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Comments on using daily egg production method to estimate the spawning biomass of jack mackerel, *trachurus declivis*, off south-eastern Australia

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This report presents my evaluations on the validity/suitability of Dr Francisco J. Neira's methods, comments on analyses and assertions by Dr Andrew Wadsley, comments on the IMAS' response by Mr. J. Lyle et al and suggestions of some alternative methods of assessment for small pelagic species, either through DEPMs or other methods that would give similar levels of certainty. This report was requested by Fisheries Management Branch, Australian Fisheries Management Authority, AFMA, headed by Mr. George Day through the SPF Resource Assessment Group, chaired by Dr. Tim Ward. Below is the summary of my comments on each of four items followed by the full report.

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**Summary**

**Evaluations on the methods used by Dr Francisco J. Neira, IMAS, University of Tasmania, regarding their validity/suitability**

Dr. Neira made a great effort to estimate the spawning biomass of jack mackerel despite the fact that adult samples were not collected synchronized with eggs. Therefore the estimates of the spawning biomass can be used only as a guide line of the status of jack mackerel in 2002 or in early 2000s, likely between 50,000-400,000mt with point estimate of 140,000 mt. Dr. Neira did point out all the weakness of this exercise and what needs to be done in the future in the discussion section. Modelling temperature dependent egg stage-to-age is of high priority. Future proper survey design with synchronized egg and adult data collection is recommended.

**Comments on analyses and assertion by Dr Andrew Wadsley**

Dr. Wadsley indicated to me that he does not consider his work as of a sufficiently detailed standard to form part of an official Australian Government review of the analysis presented in Neira (2011). He agrees with my review posted on the website in 2012.

**Comments on the IMAS' response by Dr. J. Lyle et al.**

Dr. J. Lyle et al. of IMAS provided the mean egg production of jack mackerel based on seven estimation procedures used by Ward et al. (2011) for Australian sardine spawning biomass assessment and two ageing methods from literature. The comparison of estimates based on different models for jack mackerel is similar to that for sardine (Ward et al. 2011). Both GLM-4 and log-normal models resulted in low estimates of $P_0$ while other models produced similar estimates of $P_0$ with the exception of GLM (negative binomial error) based on full data set. So if the precautionary approach is preferred to set the quota as recommended by Ward et al. (2011), the log-linear model estimate can be used, otherwise, the spawning biomass of 140,000 mt from Neira (2011) is not unreasonable to be used to set the quota. As stated in

Neira (2011),much research needs to be carried out if the DEPM is to be used in the future or other estimation procedure can be considered for spawning biomass.

**Suggestions of alternative methods of assessment for small pelagic species, either through DEPMs or other methods that would give similar levels of certainty.**

For DEPM method, alternative estimation procedure of $P_0$ can be considered: e.g. the egg mortality can be constructed by including yolk-sac larval data, the original data instead of egg data grouped by age can be used (Lo et al. 2005) and different estimates of spawning females for the spawning fraction (S) can be considered and evaluated. A species specific ichthyoplankton-trawl survey needs to be conducted during the peak spawning season to obtain estimate of spawning biomass of that species. An adaptive allocation survey design can be considered by using the continuous underway egg sampler (CUFES) for efficient allocation of additional egg samples. Other egg production estimation procedures, like nonlinear mixed effects (NLME) model used for snappers (*Pagrus auratus*) off western Australia can be considered in the future.

Two alternative methods of assessing small pelagic species can be reconsidered, which are currently used off west coast of US: the acoustic survey and aerial survey eventhough both methods had been used but unsuccessfully for jack mackerel off Australia. These two kinds of surveys need ground truth observations. Acoustic survey conducted by the Southwest Fisheries Science Center is preferred to the aerial survey conducted off Oregon and Washington by industry. The time series of biomass of Pacific sardine from acoustic survey is consistent with the spawning biomass while the time series of biomass from the aerial surveys for Pacific sardine since 2009 is not.

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**Full report**

**Comments on IMAS report on ‘Application of daily egg production toe estimate biomass of jack mackerel, *Trachuru declivis* – day fish species in the pelagic ecosystem of south-eastern Australia’ by F. J. Neira, 2011**

Dr. Neira made a great effort to estimate the spawning biomass of jack mackerel despite the fact that adult samples were not collected synchronized with eggs. The egg data used in the analysis were from October, 2002 blue mackerel survey and the adult samples came from archived samples collected in 2001-2004 or literature. Therefore the estimates of the spawning biomass can be used only as a guide line of the status of jack mackerel in 2002 or in early 2000s. Dr. Neira did point out all the weakness of this exercise and what needs to be done in the future in the discussion section. The spawning biomass in October 2002 is likely between 50,000 -400,000mt, taking into consideration all inputted adult reproductive parameter estimates from all survey data off south-eastern Australia during 2001-2004 and literature for Chile and Portugal in late 2000s. Thus all adult reproductive parameters were not estimated from the same survey and the accuracy of spawning biomass estimate is not certain.

The authors have many concerns (see discussion section) including the need to model the temperature dependent egg stage-to-age relationship. I like to address two concerns of the author, which may not be as bad as author thinks: 1. Possible negative bias of the spawning biomass. 2. The surveys of October were not at the speak spawning time (December-January) (p.6 and p. 30).

1. The negative biasness of the s. biomass: Dr Neiro thinks that the spawning biomass may be underestimated due to the egg data were used only from October 2002 and not from February

2003. The October 2002 survey covered the area between Sugarloaf Point and Cape Howe (32.5-37.0$^{o}$S) while the February 2003 survey covered the area from Cape Howe to Four Mile Creek (NSW), estern Tasmania (37.5-41.7 $^{o}$S) (Table 2.2, Figure 1, 4 and 5).

1.1 The estimate of spawning biomass is primarily based on two components: egg production ($P_0$) and the daily specific fecundity (eggs produced per day per fish weight). As we are not certain about the representative of adult data, like the sex ratio being 0.3, which is likely to be underestimated, the possible bias of the spawning biomass is unknown.

1.2 The exclusion of egg data from February, 2003 may introduce bias of estimates of $P_0$ if the adults do not migrate as there could be two groups of spawning fish: one in October in the north and the other in February in the south and the later was not surveyed in October 2002. Otherwise, if adult fish do migrate, then fish in these two areas would belong to the same group and there would be no bias of the estimate of spawning biomass. In particular, the egg densities in February is much lower than in October (Table 2.2). Thus the possible negative bias of spawning biomass may not be significant.

2 The surveys were not conducted during the peak spawning time. The peak spawning time is normally the optimal time of survey due to the high number of active females and the abundance of eggs. In theory, the DEPM can be applied throughout the spawning season. The drawback of sampling off the peak spawning time (between December and late January p.30) is that more tows or trawls are needed to achieve the same precision of the estimate. For the same amount of effort, the precision of the estimate would be much better if the samples were taken during the peak spawning time than off season.

**Comments on analyses and assertion by Dr Wadsley. Please see**

http://www.afma.gov.au/wp-content/uploads/2012/09/Att-4_Comments-onwadsleyJ.mackerel.pdf

**Comments on 'Re-analysis of mean egg production in jack mackerel' by J. Lyle, K. Hartmann, C. Buxton & C. Gardner, Institute for Marine and Antarctic Studies. .**

Dr. Lyle et al. of IMAS provided the mean egg production of jack mackerel based on seven estimation procedures used by Ward et al. (2011) for Australian sardine spawning biomass assessment. The comparison of estimates based on different models for jack mackerel is similar to that for sardine (Ward et al. 2011). Both GLM-4 and log-normal models resulted in the low estimates of $P_0$ while other models produced similar estimates of $P_0$ with the exception of GLM (negative binomial error) based on full data set.

Theoretically, one would use the original data set, say egg production-age data, to determine the best mode as mentioned in the beginning of discussion section on p.4 to check the assumption of each model based on original data, like the variance is proportional to the mean (GLM 2) or proportional to mean squared (GLM 3). Here the procedure was in the reverse order: fitting different models and then compare the results. The standard error or CV of the estimates provided information about the precision of the estimate, but it is difficult to evaluate the possible bias, if any, among all models. The log-linear model based on log-transformed data reduced the range of log-transformed data, and among year variation even after the bias-corrected anti-log transformation (Figure 5 of Ward et al. (2011)). One way to check the possible bias is to perform bootstrap, to estimate the relative bias, which can be used to correct the bias to yield unbiased estimates. In particular for both jack mackerel and sardine, the estimates of $P_0$ from log-linear model are much lower than other estimates except those from GLM-4. The ideal estimate of any parameter is an unbiased estimate with minimum variance. Quit often, some estimates are unbiased with larger variance (imprecise) while others are biased with smaller variance (precise). This may be the case here: the log linear estimates may be biased downward but precise while others may be unbiased but imprecise. As the CV of $P_0$ obtained from each model was not provided in this review, it is hard to compare the precision among all GLM estimates except the CV of $P_0$ provided by Neira for GLM model.

The statement on p. 3 is not clear to me: “Furthermore, it should be noted that the probability distributions for $P_0$ are typically positively skewed (results not shown here) with greater agreement on the lower bound of $P_0$ than on the best estimate (what is the best estimate?). That is, there is a greater agreement between methods about the lowest plausible biomass than there is about the best estimate.” One has to understand that the mean of any data set is influenced by extreme data points but the estimate of total is based on the mean value regardless of the skewness of the distribution and not the mode nor the median. The mode or median of a data set from a positive skewed distribution, like that of egg production, is more stable but would underestimate the total $P_0$, and thus the spawning biomass.

Lyle et al. used two data sets: one is partial data set (extreme cohorts excluded) and full data set. The partial data set is preferred because it provides unbiased estimate of $P_0$ with better precision than from the full data set. The young eggs, say stage 1 or <4h old, are patchy with large variance. Including young eggs in the modeling is likely to increase the variance of the estimate of egg production and mortality rate. The decreasing of older eggs are due to either hatching or dying, so the mortality is likely to be over estimated if they are included in the computation of egg mortality curve. This was apparent for the case of GLM (negative binomial error distribution) which appeared to be the most sensitive of all methods to the inclusion or exclusion of the extreme cohorts (Table 1 and 2). It would more informative to include a figure of egg mortality curves by various model and the raw data points of egg production and age.

Among all models used, the estimates of $P_0$ are similar among NLS and GLM1-4 while lognormal model produced the low $P_0$ (Table 1 and 2), similar to the results for the sardine by Ward et al. (2011). So if the precautionary (conservative) estimates are preferred to set the quota as recommended by Ward et al. (2011), the log-linear model estimate can be used, otherwise, the spawning biomass of 140,000 mt from Neira (2011) is not unreasonable to be used to set the quota.

I agree to the final statements of Discussion section. As stated in Neira (2011),much research needs to be carried out if the DEPM is to be used in the future or other estimation procedure can be used for biomass like acoustic survey.

**Suggestions of alternative methods of assessment for small pelagic species, either through DEPM or other methods that would give similar level of certainty.**

For both Jack mackerel and sardine off Australia, various models were used for the egg production and mortality estimates using the DEPM. The results from Neiro and Lyle et al. indicated that the log-normal model produced much lower estimate than other models. Researchers may check into models including spatial-temporary with environmental variables (Bernal et al. 2011, Straoudkis et al. 2006, Borchers et al. 1997). As the egg mortality some time is difficult to model due to the patchiness of eggs, yolk-sac larval data can be included in the embryonic mortality curve (Lo et al. 2001). In addition, the original data instead of egg data grouped by age can be used (Lo et al. 2005). Other egg production estimation procedures, like Nonlinear mixed effects (NLME) model used for snappers (Pagrus auratus) off western Australia can be considered in the future (Jackson and Cheng 2012). For adult parameters, the spawning fraction (S): fraction of mature females spawning per day is the most difficult parameter to estimate. For northern anchovy (*Engraulis mordo*x) off California, the fraction female fish spawned was based on number of females spawned one day after the spawning (day-1) ($S_1$), and for Pacific sardine, the average of day-1 and day-2 : ($S_{12}$), while, for Bay of Biscay anchovy ( *Engraulis encrasicolus*), the average day-0 and day-1 ($S_{01}$ ) has been used (Uriart et al. 2012). Thus for any particular species, effort needs to be made to determine the proper spawning females to compute the spawning fraction.

Ideally, a species specific ichthyoplankton-trawl survey needs to be conducted during the peak spawning season to obtain estimate of spawning biomass of that species. An adaptive allocation survey design can be considered by which the continuous underway egg sampler (CUFES) is used to efficiently allocate additional egg tows in area when the egg density from the CUFES is higher than a threshold (Checkley et al. 1997, van der Lingen et al. 1998, Lo et al. 2001). If species specific survey is not possible, like the case for jack mackerel, data from icththyoplankton samples still can be used to assess the population with less efficient estimate of the egg production and adult parameters, i.e. possible biased with high variance and thus spawning biomass.

Two alternative methods of assessing for small pelagic species that can be reconsidered for jack mackerel are the acoustic survey and aerial survey. These two survey methods are currently used off west coast of US. Both kinds of surveys need ground truth observations. The acoustic surveys have been conducted in South Africa and California, US for SPF (van der Lingen, et al. 1998, Zwolinski et al. 2011) and other areas. Off California, the two time series for sardine from DEPM and acoustic from 2006 to 2010 showed the same trend (Hill et al. 2011). Off south Africa, while the time series from 1984-1993 between the spawning biomass and acoustic survey matched very well for anchovy but not so for sardine .For Atlanto-Iberia: the acoustic biomass and DEPM spawning biomass of sardine from 1997-2009 do not match well (pers. Comm. Maria Manuel Angelico, Institute for Fisheries and Sea Research, Lisbon, Portugal). If these two time series, DEPM spawning biomass and acoustic biomass, are consistent, then one of the two surveys can be conducted yearly while the other one be conducted periodically, say every 3-5 years. The aerial surveys for Pacific sardine conducted off Oregon and Washington by industry since 2009 produced estimates with trend different from DEPM spawning biomass and acoustic biomass time series.

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