Rationale for and examples of acoustic and egg indices comparison for quality control of fish-stock survey estimates

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1. Rationale for acoustic and egg indices comparison

Understanding discrepancies in particular years between acoustic and Daily Egg Production Method (DEPM) estimates is essential to better understand potential bias impacting both estimates, and develop a weighting per year assessing the coherence between survey estimates, to input in stock assessment models (Petitgas *et al.*, 2009; ICES, 2017).

Several plans for collaborative work have been proposed within WGACEGG to compare acoustic and DEPM indices (WGACEGG 2013, 2015, 2016), until the inclusion of such comparative approach as a formal group ToR in 2017 (ICES, 2017).

Different approaches have been adopted so far, including the comparison between two P0 estimates (DEPM BIOMAN; CUFES PELGAS) and one acoustic estimate (PELGAS), analysis of the sensitivity of each estimate to its parameters, and the comparison between egg and adult maps.

We here provide some rationale on how to investigate differences between acoustic and egg indices.

Acoustic-based (B_{acou-i}) and egg-based (B_{egg-i}) fish biomass estimates are derived for a species *i* using the following equations:

$B_{acou-i} = Area \ x \ NASC \ / \ ts_i$ (Simmonds and MacLennan, 2005)

Where: *Area* (survey area) and *NASC* (areal fish acoustic density) are the observation terms, and ts_i is the Target Strength scaling factor used to convert acoustic into fish density in natural scale.

$B_{egg-i} = P_{tot-i} / DF_i = P_{0-i}.SA.W_i \ / \ (R.F.S)$ (Lasker, 1985)

Where P_{tot-i} is the observation term (total daily egg production in the survey area), and DF_i is the daily fecundity scaling factor used to convert egg into spawning fish density. DF_i is derived from P_{0-i}, the mean daily egg production in the survey area *SA*, mean fish weight W_i, sex ratio *R*, batch fecundity *F* and spawning fraction *S*.

Acoustic and egg indices can be compared within surveys, if both information are collected on the same platform, or within surveys occuring in the same areas, over the same time period. The relative discrepancy between acoustic and egg indices can be considered significant for agiven year, if the point confidence interval lays outside of the 95% confidence intervals of the linear regression between acoustic and egg indices (cf. Figure ...).

If, for a given year, B_{acou} is relatively significantly smaller/higher than B_{egg} estimated in the same area, and that B_{egg} is considered unbiased, this means that bias has been introduced either during the observation process (i.e. in *NASC or area*), and/or during scaling factor estimation (*tsi*).

Acoustic observation bias, i.e. under/over-estimation, may be caused, inter alia, by incomplete coverage of the stock distribution area, sub-optimal echosounders' performances (including calibration), fish accessibility issues (e.g. very coastal adult fish distribution, outside of survey area), echogram scrutiny error ...

Scaling factor bias would result in *tsi* over/under-estimation, which can be caused by issues with echo identification by fishing or other means, non representative echo identification data, and/or problems with haul-EDSU association or post-stratification region delineation ...

Conversely, if, for a given year, B_{egg} is relatively significantly smaller/higher than B_{acous}, and B_{acou} is considered unbiased, this means that bias has been introduced either during the observation process (i.e. in *Ptot* estimation), and/or during scaling factor estimation (*DFi*).

Total daily egg production under(over)-estimation (egg observation error) can be caused, inter alia, by an incomplete coverage of the spawning stock distribution area, and/or inadequate egg sampling or analysis. Egg scaling factor over/under-estimation may originate from either mean weight under/over-estimation, or R, F, S product over/under-estimation. due to a lack of representativity of biological samples, or processing issues.

In case of significant discrepancies between acoustic and egg indices, it is advisable to first compare observations maps, then scaling factors, then final indices, in an attempt to disentangle the bias potentially introduced at each step of the process.

2. Examples of acoustic and egg indices comparisons

Examples of intra and inter surveys egg and acoustic comparisons are presented in this section, to exemplify what can be learned from the comparison of each type of index. Codes used to produce the figures below are available in the [WGACEGG code repository[1].](https://gitlab.ifremer.fr/md0276b/wgacegg-rscripts/-/blob/master/Indices/PELGAS-BIOMANindicesComparison.r)

2.1. Intra-survey acoustic-egg comparisons

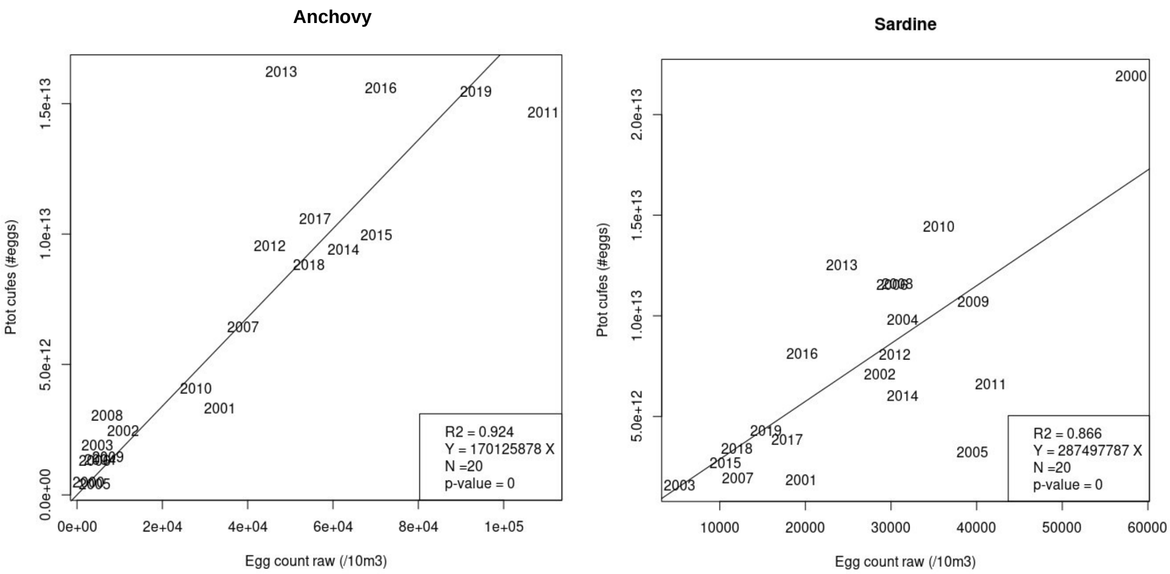


Figure 1. CUFES total egg counts vs. Ptot estimates for anchovy (left) and sardine (right), PELGAS survey.

Figure XXX shows an example of the effect of the conversion of raw anchovy and sardine total egg counts from CUFES into Total daily egg production (Ptot). It displays the changes in the egg indices series correlation resulting from the correction of raw egg counts through the application of a vertical density model and an egg mortality model (Petitgas *et al.*, 2009; Huret *et al.*, 2016). The correlation between raw egg counts and Ptot remains very high (R2 = 0.92) for anchovy and high for sardine (R2 = 0.87).

1 https://gitlab.ifremer.fr/md0276b/wgacegg-rscripts/-/blob/master/Indices/PELGAS-BIOMANindicesComparison.r

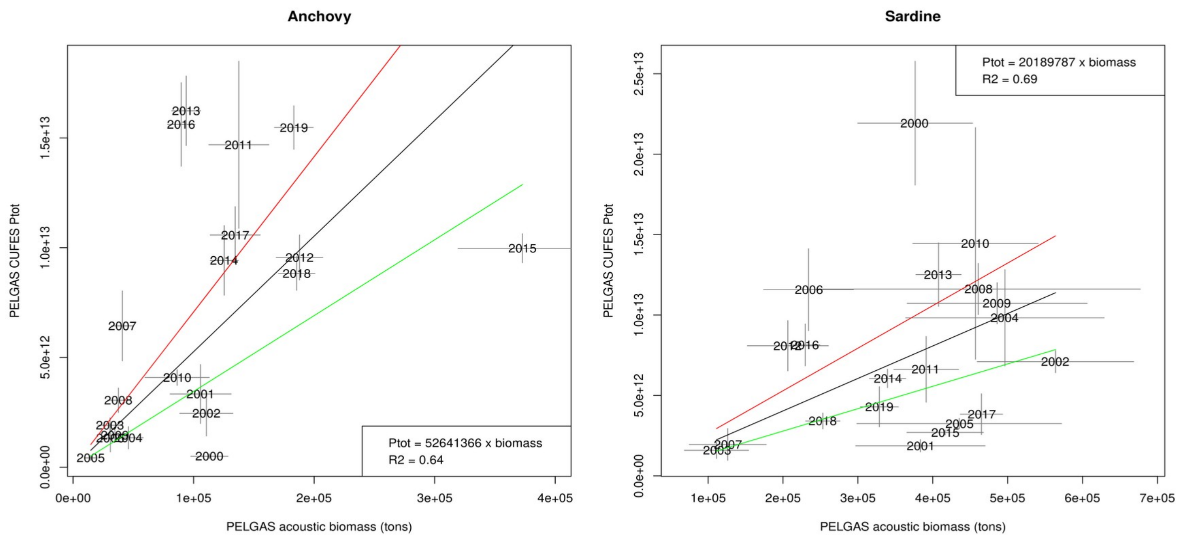


Figure 2. Acoustic biomass vs. CUFES Ptot estimates for anchovy (left) and sardine (right), PELGAS survey. Crosses: estimation error. Black line: linear regression between acoustic and egg estimates, with 95% lower (green line) and higher (red line) confidence intervals.

Figure 2 shows an example of intra-survey comparison between acoustic and egg indices.

Overall correlation between egg and acoustic indices are relatively good (R2 = 0.64 and 0.69 for anchovy and sardine respectively).

Anchovy acoustic biomass was significantly relatively higher than total daily egg production (not overlapping confidence intervals) in years 2000, 2002 and 2015. Conversely, anchovy egg Ptot was significantly relatively higher than acoustic biomass in years 2007, 2011, 2013, 2016 and 2019.

2.1. Inter-survey acoustic-egg comparisons

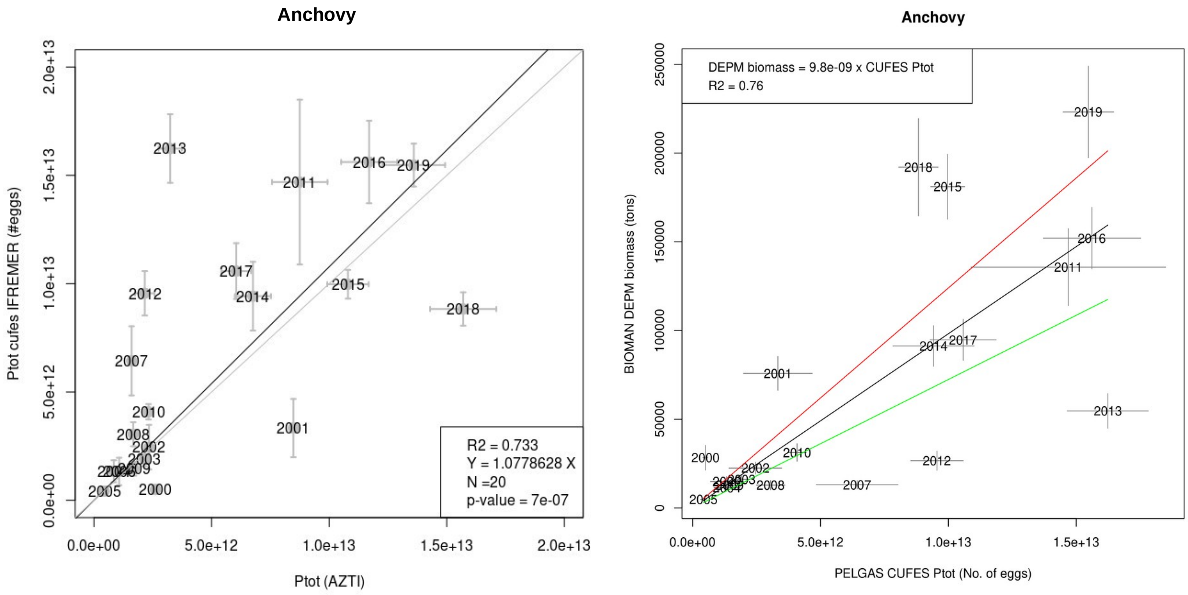


Figure 3. Anchovy eggs estimates, from PELGAS and BIOMAN surveys. Crosses: estimation error. Black line: linear regression between estimates, with 95% lower (green line) and higher (red line) confidence intervals.

Figure 3 presents the correlation between anchovy egg estimates derived from the PELGAS (Doray *et al.*, 2018) and BIOMAN (Massé *et al.*, 2018) surveys, conducted at the same time in spring in the Bay of Biscay. PELGAS egg index was derived from CUFES surface pump data (number of eggs at stage), corrected with vertical distribution and egg mortality models. BIOMAN egg index were derived from Pairovet net data, corrected with an egg mortality model, and combined with Daily Fecundity (DF) estimates derived from adult parameters, to produce a DEPM-based biomass estimate.

Overall correlations between Ptot values on one hand, and PELGAS CUFES Ptot and BIOMAN DEPM biomass estimates on the other hand, were high (R2 = 0.73). In addition slope of the regression between both Ptot is really close to one. This indicates that: i) both surveys provide coherent anchovy egg production indices, ii) the combination of BIOMAN egg index with DF estimates results in a DEPM biomass index which is well correlated with egg production indices from PELGAS and BIOMAN surveys.

Differences between indices occurring in particular years should be investigated to better assess potential bias having occurred either during the observation or correction/scaling processes.

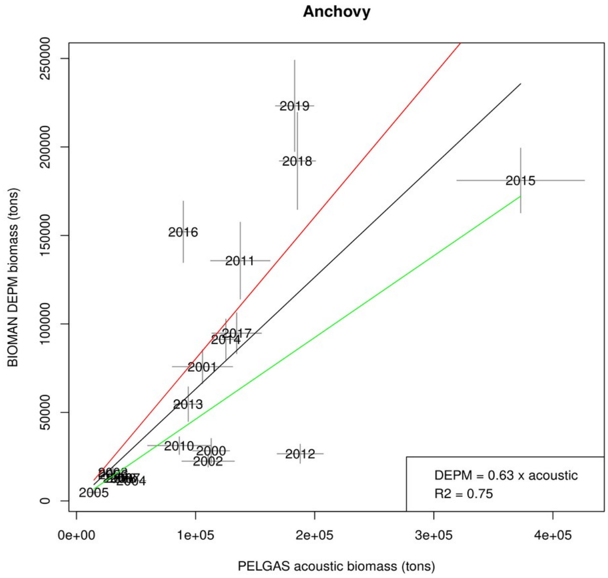
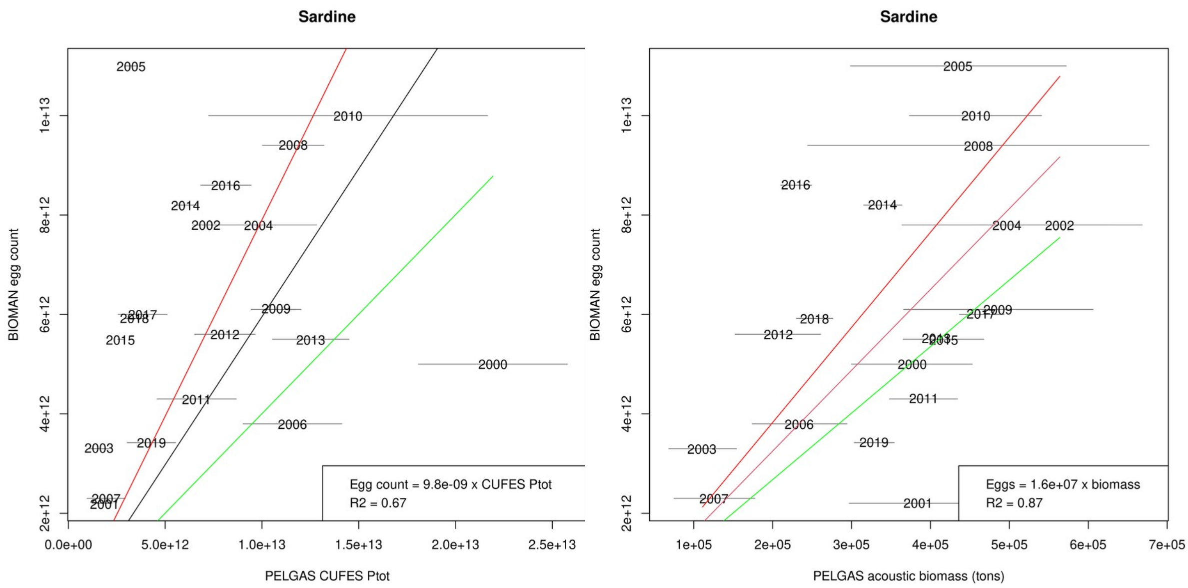


Figure 4. Anchovy acoustic vs. DEPM biomass estimates, from PELGAS (acoustic) and BIOMAN (DEPM) surveys. Crosses: estimation error. Black line: linear regression between acoustic and egg estimates, with 95% lower (green line) and higher (red line) confidence intervals.

Figure 4 presents the correlation between anchovy biomass estimates derived from acoustic data collected during the acoustic PELGAS and DEPM data collected during the BIOMAN (Massé *et al.*, 2018) survey.

Overall correlation between egg and acoustic indices are relatively good (R2 = 0.75)., with DEPM estimating biomasses lower than coustics by a factor of 0.63. Anchovy acoustic biomass was significantly relatively higher than total daily egg production (not overlapping confidence intervals) in years 2000, 2002 and 2015. Conversely, anchovy egg P_{tot} was significantly relatively higher than acoustic biomass in years 2007, 2011, 2013, 2016 and 2019.

Those discrepancies should be explored one by one to identify potential bias having occurred either during the observation or correction/scaling processes.



should be conducted annually during WGACEGG meetings, to adress the group TOR's i). Those comparisons should in our view be performed to: i) quality check the fish stock survey indices provided to stock assessment groups, ii) develop a weighting per year assessing the coherence between survey estimates, to input in stock assessment models. Those comparisons should be conducted whenever acoustic and egg data are collected for the same species, over the same time period and in the same area.

The overall agreement between indices series should be assessed while modelling one index using the other as a covariate. Survey indices collected in years where significant differences are observed in should be further investigated to assess potential observation and scaling bias. This quality check process would help develop a coherence index summarising the agreement between egg and acoustic indices. This index should be provided to assessment group together with acoustic and egg indices and their estimation error, as a synthetic quality control index of fish-stock survey estimates.

References

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