>6.5-12 km/hr</td>
<td>96</td>
<td>9</td>
</tr>
<tr>
<td>Headline height of tow</td>
<td>&lt; 130 m</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>Wingspread of tow</td>
<td>&lt; 330 m</td>
<td>30</td>
<td>-</td>
</tr>
<tr>
<td>Ambiguous bottom trawls</td>
<td>see caption</td>
<td>492</td>
<td>-</td>
</tr>
<tr>
<td>Catch</td>
<td>&lt; 60 t</td>
<td>43</td>
<td>-</td>
</tr>
<tr>
<td>Duration</td>
<td>0.5-10 hrs</td>
<td>531</td>
<td>1</td>
</tr>
<tr>
<td>Depth</td>
<td>&lt; 500 m</td>
<td>106</td>
<td>486</td>
</tr>
</tbody>
</table>

Total removed 1307 496

2.1 Assigning JMD and JMN catch for tows

Rohan et al. (2006) used a Bayesian approach to model species proportion estimates (JMD, JMN, JMM) for the jack mackerel catch from the JMA 7 TCEPR fishery. For each fishing year six spatial-temporal strata were used in the model: three spatial strata in combination with two temporal strata. The three spatial strata consisted of three regions with differing patterns in the relative proportions of the jack mackerel species. The two temporal strata are a summer fishery (October–March) and a winter fishery (April–September). The annual species proportions for the six spatial-temporal strata are shown in Appendix 1.

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1 Throughout the document, year is the fishing year, where the number is based on the calendar year in the latter part of the fishing year, e.g., 2005 denotes the 1 October 2004 – 30 September 2005 fishing year.
Each tow in the groomed data set has a longitude, latitude, month, and fishing year associated with it. These were used to assign one of the six strata to each tow, and a fishing year. A few tows (652) could not be assigned strata because their location did not correspond to any of the spatial strata, and were discarded. From the assigned strata and fishing year of a tow, the species proportions were assigned for a tow, and the JMD and JMN catch estimated. The resultant derived catch-effort data for JMD and JMN are denoted as the initial JMD data set and the initial JMN data set respectively.

The unstandardised catch rate \( \frac{t}{\text{tow}} \) for JMD increases from 1990 to 1993, then declines to 1996, after which it increases each year (Figure 2). For JMN the unstandardised catch rate is basically constant from 1990 to 1993, after which it declines, reaching a minimum in 1997. It then moves up and down, but from 2000 increases each year (Figure 2).

![Figure 2: Median catch per tow for all jack mackerel species combined (JMA), *Trachurus declivis* (JMD), and *Trachurus novaezelandiae* (JMN). The vertical lines extend to the lower and upper quartiles.](image-url)
2.2 JMD descriptive

The unstandardised catch-effort for the initial JMD data set shows the separation into a summer fishery (October–March) and winter fishery (April–September) that is used as a stratum split for the species proportions model (Figure 3). Peaks in catch and effort occur in December and June, though the CPUE is relatively constant throughout the year, except for February and March when there has been no catch and effort since the 2000 fishing year. In recent years catch-effort has moved north from statistical areas 37 and 40 to areas 41 and 42 (Figure 4).

Boxplots are shown for the most important continuous variables in the JMD CPUE data set (Figure 5). There is a noticeable change in 1999 when tow duration dropped and tow speed increased. The jack mackerel catch is assumed to approximately follow a lognormal distribution, so log-space is the most appropriate to evaluate potential outliers and deviation from the lognormal assumption. For a normal distribution about 0.5% of the observations lay below the bottom whisker, which equates to about 3 to 10 tows (each year has about 500–2000 tows). A plot of the catch in log space (6) indicates the catch distribution has a slightly longer tail to the left than a lognormal distribution.

In 1998 and 1999 there was a change in the fleet composition, with earlier vessels dropping out and new vessels coming in (7). Although the changes in tow duration and speed noted above are more abrupt (they take place in 1999), it seems likely that they are related to the change in fleet composition.
Figure 3: Summary of catch effort data for the initial JMD data set. The area of a circle is proportional to either total catch of JMD (first row), total number of tows (second row), or median catch of JMD per tow (third row). For the first row the largest circle represents 4540 t, the second row 713 tows, and for the third 9.1 t/tow.
Figure 4: Summary of catch by statistical area and fishing year for the initial JMD data set. The area of a circle is proportional to either total catch of JMD (first row), total number of tows (second row), or median catch of JMD per tow (third row). For the first row the largest circle represents 5470 t, the second row 980 tows, and for the third 10.4 t/tow.
Figure 5: Box-and-whisker plots of annual trends of the most important continuous variables included in the initial JMD data set. The central rectangle of the box plots has horizontal lines (from bottom to top) at the quartiles: 25% (lower quartile), 50% (median), and 75% (upper quartile). The interquartile range (IQR) is equal to the upper quartile minus the lower quartile. The upper whisker extends to the smallest value less than the upper quartile + 1.5*IQR; the lower whisker to the smallest values greater than the lower quartile - 1.5*IQR. Values beyond the whiskers are denoted by circles.
Figure 6: Box-and-whisker plot of $\log_{10}(\text{JMD catch})$ for the initial JMD data set.

Figure 7: Graphical representation of the number of non-zero tows by fishing vessel and year, for vessels which have done at least 50 non-zero tows for five or more years in the initial JMD data set. The area of a circle is proportional to the number of tows; the largest circle represents 554 tows.
2.3 JMN descriptive

Plots of the initial JMN catch-effort data (Figures 8 and 9) show much the same patterns as for JMD: a separation into a summer and winter fishery, and a movement in recent years of catch-effort northwards. Plots of the continuous variables in the data set (Figures 10 and 11) also show the same patterns as for JMD: a decrease in the duration of tows and an increase in their speed in 1999, and a longer left tail in the data than in the assumed lognormal distribution. In 1998 and 1999 there was a change in the fleet composition, with earlier vessels dropping out and new vessels coming in (Figure 12).

Figure 8: Summary of catch effort data for the initial JMN data set. The area of a circle is proportional to either total catch of JMD (first row), total number of tows (second row), or median catch of JMD per tow (third row). For the first row the largest circle represents 3120 t, the second row 713 tows, and for the third 10.1 t/tow.
Figure 9: Summary of catch effort data for the initial JMN data set. The area of a circle is proportional to either total catch of JMD (first row), total number of tows (second row), or median catch of JMD per tow (third row). For the first row the largest circle represents 4540 t, the second row 713 tows, and for the third 9.1 t/tow.
Figure 10: Box-and-whisker plot of annual trends of the most important continuous variables included in the initial JMN data set. The central rectangle of the boxplots has horizontal lines (from bottom to top) at the quartiles: 25% (lower quartile), 50% (median), and 75% (upper quartile). The interquartile range (IQR) is equal to the upper quartile minus the lower quartile. The upper whisker extends to the smallest value less than the upper quartile + 1.5*IQR; the lower whisker to the smallest values greater than the lower quartile – 1.5*IQR. Values beyond the whiskers are denoted by circles.
Figure 11: Box-and-whisker plot of $\log_{10}(\text{JMN catch})$ for the initial JMN data set.

Figure 12: Graphical representation of the number of non-zero tows by fishing vessel and year, for vessels which have made at least 50 non-zero tows for five or more years in the initial JMN data set. The area of a circle is proportional to the number of tows; the largest circle represents 554 tows.
3. THE CPUE STANDARDISATIONS

3.1 Early and late period split

There were a number of changes in the fishery between 1996 and 1999. In 1996 there were fewer landings because of three components (Ministry of Fisheries, 2006, p. 315): (i) changes in fishing strategy (a new code of practice was introduced to eliminate dolphin bycatch), (ii) a major company withdraw from the fishery, and (iii) marketing was difficult for the relatively low value JMM. However, the changes in fishery strategy were temporary and now most of the catch is taken by midwater trawl. In 1997 the unstandardised catch rate increased, whereas in previous years it was decreasing (Figures 6 and 11). And lastly, in 1998 and 1999 there was a change in the fleet composition, with earlier vessels dropping out and new vessels coming in (Figures 7 and 12).

Given the number of changes in the fishery it is problematic to delineate a particular year at which to split the standardisations. However, on the basis of changes in fleet composition, and when changes in the unstandardised catch rate took place, it was decided by the Pelagic Working Group to split the standardisation into two periods: early (1990–96) and late (1997–2005). So in total four standardised CPUE indices were calculated: (1) two using the estimated catch of JMD per tow: early and late period, and (2) two using the estimated catch of JMN per tow: early and late period.

3.2 Predictor variables

For all standardisations, the predictor variables shown in Table 2 were offered to the model. The year variable was forced into the models at the start, as the aim of a standardised CPUE analysis is to produce a relative biomass indexed by year. A step forward procedure was used to select predictor variables, and they were entered into the model in the order which gave the maximum decrease in the Akaike Information Criterion (AIC). Predictor variables were accepted into the model only if they explained at least 0.5% of the deviance.

Table 2: Predictor variables in the CPUE data sets. The continuous variables are offered as third degree polynomials to the standardisation.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishing Year</td>
<td>Categorical</td>
<td>Fishing year</td>
</tr>
<tr>
<td>Month</td>
<td>Categorical</td>
<td>Month of year</td>
</tr>
<tr>
<td>Method</td>
<td>Categorical</td>
<td>Either bottom or midwater trawl</td>
</tr>
<tr>
<td>Vessel</td>
<td>Categorical</td>
<td>Unique vessel code</td>
</tr>
<tr>
<td>Stat area</td>
<td>Categorical</td>
<td>Sub area fished</td>
</tr>
<tr>
<td>Duration</td>
<td>Continuous</td>
<td>Duration of trawling (h)</td>
</tr>
<tr>
<td>Depth</td>
<td>Continuous</td>
<td>Depth of water (m)</td>
</tr>
<tr>
<td>Speed</td>
<td>Continuous</td>
<td>Speed of trawl (km/h)</td>
</tr>
</tbody>
</table>

3.3 Vessel sub-selection

In a further reduction of the initial JMD and JMN data sets, only those vessels which had made at least 50 non-zero tows for five or more years were included in the final CPUE data sets (so all tows for these selected vessels were used). For all standardisations this reduced the number of vessels in the data sets substantially, while retaining a large proportion of the tows and catch (Table 3). The exception to this is the early JMN data set, where the number of vessels retained was three, and the proportions of the tows and catch retained about one third.
Table 3: The effect of the vessel sub-selection on the number of vessels and percentage and tows and catch retained for the CPUE data sets.

<table>
<thead>
<tr>
<th>Standardisation data set</th>
<th>Initial number of vessels</th>
<th>Final number of vessels</th>
<th>Initial number of tows</th>
<th>Percentage of tows retained</th>
<th>Percentage of catch retained</th>
</tr>
</thead>
<tbody>
<tr>
<td>early JMD</td>
<td>73</td>
<td>5</td>
<td>13 850</td>
<td>43</td>
<td>49</td>
</tr>
<tr>
<td>late JMD</td>
<td>44</td>
<td>7</td>
<td>14 560</td>
<td>78</td>
<td>87</td>
</tr>
<tr>
<td>early JMN</td>
<td>55</td>
<td>3</td>
<td>11 385</td>
<td>32</td>
<td>33</td>
</tr>
<tr>
<td>late JMN</td>
<td>33</td>
<td>7</td>
<td>11 744</td>
<td>80</td>
<td>80</td>
</tr>
</tbody>
</table>

The spread of the number of tows by vessel and year is shown for early and late period JMD (Figures 13 and 14) and JMN (Figures 15 and 16). Because of the years chosen for the split into early and late period, linkage of vessels across years is very good. Note that the late JMN standardisation data set begins in 1998 not 1997, as the selected vessels had no tows in 1997.
Figure 13: Graphical representation of the number of non-zero tows by fishing vessel and year, for vessels selected to go into the standardised early JMD CPUE analysis. The area of a circle is proportional to the number of tows; the largest circle represents 585 tows. The vessel codes are arbitrary labels and are not linked to those for other figures.

Figure 14: Graphical representation of the number of non-zero tows by fishing vessel and year, for vessels selected to go into the standardised late JMD CPUE analysis. The area of a circle is proportional to the number of tows; the largest circle represents 469 tows. The vessel codes are arbitrary labels and are not linked to those for other figures.
Figure 15: Graphical representation of the number of non-zero tows by fishing vessel and year, for vessels selected to go into the standardised early JMN CPUE analysis. The area of a circle is proportional to the number of tows; the largest circle represents 531 tows. The vessel codes are arbitrary labels and are not linked to those for other figures.

Figure 16: Graphical representation of the number of non-zero tows by fishing vessel and year, for vessels selected to go into the standardised late JMN CPUE analysis. The area of a circle is proportional to the number of tows; the largest circle represents 408 tows. The vessel codes are arbitrary labels and are not linked to those for other figures.
3.4 The JMD CPUE standardisations

The log of the catch rates was modelled with a linear regression model with a normal error structure.

For the early period standardisation, month and duration went first into the standardisation, explaining an additional 6.3% and 4.7% of the variance respectively (Table 4). For the late period standardisation statistical area and month went first into the standardisation, explaining an additional 5.3% and 4.1% of the variances respectively (Table 5). In both standardisations less than 20% of the variation was explained.

The selected variables were regular and plausible in their trends (Figures 17 and 18). In particular, catch rates increased with tow duration and were higher in the more northern statistical areas.

The diagnostics indicate that the catch data had more low catches and fewer high catches than in the assumed lognormal model (Figures 19 and 20).

The standardised early and late JMD CPUE indices are tabulated (Tables 6 and 7) and graphed (Figures 21 and 22). For early period JMD the standardised CPUE index shows a downward trend from the 1990 fishing year, reaching about 43% of its initial value in 1996. The late period JMD index is more irregular with a 45% drop from 1997 to 1998, then subsequently an irregular upward trend. In 2005 the late period index is nearly double its value in 1997.

### Table 4: The predictors that were accepted into the final model (0.5% additional deviance explained) for the fit of the early JMD CPUE data to the GLM.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Degrees of freedom</th>
<th>AIC</th>
<th>Percentage deviance explained</th>
<th>Additional % deviance explained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishing year</td>
<td>5</td>
<td>20507</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Month</td>
<td>11</td>
<td>20131</td>
<td>8.5</td>
<td>6.3</td>
</tr>
<tr>
<td>Duration</td>
<td>3</td>
<td>19822</td>
<td>13.2</td>
<td>4.7</td>
</tr>
<tr>
<td>Stat area</td>
<td>8</td>
<td>19556</td>
<td>17.2</td>
<td>4.0</td>
</tr>
<tr>
<td>Vessel</td>
<td>4</td>
<td>19480</td>
<td>18.3</td>
<td>1.2</td>
</tr>
<tr>
<td>Method</td>
<td>1</td>
<td>19406</td>
<td>19.4</td>
<td>1.0</td>
</tr>
<tr>
<td>Depth</td>
<td>3</td>
<td>19375</td>
<td>19.9</td>
<td>0.5</td>
</tr>
</tbody>
</table>

### Table 5: The predictors that were accepted into the final model (0.5% additional deviance explained) for the fit of the late JMD CPUE data to the GLM.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Degrees of freedom</th>
<th>AIC</th>
<th>Percentage deviance explained</th>
<th>Additional % deviance explained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishing year</td>
<td>6</td>
<td>37635</td>
<td>7.1</td>
<td>7.1</td>
</tr>
<tr>
<td>Stat area</td>
<td>8</td>
<td>36999</td>
<td>12.3</td>
<td>5.3</td>
</tr>
<tr>
<td>Month</td>
<td>11</td>
<td>36842</td>
<td>13.7</td>
<td>1.4</td>
</tr>
<tr>
<td>Duration</td>
<td>3</td>
<td>36723</td>
<td>14.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Speed</td>
<td>3</td>
<td>36614</td>
<td>15.5</td>
<td>0.9</td>
</tr>
<tr>
<td>Vessel</td>
<td>6</td>
<td>36521</td>
<td>16.3</td>
<td>0.8</td>
</tr>
</tbody>
</table>
Figure 17: Predictions from the GLM model for the early JMD CPUE standardisation (crosses or lines). Vertical bars or histograms show the data distribution for each variable. Fixed values for variables in the graphs (those variables not shown are on the x-axis) are: vessel code = B, statistical area = 40, month = March, tow duration = 4.0 h, fishing method = MW, fishing year = 1994. The vessel codes are arbitrary labels for the vessels that were selected to include in the analysis.
Figure 18: Predictions from GLM model for the late JMD CPUE standardisation (crosses or lines). Vertical bars or histograms show the data distribution for each variable. Fixed values for variables in the graphs (those variables not shown are on the x-axis) are: vessel code = B, statistical area = 40, month = July, tow duration = 2.6 h, fishing year = 2003. The vessel codes are arbitrary labels for the vessels that were selected to include in the analysis.
Quantiles of standard normal

Figure 19: The diagnostic plot for the early JMD GLM model showing sorted normalised residuals from the standardisation model (y-axis) plotted against the corresponding quantiles of the standard normal distribution (x-axis).

Quantiles of standard normal

Figure 20: The diagnostic plot for the late JMD GLM model showing sorted normalised residuals from the standardisation model (y-axis) plotted against the corresponding quantiles of the standard normal distribution (x-axis).
Table 6: Standardised CPUE indices for the early JMD standardisation.

<table>
<thead>
<tr>
<th>Fishing year</th>
<th>Index</th>
<th>c.v.</th>
<th>Number of tows</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>2.07</td>
<td>0.10</td>
<td>716</td>
</tr>
<tr>
<td>1991</td>
<td>2.05</td>
<td>0.10</td>
<td>688</td>
</tr>
<tr>
<td>1992</td>
<td>1.90</td>
<td>0.10</td>
<td>947</td>
</tr>
<tr>
<td>1993</td>
<td>1.56</td>
<td>0.09</td>
<td>1088</td>
</tr>
<tr>
<td>1994</td>
<td>1.37</td>
<td>0.09</td>
<td>1444</td>
</tr>
<tr>
<td>1995</td>
<td>1.28</td>
<td>0.09</td>
<td>597</td>
</tr>
<tr>
<td>1996</td>
<td>0.89</td>
<td>0.10</td>
<td>502</td>
</tr>
</tbody>
</table>

Table 7: Standardised CPUE indices for the late JMD standardisation.

<table>
<thead>
<tr>
<th>Fishing year</th>
<th>Index</th>
<th>c.v.</th>
<th>Number of tows</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>1.69</td>
<td>0.13</td>
<td>160</td>
</tr>
<tr>
<td>1998</td>
<td>0.92</td>
<td>0.11</td>
<td>252</td>
</tr>
<tr>
<td>1999</td>
<td>2.70</td>
<td>0.08</td>
<td>712</td>
</tr>
<tr>
<td>2000</td>
<td>2.15</td>
<td>0.08</td>
<td>717</td>
</tr>
<tr>
<td>2001</td>
<td>2.67</td>
<td>0.07</td>
<td>1240</td>
</tr>
<tr>
<td>2002</td>
<td>2.85</td>
<td>0.07</td>
<td>1760</td>
</tr>
<tr>
<td>2003</td>
<td>2.38</td>
<td>0.06</td>
<td>2272</td>
</tr>
<tr>
<td>2004</td>
<td>2.59</td>
<td>0.07</td>
<td>2055</td>
</tr>
<tr>
<td>2005</td>
<td>3.23</td>
<td>0.07</td>
<td>2002</td>
</tr>
</tbody>
</table>

Figure 21: Standardised index for the early JMD CPUE data set with 95% confidence intervals shown.
3.5 The JMN CPUE standardisations

The log of the catch rates was modelled with a linear regression model with a normal error structure.

Statistical area is highly prominent for both the early and late CPUE standardisation, accounting for 36.5% and 32.9% of the additional variance explained respectively (Tables 8 and 9).

The variation of the catch rate with the other selected variables is shown in Figures 23 and 24. In both cases the catch rate \( (t/tow) \) increases with tow duration. JMN is generally found in water shallower than 150 m (Ministry of Fisheries, 2006, p. 316), which is consistent with the catch rate trends shown with depth. Most of the JMN catch-effort data is for depths between 50 m and 200 m (see Figure 5), so the catch rate curve shown outside this range is an artefact of fitting a third degree polynomial, not from fitting data.

The diagnostics indicate that the catch data had more low catches and fewer high catches than in the assumed lognormal model (Figures 25 and 26).

The resultant standardised JMN CPUE is tabulated (Tables 10 and 11) and graphed (Figures 27 and 28). For the early period JMN the standardised CPUE is essentially flat for 1990–91, and then gradually declines. In 1996 the index is 34% of its value in 1990. The late period JMN index double from 1998 to 1999 (there was no vessel coverage in 1997). Subsequently it remains flat but irregular until a 27% drop in 2003, after which it remains flat. In 2005 the index is nearly double its value in 1998.
Table 8: The predictors that were accepted into the final model (0.5% additional deviance explained) for the fit of the early JMN CPUE data to the GLM.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Degrees of freedom</th>
<th>AIC</th>
<th>Percentage deviance explained</th>
<th>Additional % deviance explained</th>
</tr>
</thead>
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<tr>
<td>Fishing year</td>
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<td>15010</td>
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<td>4.4</td>
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<tr>
<td>Stat area</td>
<td>6</td>
<td>13273</td>
<td>40.9</td>
<td>36.5</td>
</tr>
<tr>
<td>Month</td>
<td>11</td>
<td>12948</td>
<td>46.3</td>
<td>5.4</td>
</tr>
<tr>
<td>Duration</td>
<td>3</td>
<td>12759</td>
<td>49.1</td>
<td>2.8</td>
</tr>
<tr>
<td>Depth</td>
<td>3</td>
<td>12660</td>
<td>50.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Method</td>
<td>1</td>
<td>12617</td>
<td>51.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Vessel</td>
<td>2</td>
<td>12553</td>
<td>52.1</td>
<td>0.9</td>
</tr>
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</table>

Table 9: The predictors that were accepted into the final model (0.5% additional deviance explained) for the fit of the late JMN CPUE data to the GLM.

<table>
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<tr>
<th>Predictor</th>
<th>Degrees of freedom</th>
<th>AIC</th>
<th>Percentage deviance explained</th>
<th>Additional % deviance explained</th>
</tr>
</thead>
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<td>1.6</td>
</tr>
<tr>
<td>Stat area</td>
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<td>32.9</td>
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<tr>
<td>Month</td>
<td>9</td>
<td>30961</td>
<td>37.8</td>
<td>3.3</td>
</tr>
<tr>
<td>Depth</td>
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<td>30828</td>
<td>38.8</td>
<td>0.9</td>
</tr>
<tr>
<td>Duration</td>
<td>3</td>
<td>30730</td>
<td>39.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Speed</td>
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<td>30659</td>
<td>39.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Vessel</td>
<td>6</td>
<td>30584</td>
<td>40.5</td>
<td>0.6</td>
</tr>
</tbody>
</table>
Figure 23: Predictions from GLM model for the early JMN CPUE standardisation (crosses for lines). Vertical bars or histograms show the data distribution for each variable. Fixed values for variables in the graphs (those variables not shown are on the x-axis) are: vessel code = B, statistical area = 40, month = August, tow duration = 4.2 h, fishing method = MW, fishing year = 1994. The vessel codes are arbitrary labels for the vessels that were selected to include in the analysis.
Figure 24: Predictions from GLM model for the late JMN CPUE standardisation (crosses and lines). Vertical bars or histograms show the data distribution for each variable. Fixed values for variables in the graphs (those variables not shown are on the x-axis) are: vessel code = C, statistical area = 36, month = December, tow duration = 2.7 h, fishing year = 2003. The vessel codes are arbitrary labels for the vessels that were selected to include in the analysis. Note that the selected vessels had no data for February and March, so there are no estimated month effects for these months.
Figure 25: The diagnostic plot for the early JMN GLM model showing sorted normalised residuals from the standardisation model (y-axis) plotted against the corresponding quantiles of the standard normal distribution (x-axis).

Figure 26: The diagnostic plot for the late JMN GLM model showing sorted normalised residuals from the standardisation model (y-axis) plotted against the corresponding quantiles of the standard normal distribution (x-axis).
Table 10: Standardised CPUE indices for the early JMN standardisation.

<table>
<thead>
<tr>
<th>Fishing year</th>
<th>Index</th>
<th>c.v.</th>
<th>Number of tows</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>0.50</td>
<td>0.41</td>
<td>552</td>
</tr>
<tr>
<td>1991</td>
<td>0.64</td>
<td>0.40</td>
<td>320</td>
</tr>
<tr>
<td>1992</td>
<td>0.34</td>
<td>0.41</td>
<td>719</td>
</tr>
<tr>
<td>1993</td>
<td>0.23</td>
<td>0.41</td>
<td>373</td>
</tr>
<tr>
<td>1994</td>
<td>0.22</td>
<td>0.41</td>
<td>932</td>
</tr>
<tr>
<td>1995</td>
<td>0.20</td>
<td>0.41</td>
<td>261</td>
</tr>
<tr>
<td>1996</td>
<td>0.17</td>
<td>0.41</td>
<td>480</td>
</tr>
</tbody>
</table>

Table 11: Standardised CPUE indices for the late JMN standardisation.

<table>
<thead>
<tr>
<th>Fishing year</th>
<th>Index</th>
<th>c.v.</th>
<th>Number of tows</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>0.10</td>
<td>0.17</td>
<td>67</td>
</tr>
<tr>
<td>1999</td>
<td>0.22</td>
<td>0.10</td>
<td>367</td>
</tr>
<tr>
<td>2000</td>
<td>0.24</td>
<td>0.10</td>
<td>403</td>
</tr>
<tr>
<td>2001</td>
<td>0.22</td>
<td>0.08</td>
<td>1022</td>
</tr>
<tr>
<td>2002</td>
<td>0.26</td>
<td>0.08</td>
<td>1466</td>
</tr>
<tr>
<td>2003</td>
<td>0.19</td>
<td>0.08</td>
<td>2054</td>
</tr>
<tr>
<td>2004</td>
<td>0.18</td>
<td>0.09</td>
<td>2010</td>
</tr>
<tr>
<td>2005</td>
<td>0.19</td>
<td>0.08</td>
<td>1948</td>
</tr>
</tbody>
</table>
Figure 27: Standardised index for the early JMN CPUE data set with 95% confidence intervals shown.

Figure 28: Standardised index for the late JMN CPUE data set with 95% confidence intervals shown.
4. DISCUSSION

Standardised CPUE indices are important inputs to stock assessments, where their use is as relative biomass indices. Commonly it is assumed that CPUE is linearly proportional to vulnerable biomass, but it can be difficult if not impossible to directly evaluate this assumption. Nonetheless, the size of some of the yearly percentage changes in the CPUE indices indicate that at least parts of the series are not tracking abundance. For instance, the late JMD CPUE series dropped by nearly 50% from 1997 to 1998, then nearly tripled the following year. Such large yearly changes in abundance seem implausible, at least under the implicit assumption that JMA 7 forms a single stock without immigration or migration to other areas.

Further criteria to evaluate the standardised CPUE indices are the appropriateness of the measure of CPUE, data quality and adequacy, and the validity of the model used for the standardisation (Dunn et al. 2000). With regard to the appropriateness of the measure of CPUE, the main concern would be that the measure of effort (tow) has some underlying trend that is not accounted for. Changes in tow speed and tow duration are accounted for by the standardisation, but changes in technology (e.g., GPS) that potentially increase the effective effort cannot be easily incorporated into the standardisation.

Data quality involves the components of accuracy (recorded values on average reflect the true values) and precision (how close recorded values are to the true values). With regard to the categorical quantities used in the standardisation of vessel, month, statistical area, and fishing year it seems unlikely that there are any issues with regard to data quality. There has been some doubt expressed that what is recorded as the fishing method (bottom trawl or midwater trawl) is accurate (Graeme McGregor, Ministry of Fisheries, pers. comm.), but ambiguous bottom trawls were pruned from the initial data set, and in any case the standardisation models indicate the method is not an important predictor variable. The accuracy and precision of the quantities speed and tow duration (derived from start and stop times for a tow) are unknown.

Species proportion estimates from a Bayesian analysis were used to derive the catch for JMD and JMN for each tow, this catch then being used in the standardisation. Not incorporated into the analysis presented here is the uncertainty in the species proportion estimates, so the c.v.s presented for the standardised indices should be considered a lower bound, and the additional uncertainty due to species proportions uncertainty investigated in a future study.

All four standardisation diagnostics indicate that the catch data had more low catches and fewer high catches than in the assumed lognormal model (Figures 19 and 20). However, these tails become noticeable at approximately two standard deviations away from the mean (in log-space) and are not thought be influential in the standardisation process, though no formal analysis of this has been done.

5. ACKNOWLEDGEMENTS

Thanks to the Pelagic Stock Assessment Working Group for their input and review of material.

6. REFERENCES


APPENDIX 1: BAYESIAN SPECIES PROPORTIONS

The species proportions are based on an updated version of Rohan et al. (2006), where an informed prior is used instead of an uninformed prior. In years where there were insufficient data new Bayesian estimates weren't conducted (presumably the estimate remains unchanged from the last estimated year) and it was decided to use linear interpolation to fill in these years. In some strata the Bayesian estimate doesn't go back to 1990, so it was decided to extrapolate back the value of the first estimated year for these years. A better approach would be to use the estimated value based on the informed prior, but there should be very little difference between the values obtained. Proportions that were extrapolated or interpolated have shaded cells in the tables.

A, B, and C refer to the spatial element of the strata. The temporal element is denoted by either 1 (summer fishery) or 2 (winter fishery).

Table A1: Strata A1 species proportions.

<table>
<thead>
<tr>
<th>Fishing year</th>
<th>JMD</th>
<th>JMM</th>
<th>JMN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>0.88</td>
<td>0.12</td>
<td>0.00</td>
</tr>
<tr>
<td>1991</td>
<td>0.88</td>
<td>0.12</td>
<td>0.00</td>
</tr>
<tr>
<td>1992</td>
<td>0.93</td>
<td>0.07</td>
<td>0.00</td>
</tr>
<tr>
<td>1993</td>
<td>0.68</td>
<td>0.32</td>
<td>0.00</td>
</tr>
<tr>
<td>1994</td>
<td>0.61</td>
<td>0.39</td>
<td>0.00</td>
</tr>
<tr>
<td>1995</td>
<td>0.65</td>
<td>0.36</td>
<td>0.00</td>
</tr>
<tr>
<td>1996</td>
<td>0.68</td>
<td>0.32</td>
<td>0.00</td>
</tr>
<tr>
<td>1997</td>
<td>0.69</td>
<td>0.32</td>
<td>0.00</td>
</tr>
<tr>
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<td>0.32</td>
<td>0.00</td>
</tr>
<tr>
<td>1999</td>
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<td>0.32</td>
<td>0.00</td>
</tr>
<tr>
<td>2000</td>
<td>0.73</td>
<td>0.32</td>
<td>0.00</td>
</tr>
<tr>
<td>2001</td>
<td>0.72</td>
<td>0.23</td>
<td>0.05</td>
</tr>
<tr>
<td>2002</td>
<td>0.69</td>
<td>0.26</td>
<td>0.05</td>
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<tr>
<td>2003</td>
<td>0.74</td>
<td>0.22</td>
<td>0.04</td>
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<tr>
<td>2004</td>
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<td>0.22</td>
<td>0.04</td>
</tr>
<tr>
<td>2005</td>
<td>0.74</td>
<td>0.22</td>
<td>0.04</td>
</tr>
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Table A2: Strata A2 species proportions.

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<th>Fishing year</th>
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<th>JMN</th>
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<tbody>
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<td>1990</td>
<td>0.26</td>
<td>0.74</td>
<td>0.00</td>
</tr>
<tr>
<td>1991</td>
<td>0.26</td>
<td>0.74</td>
<td>0.00</td>
</tr>
<tr>
<td>1992</td>
<td>0.26</td>
<td>0.74</td>
<td>0.00</td>
</tr>
<tr>
<td>1993</td>
<td>0.26</td>
<td>0.74</td>
<td>0.00</td>
</tr>
<tr>
<td>1994</td>
<td>0.19</td>
<td>0.81</td>
<td>0.00</td>
</tr>
<tr>
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<td>0.81</td>
<td>0.00</td>
</tr>
<tr>
<td>1996</td>
<td>0.18</td>
<td>0.82</td>
<td>0.00</td>
</tr>
<tr>
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<td>0.19</td>
<td>0.81</td>
<td>0.00</td>
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<tr>
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<tr>
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### Table A4: Strata B2 species proportions.

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</tr>
<tr>
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<td>0.32</td>
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</tr>
<tr>
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<td>0.00</td>
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<tr>
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<td>0.32</td>
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<tr>
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<tr>
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<td>0.34</td>
<td>0.03</td>
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<tr>
<td>2004</td>
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<th>JMN</th>
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<td>0.01</td>
</tr>
<tr>
<td>1991</td>
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<td>0.00</td>
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<tr>
<td>1992</td>
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<td>0.01</td>
</tr>
<tr>
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<td>0.90</td>
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<td>0.01</td>
</tr>
<tr>
<td>1994</td>
<td>0.89</td>
<td>0.10</td>
<td>0.01</td>
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</tr>
<tr>
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<td>0.17</td>
<td>0.03</td>
</tr>
<tr>
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<td>0.17</td>
<td>0.03</td>
</tr>
<tr>
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<td>0.17</td>
<td>0.03</td>
</tr>
<tr>
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<td>0.80</td>
<td>0.18</td>
<td>0.03</td>
</tr>
<tr>
<td>2001</td>
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### Table A6: Strata C2 species proportions.

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