The Commonwealth Small Pelagic Fishery

Review of Estimates of Jack Mackerel Biomass

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Summary

Estimates of 2002 jack mackerel spawning biomass given in the Neira 2011 Report, on which the increase in the 2012/2013 TAC is based, are inconsistent with the egg abundance-at-age data presented in the Report. Key parameters presented in Table 3.1 of the Report are not reproducible, casting serious doubt as to the reliability and validity of the analysis.

Reproducibility is the hallmark of good and reliable scientific analysis, all the more so in this case when the outcome of setting an unsafe TAC may seriously impact Australian jack mackerel stocks.

Because the calculation of these key parameters is not reproducible, the Total Allowable Catch Determination 2012/2013 set by the AFMA of 10,100 t for jack mackerel is based on unreliable statistical analysis and is unsafe.

Using correct parameters, the TAC of 10,100 t is 21.5% of the estimated spawning biomass of 47,000 t which <u>exceeds the maximum 20% RBC</u> for Tier 1 stock. Under the rules of the Small Pelagic Fish Harvest Strategy for Tier 2 stock the TAC should be no more than 3,500 t.

Introduction

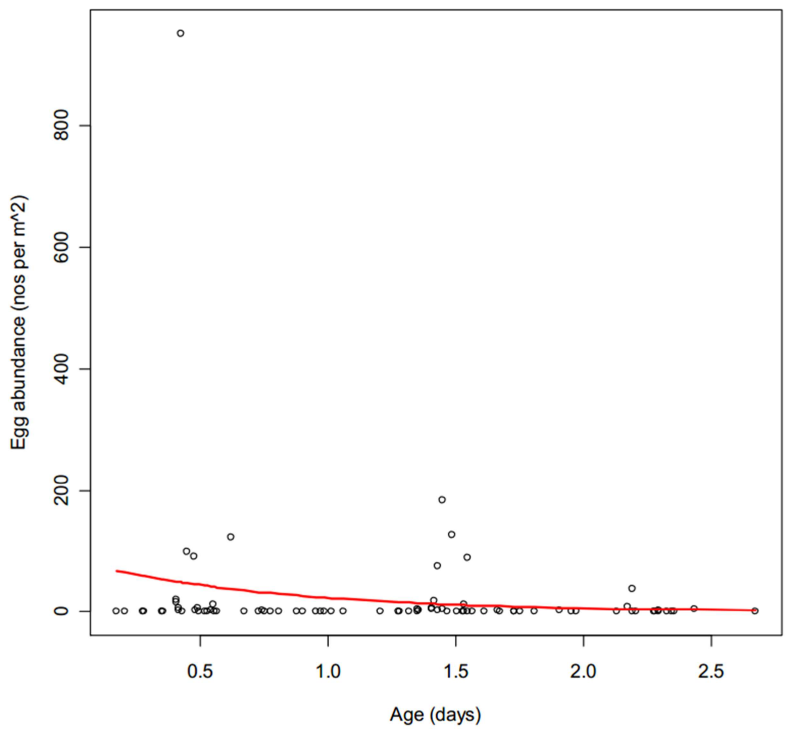
1. The Total Allowable Catch (TAC) for 2012/2013 for jack mackerel in the East zone was increased from 5,000 t (in 2011/2012) to 10,100 t after taking into account newly available information based on 2002 egg survey data (Buxton *et al.* 2012, Neira 2011).
2. The Neira 2011 analysis estimated spawning biomass of jack mackerel in October 2002 to be approximately 114,900 to 169,000 t with a "best estimate" of 140,000 t quoted by Buxton *et al.*, although Neira only refers to this number with the disclaimer "Spawning biomass estimates reported here for the jack mackerel off southern NSW (~140,000 t) are largely imprecise and, as such, need to be taken with due caution".
3. The TAC of 10,100 t is a less than the Recommended Biological Catch (RBC) of 10,600 t which is 7.5% of the 140,000 t biomass estimate, 7.5% being the maximum allowable RBC under the Small Pelagic Fishery Harvest Strategy for Tier 2 stock.
4. Because the TAC for 2012/2013 is based on the spawning biomass estimate of Neira 2011 it is critical to the setting of a safe quota that this estimate be reliable.
5. This review does not look at the fishery science used to generate the data going into the estimate, but only the statistical analysis. Once fish stock parameters have been determined, the basic statistical analysis is simple using undergraduate-level mathematical concepts and can be carried out within MS Excel™.

Spawning Biomass Model

6. In his report, Neira estimates spawning biomass B (t) using the equation B = P_0 A k / (R F S / W_f).
7. In this equation P_0 = egg production per unit of area per day (eggs / 0.05m2 / day), A = spawning area (km2), k = conversion factor (in this case k=20, to convert eggs / 0.05m2 / day to eggs / m2 / day), R = fraction of mature females by weight (sex ratio), F = batch fecundity (number of oocytes released per mature female per batch), S = spawning fraction (proportion of mature females spawning each day), and W_f = mean weight of mature females in the population. [Note that Neira refers to the conversion factor k as a factor to convert grams to metric tonnes, but this is incorrect as a units analysis and the results of his calculations show that it is required only to convert areas from m2 to 0.05m2.]

Mean Daily Egg Production

8. The value P_0 = egg production per unit of area per day is calculated from a model that assumes all eggs to be spawned and instantaneously fertilized at a specific time, and affected by a constant exponential mortality rate, with daily egg abundance-at-age data in each sample to be independent observations from a population with a common P_0 and instantaneous mortality rate Z, $P_t = P_0\, e^{-Z\,t}$.
9. Neira calculated this value by fitting both a NLS (non-linear least squares model) and a GLM (generalized linear model with negative binomial error distribution) to jack mackerel eggs caught in 2002 off southern New South Wales for cohorts aged using two different temperature-dependent egg incubation models.
10. For one such incubation model, his results (Figure 8a) are reproduced below.



In this figure, measured egg abundance (number of eggs per m2) is plotted against the estimated age of the egg cohorts (in days). The solid (red) line is a fitted mortality curve derived from GLM. The raw data values (egg abundance / cohort age) are not given in the report.

Spawning Biomass Estimate

11. From this data, Neira (Table 3.1) gives the following values for P_0 (in units eggs/0.05m2/day):

P_0 (eggs/0.05m2/day):	Incubation Model #1	Incubation Model #2
Non-linear regression (NLS)	**3.36**	**4.93**
Generalized Linear Model (GLM)	**3.80**	**3.92**

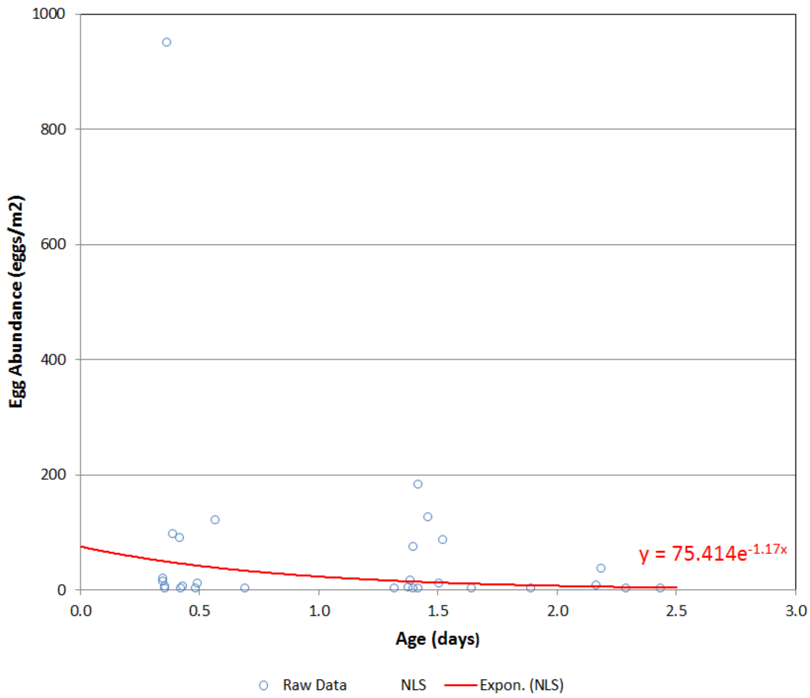
12. Using these values and estimates of spawning area (A = 23,934 km2), female weight (W_f = 311.4 g), fecundity (F = 62,947), sex ratio (R = 0.346) and spawning fraction (S = 0.20) estimates of 2002 spawning biomass were calculated (Table 3.1):

Spawning biomass (t):	Incubation Model #1	Incubation Model #2
Non-linear regression (NLS)	**114,943**	**168,817**
Generalized Linear Model (GLM)	**130,082**	**134,218**

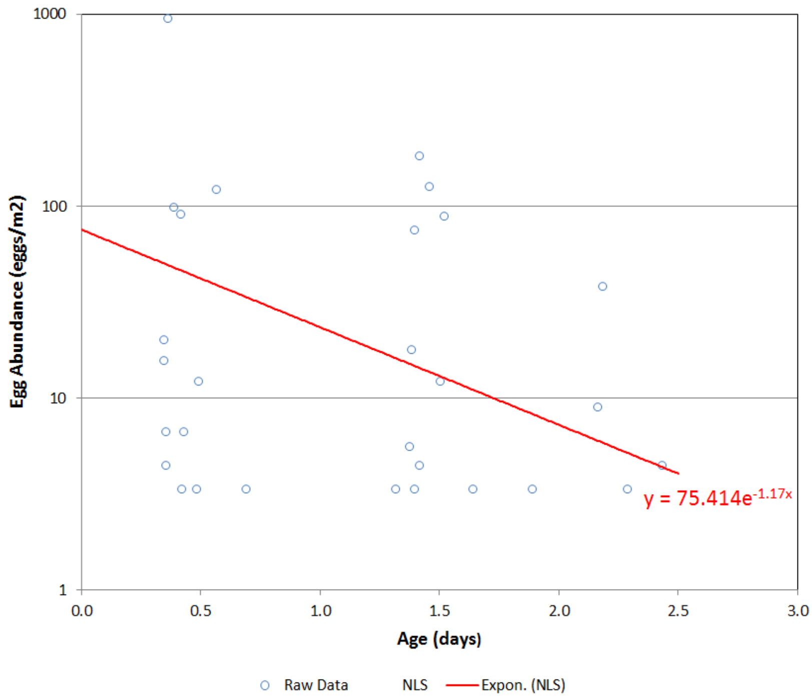
13. As a check, for the NLS model we have B = (3.36 x 23,934 x 20) / (0.346 x 62,947 x 0.20 / 311.4) = 114,980 which, to 4 figures, equals the table value of 114,943; and for the GLM model B = (3.80 x 23,934 x 20) / (0.346 x 62,947 x 0.20 / 311.4) = 130,037 which, to 4 figures, equals the table value of 130,082.
14. This calculation demonstrates that the estimates of jack mackerel biomass were derived from the values reported in Table 3.1*,* using the units presented in the table. In particular, the estimates of biomass depend on the value of P_0 derived from the daily egg abundance-at-age data.

Digitized Data

15. Because the raw numerical values plotted in Figure 8a were not given in the report, these quantities were digitized from the Figure and are tabulated here in the Appendix. Because of loss of resolution, these values may differ from the actual values used in Neira's analysis but will agree to within the diameter of the markers used in Figure 8a; also, if there were duplicate data points in the raw data, these will not have been included.
16. The digitized values were plotted using MS Excel™ and are shown below.



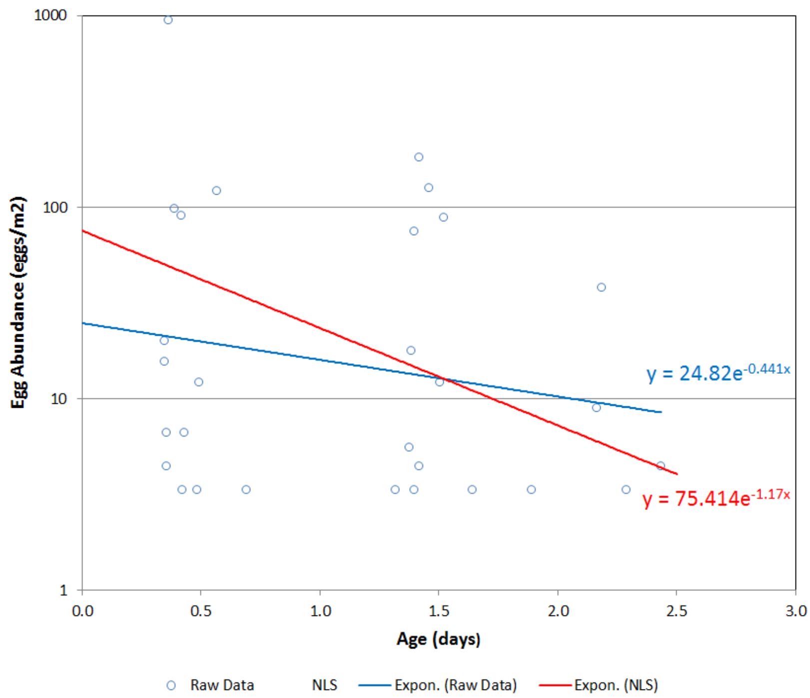
17. In this plot, we show the same data as Figure 8a of the Neira report, except here we show the NLS curve calculated from the values given in Table 3.1 of the report and scaled by the ratio 23,934 / 21,327 to account for the difference between the spawning area and the survey area (Neira and Lyle 2011) with units converted from eggs/0.05m2 to eggs/m2. The equation is not a trend line fitted to the data, but the NLS curve presented in the report. Extreme data (which corresponds to eggs of age < 4 hr and eggs which would have hatched with probability > 98% at the mean station temperature, Neira and Lyle 2011) were not included in the original plot; thus the total number of non-zero data points (29) may not be equal to the number of positive samples listed elsewhere in the report.
18. A linear scale is not appropriate for plotting data which follows an exponential decline as it visually masks the influence of low value points. Usually a log(x) or log(1+x) plot is used to display the data, the latter transform is used if zero value points are also displayed (Neira and Lyle 2011). A log plot of the data is shown in the figure below:



The exponential decline trend plots as a linear curve on this log plot. Note that more than half of the data points (15) have egg abundances of less than 10 eggs/m2.

Non-Linear Least Squares

19. We used the inbuilt non-linear trend function in MS Excel™ to calculate a NLS exponential trend line fitted to the raw data. This trend line (blue) and the corresponding equation, are shown in the following figure:



This trend line was calculated using all of the positive data points shown in Figure 8a of the Neira report.

20. We expected this trend line to be similar (within data tolerances) to the NLS trend line presented in the report, as the report states that the data used to derived the egg abundance mortality trends is shown in Figures 8a and 8b for the two different age models.

Calculation of Weighted P_0 Value

21. Using the unweighted value derived from the MS Excel™ trend line of 24.82 eggs/m2, we calculate a weighted P_0 value (eggs/0.05m2/day) by P_0 = 0.05 x 24.82 x 21327 / 23934 = 1.106 which is 1/3rd of the value 3.36 eggs/0.05m2/day given in the report based on the same dataset and analysis method.
22. We conclude that the egg abundance / age data plotted in Figure 8a <u>is not consistent</u> with the weighted P_0 values presented in the report.
23. We have not carried out a GLM trend fit to the data, but based on the close correspondence between the reported NLS parameters and the GLM parameters, it is likely that the same inconsistency is present in the GLM analysis. The NLS fit presented above is independent of any interpretation of the data (with extreme data already excluded from the plot). Whether one is a marine scientist or mathematician, the outcome will be the same.

Conclusion

24. We assume that the data presented in Figures 8a and 8b represents all of the (non-extreme) 2002 egg abundance / age data generated through the course of the Neira 2011 DEPM study and that this data can be relied upon to derive weighted P_0 values.
25. The implications of our analysis are significant for the spawning biomass estimates which correctly are 1/3rd of the reported values. The "best estimate" of 140,000 t of spawning biomass should correctly be 47,000 t.
26. The 47,000 t estimate of spawning biomass is consistent with the decline in, and low level of, catches of jack mackerel taken in Commonwealth waters over the past 10 years [see Figure below].
27. Using correct estimates of weighted P_0, a 2012/2013 TAC of 10,100 t is 21.5% of the estimated spawning biomass of 47,000 t which exceeds the maximum 20% RBC for Tier 1 stock. Under the rules of the Small Pelagic Fish Harvest Strategy for Tier 2 stock the TAC should be no more than 3,500 t, which <u>is less than</u> the 2011/2012 TAC.
28. *Reproducibility* is the hallmark of good and reliable scientific analysis, all the more so in this case when the outcome of setting an unsafe TAC may seriously impact Australian jack mackerel stocks.
29. The estimates of weighted daily egg abundance P_0 given in the Neira 2011 report are not reproducible, as shown by the simple analysis presented above. This casts serious doubt as to the reliability and validity of the biomass estimates for jack mackerel on which the 2012/2013 TAC has been based.
30. The Small Pelagic Fishery Total Allowable Catch Determination 2012 of 10,100 t for jack mackerel is based on unreliable statistical analysis and is unsafe.

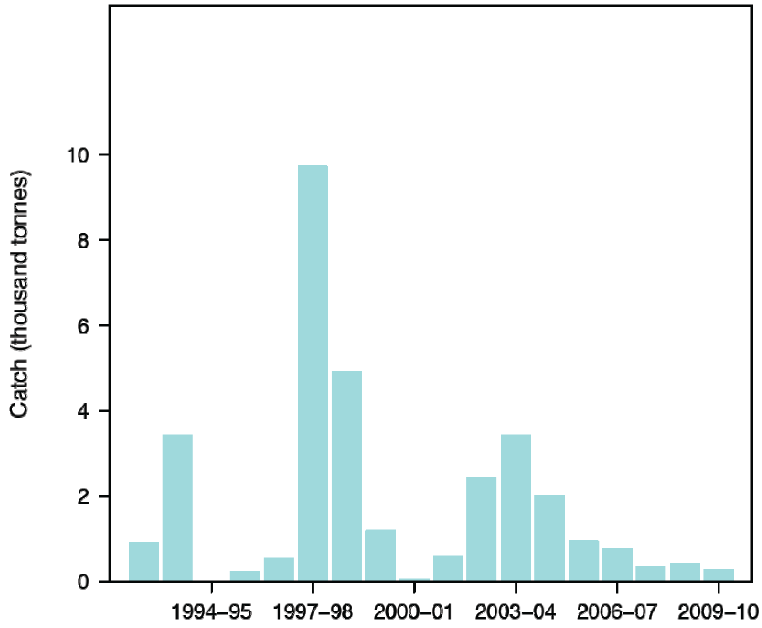


Figure 7.5 Commonwealth jack mackerel catch, 1992-93 to 2009-10
http://adl.brs.gov.au/data/warehouse/fishstatus20109abff00101/fishstatus20109abff00101_11a/07_FishStatus2010SmallPelagic_1.00.pdf

References

1. Buxton *et al.*: Colin Buxton, Gavin Begg, Jeremy Lyle, Tim Ward, Keith Sainsbury, Tony Smith, David Smith, *The Commonwealth Small Pelagic Fishery: General background to the scientific issues*, August 2012.
2. Neira (2011): Francisco J. Neira, *Final Report, Application of daily egg production to estimate biomass of jack mackerel, Trachurus declivis - a key fish species in the pelagic ecosystem of south-eastern Australia*, Fisheries, Aquaculture & Coasts Institute for Marine & Antarctic Studies (IMAS) University of Tasmania (2011).
3. Neira and Lyle (2011): Francisco J. Neira and Jeremy M. Lyle, *DEPM-based spawning biomass of Emmelichthys nitidus (Emmelichthyidae) to underpin a developing mid-water trawl fishery in south-eastern Australia*, Fisheries Research 110 (2011) 236–243.

Qualification

Professor Andrew Wadsley PhD, MSc, Bsc (Hons). Professor Wadsley received a BSc (Hons) and University Medal in Mathematics from the Australian National University in 1970, the Statistical Society of Australia Prize in 1969, an MSc from the University of Warwick (UK) in 1972, and a PhD (Mathematics) from the University of Warwick (UK) in 1974. He has more than thirty-seven years in the petroleum and steel industries, starting as a well-site petroleum engineer with Shell International in 1975. Professor Wadsley is a Principal of Australian Risk Audit, an Executive Director of Western Australia based Stochastic Simulation Limited founded in 2008, Director of Exploration and Production Consultants (Australia) Pty Ltd founded in 1988, Chairman of Optimiser Pty Ltd, a Western Australia based Digital Management Company, and adjunct associate Professor in Petroleum Engineering at the Curtin University of Technology. He is a member of the Society of Petroleum Engineers and the Society for Industrial and Applied Mathematics. Professor Wadsley has extensive experience in the auditing and uncertainty analysis of major resource projects including two recent carbon-dioxide sequestration projects in Australia, numerous oil and gas field developments both locally and internationally, and is also an expert in the mercury contamination of natural gas. He has been Umpire and Expert Witness for dispute resolution within the oil and gas industry. He is an expert in the numerical modelling and uncertainty analysis of multi-phase transport processes and is the author of commercially available software programs which are currently used by several of the world's largest oil and gas companies.

Appendix: Digitized egg abundance-at-age data from Figure 8a, Neira 2011.

age	abundance	age	abundance
0.343	15.686	1.383	17.927
0.343	20.168	1.397	3.361
0.351	4.482	1.397	75.070
0.354	6.723	1.416	4.482
0.362	952.381	1.416	183.754
0.384	98.599	1.457	126.611
0.414	90.756	1.504	12.325
0.420	3.361	1.520	88.515
0.428	6.723	1.638	3.361
0.483	3.361	1.888	3.361
0.491	12.325	2.162	8.964
0.565	122.129	2.184	38.095
0.689	3.361	2.289	3.361
1.314	3.361	2.434	4.482
1.372	5.602		