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Catch-at-age structure of CJM for 1990-2018 using a new ageing criterion

Chile

Catch-at-age structure of Jack Mackerel for the period 1990-2018 using a new ageing criterion.

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Abstract

The new criteria of age allocation based on the results of the validation allowed to obtain a different ageing structure for jack mackerel. These results are characterized for the shift of the catch age structure towards younger age groups obtaining from them mean sizes and weights greater than those registered with the historic criteria of age allocation. The new allocation shall affect both the selectivity of the fleets on younger individuals and the sensibility of the model to estimate recruitments. As a challenge, we suggest the conduction of cross match otolith Reading including the new criteria amongst the different SPRFMO laboratories.

Introduction

The joint-stock assessment model for Jack Mackerel (JJM) used for the South Pacific Regional Fisheries Management Organisation (SPRFMO) integrates (2) two age-structured fishery-dependent and (1) one age-structured fishery-independent time series, both annually provided by Chile for fitting purposes. Those data series help for interpreting the age-vulnerability pattern of fishing fleets operating along the central-south and north, as well as describe the age-acoustic surveyed abundance at southern Chile, respectively.

An increasing effort has been devoted during the last four years to improving the quality of age data of Jack Mackerel (Cerna *et al.* 2016), prominently in the context of the collaborative age-structured data-use framework with the SPRFMO, and particularly for offshore trawling fleet which uses the age-length keys provided by Chile to calculate the catch age composition for the SPRFMO high-seas convention area. Recent ageing studies have identified two issues in the reading otolith protocol of Jack Mackerel conducted by the Development Fisheries Institute (IFOP). First, several workshops and meetings dedicated to the ageing analysis of Jack Mackerel have recognised disagreement in the identification of the first growth ring with an annual periodicity. Second, one or two false increments (annulus) were identified, raising a relevant source of difference in the age analysis (SC5-JM02, SC-04-JM-05).

Jack Mackerel showed to have particularly complicated ring structures because in many cases one annulus may contain double or multiple translucent areas (Cerna *et al* 2016, SC-04-JM-05). Therefore, the potential of inaccurate ageing is high and may result in a bias of age estimation. The description of annual periodicity formation of hyaline and opaque growth zones was first reported by Aguayo *et al.*, (1981). This estimation appears to be consistent with the annuli structure of the other species of the same genus. However, discrimination between a real and a false annual growth is not an easy task in the Jack Mackerel fishery.

This issues in the ageing interpretation triggered substantial differences in Jack Mackerel growth models (SPRFMO, 2018), which should affect the construction of catch-age compositions and age-length keys used by the JJM. This paper describes a new historical age-composition time series constructed using an improved ageing protocol that takes into account issues concerning the identification of the first growth ring. Ageing protocol arose from the age validation methods (SC5-JM02) and compared the age estimation by conventional methods (historic criteria) with the new criteria resulting in order to improve the age- structured data used by the SPRFMO.

Methods

The individual age of Jack Mackerel has been estimated using standard skeletochronology techniques of whole and cross-sectioned otolith in which an opaque and translucent ring is identified and counted as an annual increase or annulus. Using the new ageing criteria, changes in the age-structured time series for the period 1990-2018 were performed integrating geographic position, date of capture, fish fork length, and the size and radius (mm) of each otolith sampled (n=133,943).

Change of ageing criteria in the historical data series

Age determination of Jack Mackerel (FIPA N° 2014-32) was validated using three methods: 1) primary micro-increment reading in 45 sagittal otoliths of young-of-the-year (YOY) fish to validate the first annulus; 2) modal-progression of strong year-class to validate the second annulus, and 3) bomb-radiocarbon trials of 15 otolith cores whose year of formation ranged from 1960 to 1972, to validate the absolute age in older fish over 38 cm fork length (FL). These findings demonstrated high growth in the first years of development, which was indicative of age overestimation using the conventional ageing criteria (Cerna *et al.* 2016, SC5-JM02).

The most important results were as follows:

- The first growth zone, which has historically been considered the first annulus could only be counted 185 ± 34 daily microincrements, a number well below the 365 days required to be considered the first *annulus* (Table1).
- The second growth zone (historically considered as the second *annulus*) finished its formation around 352 ± 79 days and should be considered the correct first annulus (Table1).
- The third growth zone (historically considered the third *annulus*) was completed in about 489 ± 58 days, and could not be considered the second *annulus* (Table1).
- The modal-progression of strong year-class method confirmed that the fourth and fifth ring of old ageing criteria corresponded to the second and third annulus, respectively (Table2).
- The bomb radiocarbon method confirms that from the sixth ring and onwards corresponded to annuli (Cerna *et al* 2016).

Table 1. Basic statistic of mean daily age and length at the end of translucent ring formation of sagittal otoliths of Trachurus murphyi < 26 cm in fork length

Translucent rings	Fork length (cm)		Age (days)		n
	Mean \pm sd	min - max	Mean \pm sd	min - max	
0	8.3 \pm 3.3	3.4 - 13.8	96 \pm 20	56 - 134	28
1	16.3 \pm 0.6	15.7 - 17.0	185 \pm 34	150 - 230	15
2	21.4 \pm 1.8	18.6 - 23.0	352 \pm 79	251 - 461	15
3	23.4 \pm 1.3	22.0 - 25.0	489 \pm 58	379 - 565	13

Table 2. Estimated fork length (mean and standard deviation (s.d)) from an annual modal progression of a strong year class (PSYC), compared with mean length of aged fish for each translucent ring of sagittal otolith of jack mackerel for the period 2008 to 2011 from Chilean fisheries. The bold number indicates the match between approaches to identify the true annuli.

Translucent Rings	Mean ± sd of Fork length frequency (cm)								Ring Category	
	2008		2009		2010		2011			
	Ageing	PSYC	Ageing	PSYC	Ageing	PSYC	Ageing	PSYC		
1	14.5±1.9	14.6±1.5	20.7±1.6	23.1±2.4			31.1±1.6	30.0±3.1	False	
2									True	
3						25.4±1.4			no mode	False
4						28.1±0.9			27.0±3.1	True
5									True	
	Recruitment		Age 1		Age 2		Age 3			

The method to correct the historical age series of Jack Mackerel consisted in identify and change age of each rings of the data base, according to the following criteria:

- The first and third rings of ageing old criteria corresponded to checks or false rings and were removed of the data base (Table 2).
- The second, four and fifth rings of ageing old criteria were reassigned as correct first, second and third annulus in new reading method (Table 2)
- Since sixth ring were reassigned as a fourth, fifth annuli, consecutively until last ring of each register in the base data.

These were the most accurate way to correct the historical age series according to the new ageing criteria. All analysis was performed in R.

Reconstruction of catches by age group

We estimate the catch at age structure of Jack Mackerel using age length keys coming from the historic criteria and the validated criteria according to the following procedure. The age structure of the catch was estimated with the quarterly age keys constructed for each fleet in order to extrapolate the catch by length stratum to catch by age group.

Once a key is available, fish samples that were only measured for length can be distributed to age groups accordingly. This is possible because it is assumed that the sample of aged fish and the sample of fish measured for length are simple random samples from the same population, thus the probability that a fish is of a particular age, given its length is the same in both samples.

The individuals present in each length interval (N_j) are assigned to different ages according to a size-age key. The number of individuals belonging to each age group according to size interval is estimated as

$$N_{ij} = q_{ij}/N_j,$$

where:

- N_j : Estimated number of individuals in length j .

- N_{ij} : Estimated number of individuals of length j that belong to age group i
- q_{ij} : Probability of individuals of length j belonging to an age group i

The abundance by age group is obtained by:

$$N_i = \sum_{j=1}^n N_{ij}$$

where:

- N_{ij} : Estimated number of individuals of length j that belong to age group i
- N_i : Estimated number of individuals in age group i .

Marginal increment

As a rule, if the marginal increment is translucent it is not counted because it is not fully formed. In the fourth cycle above, we calculate the proportion of the translucent increment i in relation of the increment $i-1$.

Age group

The age group is the number of calendar years after the date of capture, for this purpose each fish will be assigned depending on the year in which it was spawned and on the date of capture, simplifying the identification of annual class per fish. This estimate is calculated with the number of rings observed in the otolith, the type of edge of the otolith and an arbitrary date of birth. In Chile, the first date of birth is taken as a convention on January 1.

Length weight parameters

The length-weight relationship is widely used in fisheries to estimate weight from the length of an individual and also to estimate condition indices. The most frequently used expression for this relationship corresponds to the allometric equation where the weight is expressed as a function of length, and its parameters are estimated by linear regression of log-transformed data. Since variability in weight usually increases with length, this transformation has the advantage that it tends to stabilize the weight variance but introduces a bias factor in back-transformed predictions which requires correction.

The weight/length model is

$$W_i = a * L_i^b,$$

and can derive a simple linear regression model applying a logarithmic transformation

$$\ln(W_i) = \ln(a) + b * \ln(L_i),$$

where W_i represents the weight and L_i the length of the i -th fish; a and b correspond to the intercept and slope, respectively.

Mean length

The average length for each age group is expressed as

$$\bar{p}_i = \frac{\sum_{j=1}^n l_j n_{ij}}{n_i},$$

where:

- l_j : Fork length j
- n_{ij} : Estimated number of individuals of length j that belong to age group i
- n_i : Estimated number of individuals in age group i .

Variance

The variance of the mean length is expressed as

$$P_i = \sum_{j=1}^L p_j q_{ij}$$

$$\sigma_{p_j} = \sum_{j=1}^L \left(\frac{p_j^2 q_{ij}(1 - q_{ij})}{n_j - 1} + \frac{p_j(q_{ij} - P_i)^2}{N} \right)$$

where:

- n_j : Estimated number of individuals of length j
- N : sample Size
- p_j : Sample size for each length stratum j
- q_{ij} : Probability of individuals of length j belonging to an age group i

Mean weight

Assuming that the length is a normal random variable the expected function value of W_L could be defined as

$$E(W) = a(\bar{p}_i^b + a_1 \bar{p}_i^{b-2} \sigma^2 + a_2 \bar{p}_i^{b-4} \sigma^4),$$

where:

- \bar{p}_i : Mean length at age group i
- σ : Mean length at age i
- a : y-intercept
- b : Slope
- a_1 : Pienaar and ricker coefficient (1)
- a_2 : Pienaar and ricker coefficient (2)

Results

Analyses are illustrated using a set of years (1990, 2000, 2012, 2018) to make it easy to see.

Change of ageing criteria in the historical data series

Size distribution by GE of the otolith structure with the old and new criteria of allocation disaggregated by fleet and trimester shows larger sizes of the specimens of GE with the new allocation criteria (Figure 1). The average difference in the size by age between both criteria is 4.92 cm LH (Figure 2).

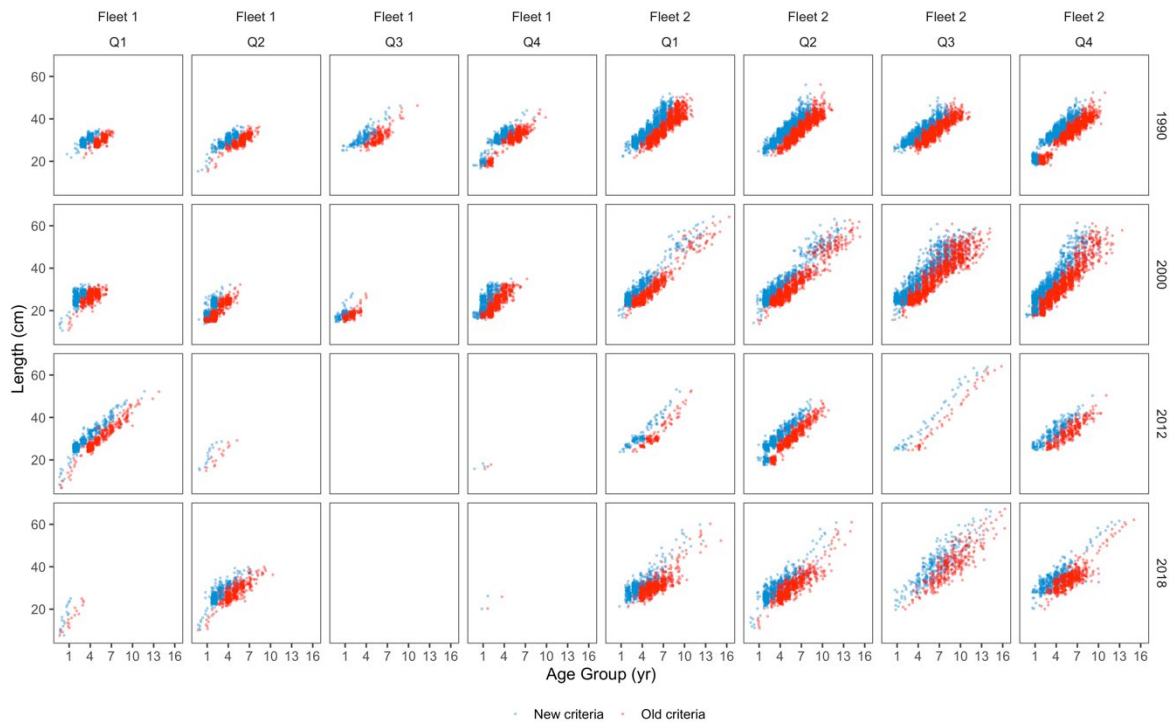


Figure 1. Size distributions by GE of the readings conducted with the old and new allocation criteria for 1990, 2000, 2012, 2018.

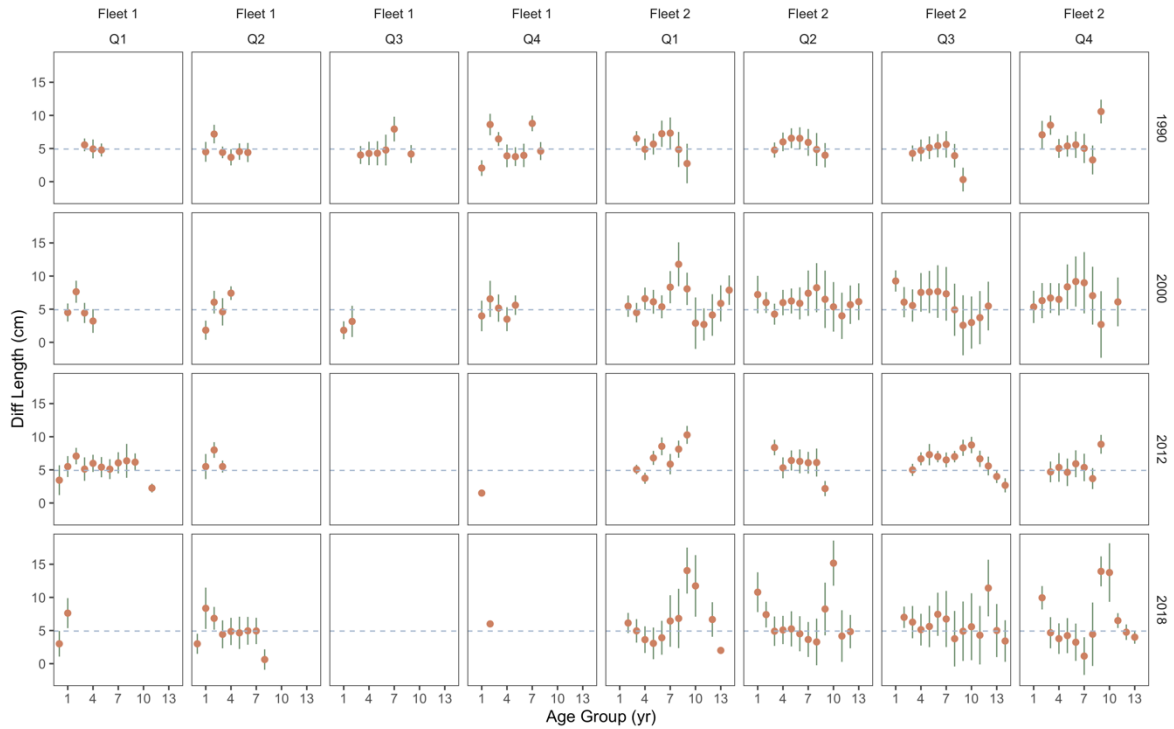


Figure 2: Length difference by age between the old and new ageing criteria. Horizontal line shows the total average difference (4,92 cm) for all combination.

Reconstruction of catches by age group

Application of a new criterion generates relevant changes in the structure by GE of the catch in the historic series, where age distribution is moved to the left, increasing the frequency in younger specimens with respect to the estimated structure from the historic reading criteria (Figure 3).

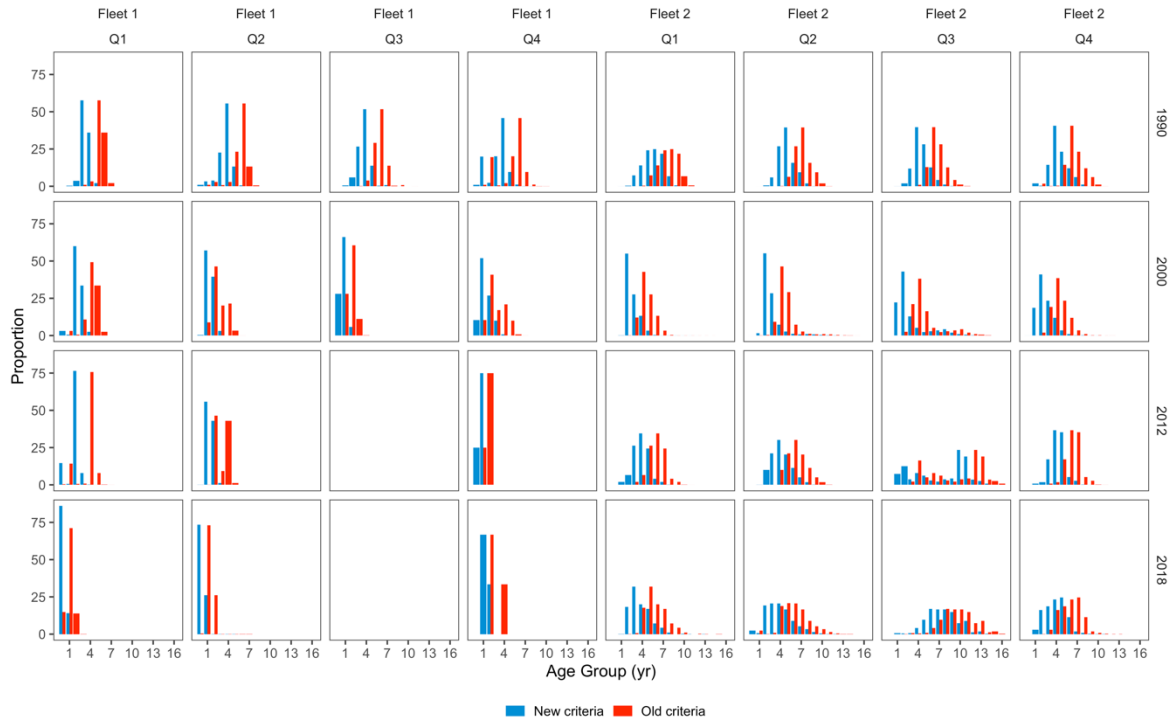


Figure 3: Catch at age estimated with new and old ageing criteria for 1990, 2000, 2012, 2018

Another important change in the new age structure is that it allows the visualization of the entry of new annual classes in most of the years (GE 0 and I), which are not visible in the old structure where age distribution starts from GE II most of the years (Figure 4)

Mean weights by GE

The new allocation criterion estimates for a same GE specimens of a higher mean weight when compared with those estimated from the age structure conducted with historic criterion. This increase in the mean weight shows a stock with an accelerated growth with respect of the growth dynamics assumed in the model for the stock assessment applied by the SPRFMO (Figure 5)

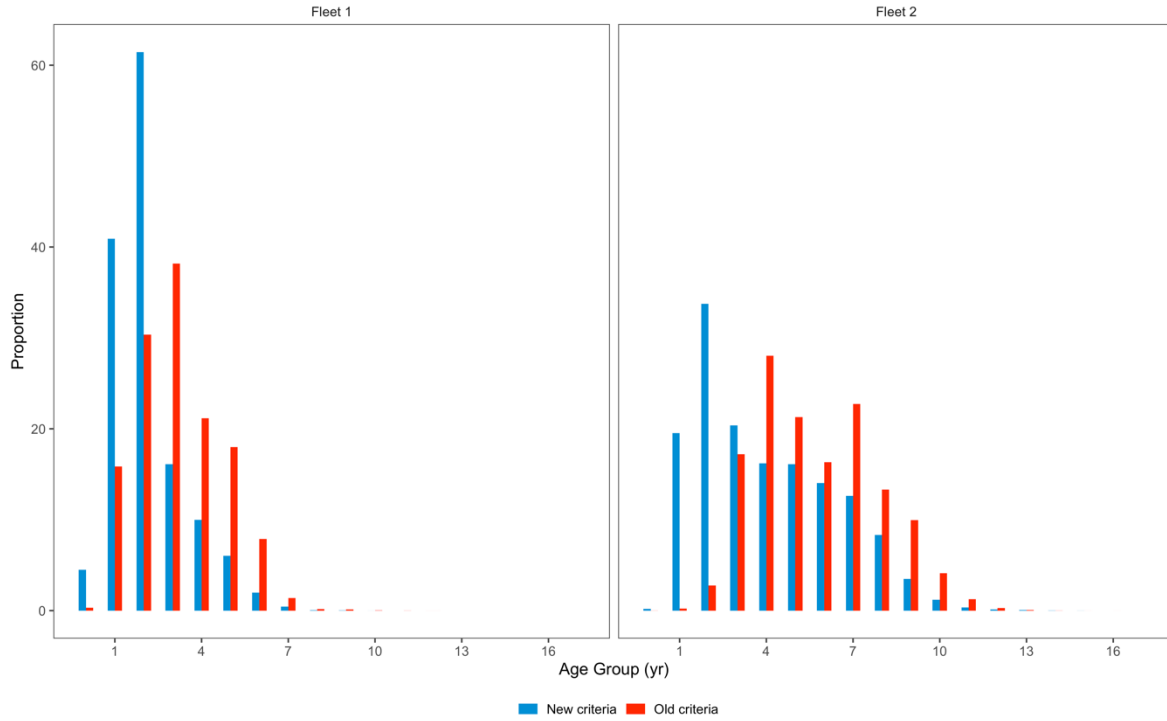


Figure 4. Mean structure for GE of the readings conducted with the old and new allocation criteria for the period 1990-2018.

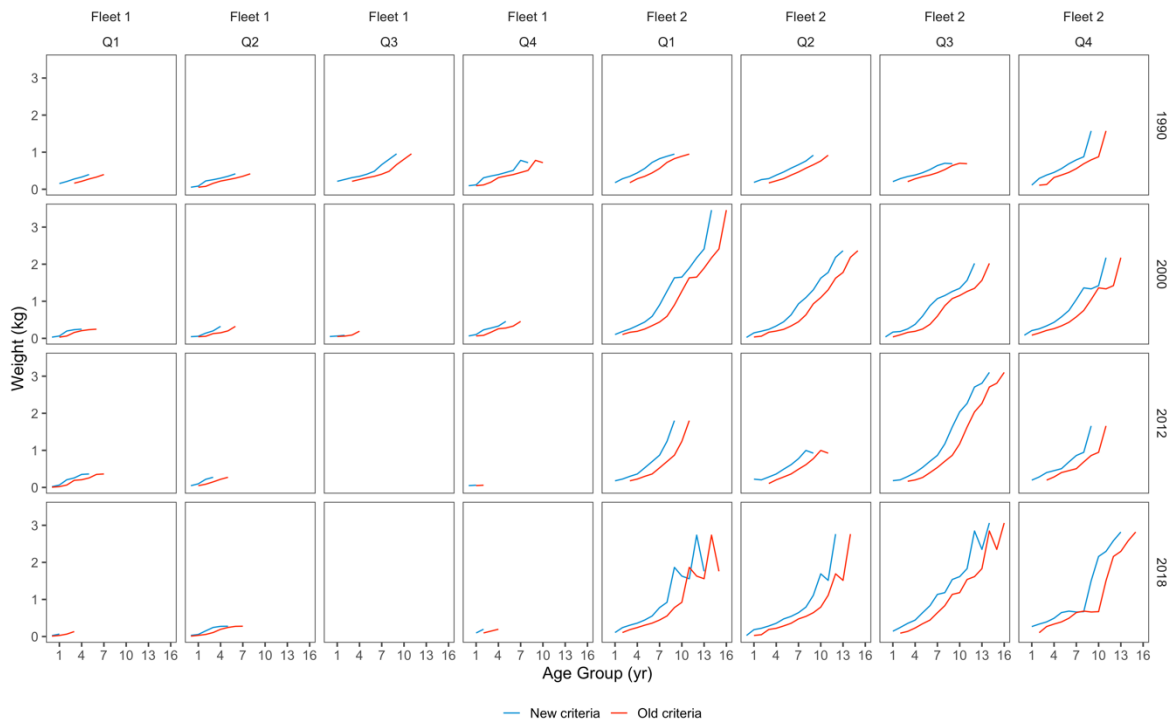


Figure 5: Mean weight of GE estimated with the old and new allocation criteria for 1990, 2000, 2012, 2018.

Discussion

Modification of the historic series from the new allocation criteria is supported by the evidence derived from the results of the validation of jack mackerel age with a multidisciplinary approach that included methods of daily micro increase, progression of strong year classes and radiocarbon bomb (Cerna *et al* 2016, SC5-JM02, SC-04-JM-05). Being the experimental validation of the periodicity of the primary micro increases and the first annulus confirmed with the FIPA 2017-61 study (Araya *et al.*, 2019). In this sense, modification of the historic series of catch by GE strictly kept to the validation study findings and is moving towards the improvement of the accuracy of the stock assessment of this resource.

It is important to mention that the reconstruction of the age structure of jack mackerel catch was only possible to conduct partially (between 1990 and 2018) due to the lack of biological information and the captures fractioned by trimester between 1975 and 1989. However, the period of the years available is enough to reproduce the historic dynamics of the resource in the South Pacific.

We believe that, with a subsequent challenge, it is necessary to conduct reproducibility tests aimed at improving the accuracy amongst the different laboratories that supply the information on age structure for the SPFM0 stock assessment evaluation model. This would enable the consolidation of the criteria to identify, measure, and count the growing rings and it may be spelled in a reading protocol developed with the countries involved.

An analysis for the assessment of the bias produced by the overestimation of the age in the readings conducted with the historical criteria is needed. This analysis is to be compared with the age estimations conducted with the criteria established after the validation of the age conducted by Cerna *et al* (2016).

The new age structures represent an accelerated growth with respect to the structures currently used in the JJM model. This characteristic probably leads to a change in the conceptual model used by the SPRFMO, since it implies the modification of other parameters of life history, such as natural mortality and parameters that modulate the reproductive process. However, it seems that the new age structures might represent in a better manner the recruitment dynamics of jack mackerel, by representing in a better manner the GE 0 and 1.

The change in the growth process should be adopted with caution and subjected to an extensive process of sensitization that allows its adoption under the current framework of jack mackerel assessment in the South-Est Pacific developed by the SPRFMO.

References

- Araya, M., Medina M., Segovia E., Peñailillo J., Avilés M., Guisen K., Arcos A., Charlin J., Pacheco C., Plaza G., Galeano AM., Contreras J., Rodríguez C., Cisterna L., Sepúlveda A., Neira M., Sanhueza E. 2019. Validation of the formation of the daily growth rings of Jack mackerel. Final Report, FIPA Project 2017-61. 95 p.
- Cerna JF, C Valero, G Moyano & L Muñoz. 2016. Protocolo de lectura de otolitos de jurel. Informe Final, Proyecto FIPA 2014-32. 103 http://www.subpesca.cl/fipa/613/articles-96046_archivo_01.pdf
- SPRFMO, 2018. Report of the Jack mackerel stock assessment. Valparaiso Chile, May 28th - 30th , 2018.
- SC5-JM02, 2017. Age validation and growth function of Chilean jack mackerel (*Trachurus murphyi*) off Chile. 5th Meeting of the Scientific Committee Shanghai, China
- SC-04-JM-02. Analysis of jack mackerel otolith microstructure. 4th Meeting of the Scientific Committee. The Hague, Kingdom of the Netherlands.