7th MEETING OF THE SCIENTIFIC COMMITTEE

La Havana, Cuba, 7 to 12 October 2019

SC7-HM02

Habitat Monitoring of Jack mackerel based on acoustics from fishing vessels

Chile

Habitat Monitoring of Chilean Jack Mackerel based on acoustics from fishing vessels

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Abstract

Mean density estimates and spatial distribution obtained from acoustic data recorded by 8 vessels of the Chilean jack mackerel (CJM) fishing fleet in their usual fishing operations during the years 2018 and 2019 are presented and compared with previous years. The abundance calculation was made only for the year 2019 based on a completely random sampling design through the geostatistical method. Acoustic data was collected with eco-integration systems that allow digital recording of the information during the entire trip of the vessels from the harbour to the fishing grounds and back to the harbour. During the years 2018 and 2019, CJM was distributed near the coast during the first three months, moving south to reach 42°30' S in the month of March 2018, while in the same month of the year 2019 CJM moved north, reaching 34°00' S. In April of both years, CJM began to migrate towards the west acquiring an oceanic distribution. In July, a change in the pattern of CJM was observed in both years, adopting a wide longitudinal distribution, occurring both near the coast and at the oceanic sector, reaching 77°00' W.

Average acoustic densities in m^2/nm^2 corresponding to the years 2018 and 2019 were calculated and the highest acoustic densities were registered in 2019. On the other hand, when comparing between years, during the year 2018 the highest densities were observed in the months of February, March and December in ascending order, whose maximum was approximately 2000 m^2/nm^2, while in 2019 the highest densities were observed in the months of February and April, achieving values that exceed 9000 m^2/nm^2.

The total abundance of CJM was estimated in 2664 millions of individuals that in biomass represents a total of 1,081,072 tons of CJM in the central-south zone of Chile, with a coefficient of variation of 4.96%. Results obtained were used to update the series of historical estimates of relative abundance that are registered for this fleet since 2004.

Introduction

The Chilean jack mackerel (*Trachurus murphyi*), is a transboundary species that has a wide geographic distribution in the South Pacific, from the Galapagos Islands to the southern region of Chile, in oceanic and coastal waters (Serra, 1991). In international waters it is distributed in large schools up to 160°W, mainly between 33°S and 48°S (Gretchina, 1992).

Its migration is mainly related to their spawning and feeding behaviour, with an annual cycle involving offshore migration in spring to spawn in oceanic waters returning to the coastal areas of Chile and Peru in summer-autumn related to the availability of food at the coast (Quiñones *et al*., 1997; Miranda *et al*., 1998). During autumn and winter, CJM aggregate in compact schools providing high availability mostly for the fishing fleet off the Chilean coast, particularly in the central-south zone of Chile (Serra, 1991; Arancibia *et al*., 1995a, b).

Traditionally, most acoustic research cruises aimed at estimating CJM abundance have been executed on vessels dedicated exclusively to research. Currently, to quantify the stock of CJM a direct evaluation cruise is carried out every two years, this is usually done in June, within the framework of the research program of the National Research Fond for Fisheries and Aquaculture (FIPA). Despite the existence of a program that allows estimating the stock of CJM with contributions from the state through the FIPA, it is still unknown to what fraction of the population the abundance estimate given by these studies is related. On the other hand, the discussion about the time window in which the evaluation is carried out persists, because the time of study is governed more by a calendar of use of the boat than to the dynamics of the resource to be evaluated.

The need to obtain direct information by identifying and quantifying acoustic targets, together with the collection of biological and environmental information, requires specialized systems, which are available on board some fishing vessels and therefore, can be used to obtain a greater volume of information to strengthen current research tools, improving the predictability of the evaluation model, especially with the incorporation of independent indicators obtained from the fishing activity of the fleet. Consequently, the need to implement the acoustic evaluation method with vessels of the regional fleet to quantify the available CJM biomass and its variations throughout the year is strongly recognized, a background that supports the need for the present study, whose main objective is estimate the levels of abundance and biomass available in Chile through acoustic information obtained from boats of the Chilean jack mackerel fishing fleet. The estimation of the available biomass is essential for the design and elaboration of independent indices of annual change of the biomass of the resource that allows introducing them as auxiliary indices of the stock assessment of CJM (Sepúlveda *et al*., 2004).

Material and Methods

<u>Equipment and working platforms</u>

The acoustic information was obtained from fishing trips made by 8 fishing vessels of the national fleet between 2018 and 2019, all equipped with echo sounders that allow recording information. Some of the echo sounders were previously calibrated following the recommendations of their manufacturer. Only data obtained by calibrated echo sounders was used to estimate CJM abundance.

<u>Acoustic information analysis and abundance estimation</u>

The acoustic information was processed using the Echoview echogram analysis software (v. 9.0). Acoustic data was filtered to eliminate all sources of noise. The concept of noise should be understood as any acoustic signal, whether biological, mechanical, and/or electrical interference that is not part of our interest or represents false measurements (i.e. double bottom echoes and transducer resonance). The analysed information was eco-integrated into Basic Sampling Units (UBMs) of 1 nautical mile (nm), obtaining the NASC (Nautical Area Scattering Coefficient) value for each cell and region, which was used to determine abundance and spatial distribution of CJM. The estimation was made on the basis of a completely random sampling design through the geostatistical method. To obtain the estimates, ordinary kriging was used, four variogram models were evaluated: matern, spherical, exponential and Gaussian (Cressie, 1993), being adjusted to the experimental variogram data minimizing the sum according to the weighted least squares procedure (Cressie, 1993), a cross-validation was also carried out (Deutsch & Journel, 1998) of the parameters considered in the adjusted theoretical variogram and the parameters to be used in the interpolation by kriging (i.e. parameters of the theoretical variogram, search radius, maximum number of pairs to use in interpolation). The parameters of the theoretical variogram and the kriging selected after cross-validation were used to calculate the optimal weights to be assigned to each sampling point and to estimate the density using:

$$z^* = \sum_{i=1}^{N} \lambda_i z(x_i)$$

Where *N* is the number of samples, λ_i is the weighting attributed to the sample x_i, y:

$$\sum \lambda_i = 1$$

The N weights λ_i were calculated to ensure that the estimator is unbiased and that the estimation variance is minimal (Journel & Huijbregts, 1978; Petitgas, 1993).

The estimate of the average density Z(V)* of CJM, was obtained by averaging the local estimates calculated in each of the grid nodes that covers the domain area of the estimation polygon (A_V).

$$Z(V)^* = \frac{1}{N} \sum_i Z^*(x_i)$$

Total abundance (At) is the result of the product between the average density obtained by kriging within the polygon and the area of the polygon (AV), divided by sigma (σ).

$$A_t = \frac{Z(V)^* \cdot A_V}{\sigma}$$

where,

$$\sigma = 4\pi \bullet 10^{(TS/10)}$$

and the Target Strenght, $TS = 20\,\mathrm{Log}_{10}\,(\mathrm{LH}) - 68.91$; (Lillo *et al*, 1996)

where LH is the Fork Length of sampled fish.

Total biomass (B_t) is the result of the product between total abundance and average CJM weight, obtained from sampling.

$$B_t = A_t \cdot \overline{W}$$

The results obtained were used to update the historical series of estimates of relative abundance that INPESCA has been estimated since 2004.

Sampling and determination of biological indicators

In the vessels, operational information was recorded corresponding to each catch, where logbooks were completed with operational data associated with CJM structural indicators. The operational information recorded during each fishing set is detailed below:

a. - Position of the catch (Latitude and Longitude).

b. - Date and time of the catch.

c. - Capture obtained.

Biological-specific sampling and size frequencies of fishing sets sought to generate base information to account for:

a. - The composition of sizes in the catches,

b. - The average weights to size,

The information obtained was used to estimate abundance and CJM biomass.

Results

Spatial distribution of Chilean Jack mackerel

During 2018 the CJM was distributed near the coast during the first three months (Figure 1), moving south to reach 42°30' S in the month of March, and then in April the resource began to migrate slowly westward acquiring an oceanic distribution. In July, an important change was observed, CJM adopted a wider distribution, occurring near the coast up to the ocean sector, reaching 77°00' W. Between March and May, the highest values of acoustic density were observed, with values close to 80,000 m^2/nm^2.

In year 2019 (Figure 2) a similar pattern was observed, the first three months the resource occurs close to the coast, and in April begun to move away towards the oceanic sector, but their displacement was towards the North, reaching 34°00' S. In July, a distribution equal to the previous year was observed for the same month, both coastal and oceanic. Finally, in March and April, the highest acoustic density values were observed with values close to 250,000 m^2 / m^2 and 300,000 m^2 / m^2 respectively.

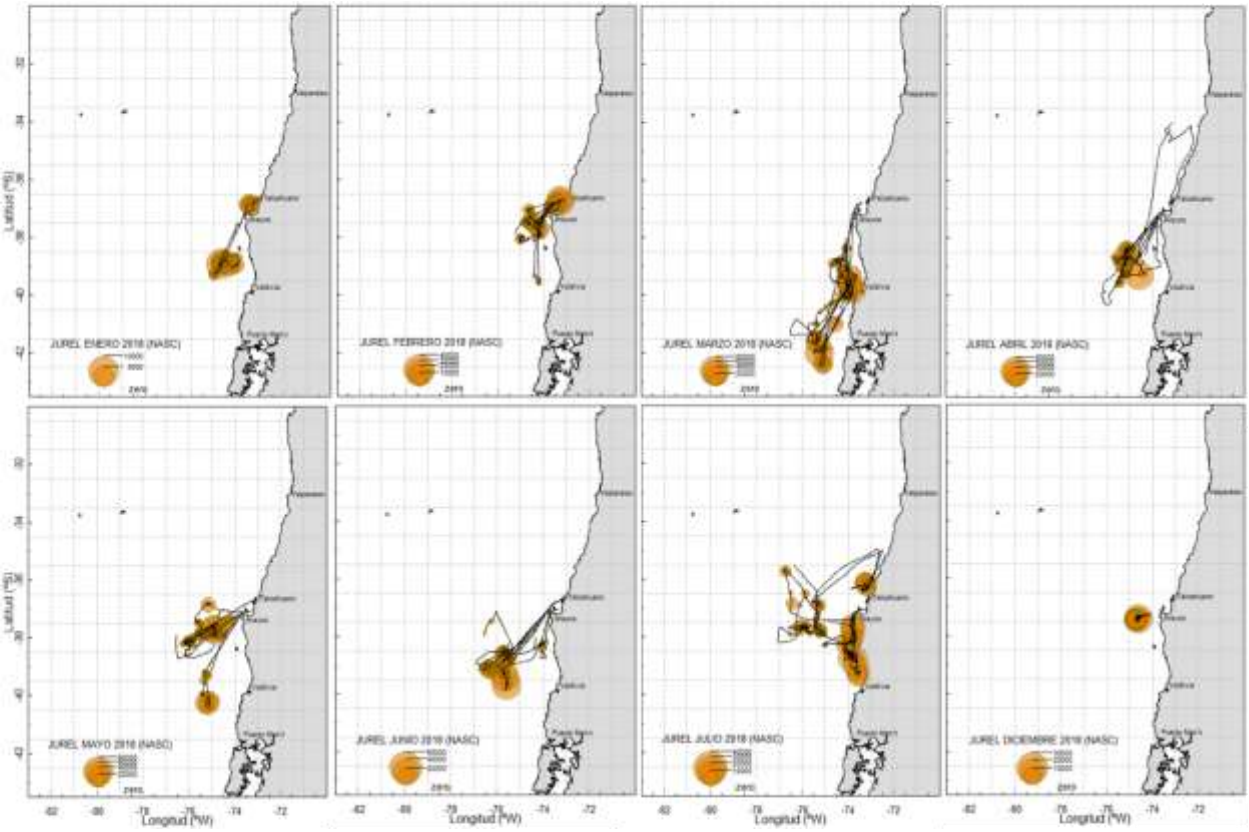

Figure 1. - Spatial distribution of Chilean jack mackerel density during 2018.

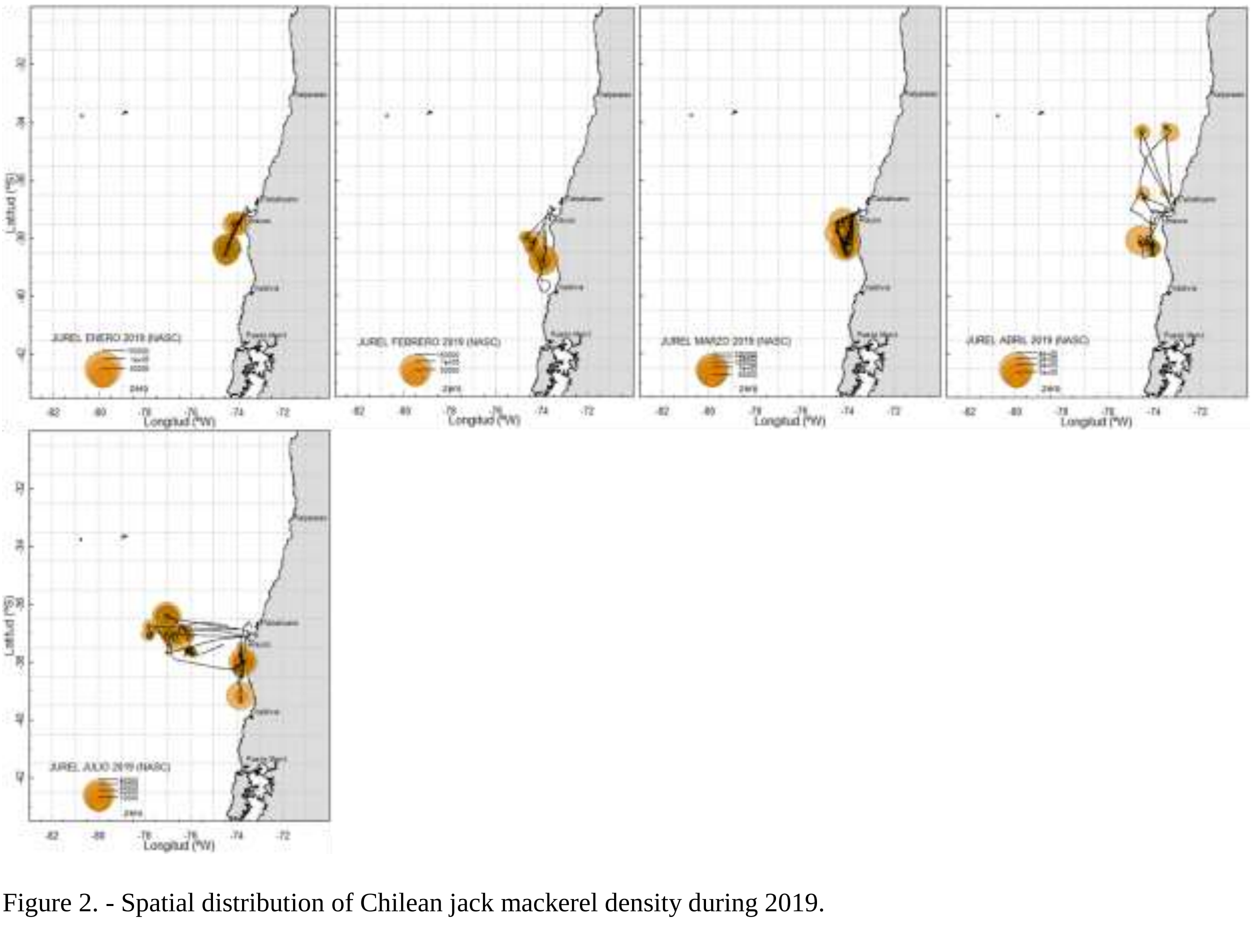

Figure 2. - Spatial distribution of Chilean jack mackerel density during 2019.

Variations in Chilean jack mackerel density between 2004 and 2019

Table 1 shows the results of the CJM density calculations (ton/nm^2) during the month of May of each year, considering positive average density (only values greater than zero) and the average density including zeros. In addition, the results of the total of sum of the densities, the number of days with registers and the number of schools detected for each year in the month of May are presented. In this regard, the highest average densities occurred in the years 2005, 2009, 2018 and 2019, however, when comparing the average density of CJM with the number of schools detected, it is observed that during the years 2005, 2009 and 2018 a large number of schools were detected, while in 2019 despite the amount of schools was lower, it recorded the highest average density of the series, which can be associated with the detection of larger and denser schools during that year. The same pattern was observed when comparing the positive average densities (greater than zero) during the years 2012, 2013, 2014 and 2019, where few schools were detected but with high values of positive density, which would indicate that during years 2012, 2013 and 2014 the vessels were moving greater distances to find commercial fishing areas and therefore there was a greater number of UBMs without schools. Finally, it is important to say that in the case of the year 2019, having less information for the month of May because this fleet was achieving their quota, the information for the month of April was used.

Table 1. Annual Chilean jack mackerel density from 2004 to 2019.

May	Analysed days	Number of Schools	Mean Density only positive (ton/nm^2)	Mean Density (ton/nm^2)	Sum of density (ton/nm^2)
2004	6	99	366.31	66.79	36,264
2005	15	1,098	462.41	122.82	507,722
2009	25	1,350	462.92	119.43	623,553
2010	24	1,474	70.00	38.23	103,182
2011	22	42	792.14	15.63	33,270
2012	18	62	1,714.64	71.64	106,308
2013	7	21	1,045.86	70.26	106,248
2014	7	24	1,526.74	42.40	36,642
2015	25	592	190.78	27.81	112,943
2016	35	655	341.02	42.10	223,365
2017	7	123	439.86	72.43	54,103
2018	19	2,871	168.14	106.14	482,744
2019	15	173	3,046.88	268.52	527,110

The comparison of monthly average acoustic densities in m^2/nm^2 (Figure 3) corresponding to the years 2018 and 2019, clearly observed that the highest acoustic densities were registered in 2019. On the other hand, when comparing inside 2018, the highest densities were observed in the months of February, March and December in an increasing order, whose maximum was approximately 2,000 m^2/nm^2, while in 2019 the highest densities were observed in the months of February and April, the latter with values that exceed 9,000 m^2/nm^2.

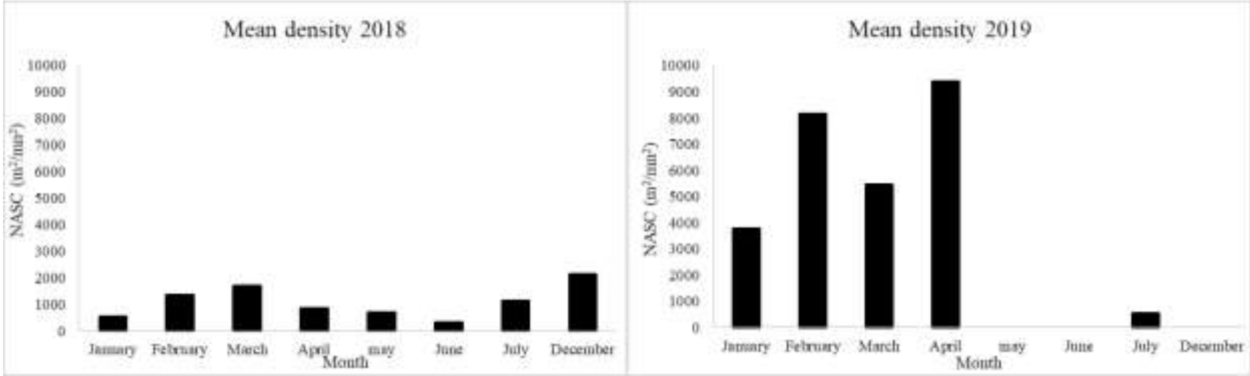

Figure 3. - Average monthly acoustic density during the years 2018 and 2019.

Chilean Jack mackerel abundance during 2019

To estimate the abundance and biomass of CJM the data obtained during the months of February and March of the year 2019 were used. According to the geostatistical analysis the best adjustment of variogram was obtained by the Gaussian model (Figure 4), with a range of 6.9 km, and an average density of 477.5 m^2/nm^2 in an effective distribution area of the resource of 9788.9 nm^2.

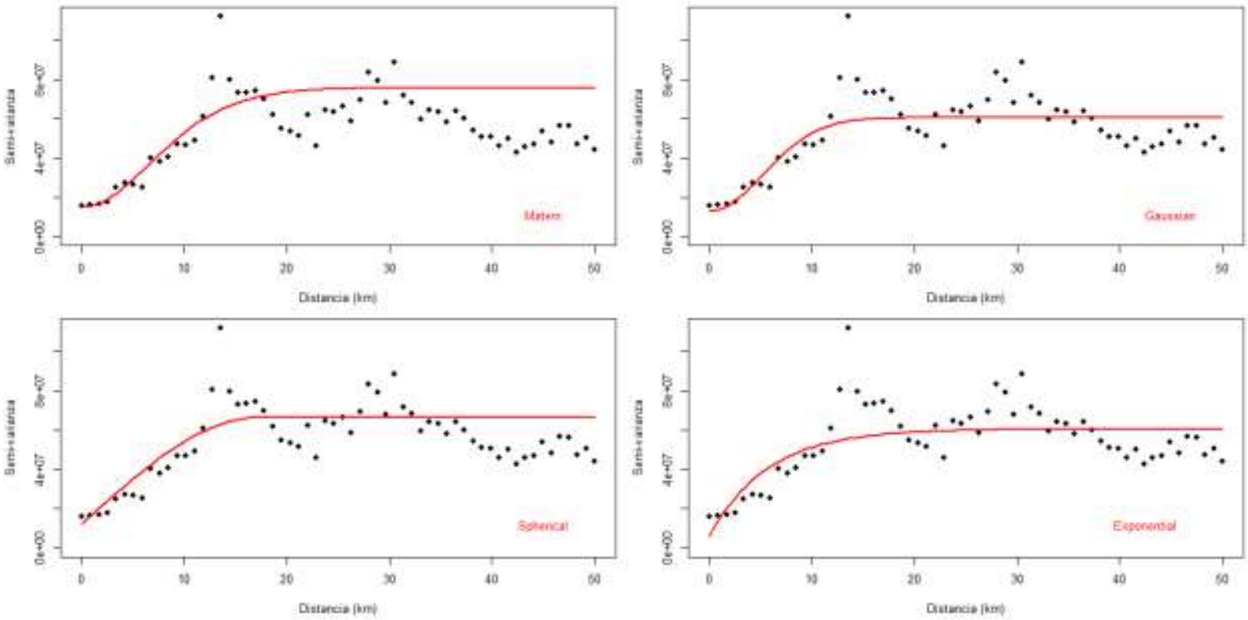

Figure 4. - Model adjustment. Experimental Variogram (points) and theoretical variogram (solid line) of 4 different geostatistical models of Chilean jack mackerel density.

Table 2 shows the results of the estimation of abundance and biomass at CJM by size, and the greatest abundance and biomass occurred at individuals of 31 cm in fork length with a biomass of 132,930 metric tons, followed by individuals of 31, 34 and 35 cm FL with 119,000, 114,895 and 108,696 tons, respectively.

The total abundance calculated for the year 2019 was 2,664 millions of individuals, representing a biomass of 1,081,072 tons of CJM in the central south zone of Chile, with a coefficient of variation of 4.96%.

Table 2. - Results of the Chilean jack mackerel abundance and biomass estimate for the year 2019.

Length (cm)	TS (dB)	Abundance (ind)	Biomass (t)
27	-40.28	2,804,836	581
28	-39.97	71,523,325	16,669
29	-39.66	297,312,644	77,662
30	-39.37	455,785,892	132,930
31	-39.08	367,433,550	119,217
32	-38.81	246,825,591	88,792
33	-38.54	239,813,500	95,347
34	-38.28	262,252,190	114,895
35	-38.03	225,789,319	108,696
36	-37.78	152,863,576	80,647
37	-37.55	91,157,178	52,573
38	-37.31	74,328,161	46,749
39	-37.09	50,487,053	34,552
40	-36.87	60,303,980	44,811
41	-36.65	19,633,854	15,809
42	-36.45	9,816,927	8,549
43	-36.24	12,621,763	11,865
44	-36.04	5,609,673	5,683
45	-35.85	5,609,673	6,113
46	-35.65	0	0
47	-35.47	4,207,254	5,281
48	-35.29	4,207,254	5,655
49	-35.11	0	0
50	-34.93	0	0
51	-34.76	1,402,418	2,296
52	-34.59	0	0
53	-34.42	0	0
54	-34.26	1,402,418	2,765
55	-34.10	1,402,418	2,935
Total	-36.84	2,664,594,448	1,081,072

Conclusions

- In 2018 and 20109 the Chilean jack mackerel showed a coastal distribution during January, February and March, and then began to migrate to the west in April. Also, in July there was a change in the pattern of CJM distribution in both years, adopting a wide longitudinal distribution, occurring both near the coast and in the oceanic sector.
- There was a considerable increase in the average density of CJM in 2019 compared to the previous year, also, in 2019 the highest average density in the historical series was recorded since 2004.
- The highest average densities occurred in the years 2005, 2009, 2018 and 2019, however, when comparing the average density of CJM with the number of schools detected, it is observed that during the years 2005, 2009 and 2018 it was detected a large number of schools, while in the year 2019, despite the number of schools was lower, recorded the highest average density of the series, which can be associated with the detection of larger and denser schools during that year. The same pattern was observed when comparing

the positive average densities (greater than zero) during the years 2012, 2013, 2014 and 2019, where few schools were detected but with high values of positive density, which would indicate that during the years 2012, 2013 and 2014 the vessels were traveling greater distances to find commercial fishing areas and therefore there was a greater number of UBMs without schools.

- The total abundance calculated for the year 2019 was 2,664 million individuals, which in biomass represents a total of 1,081,072 tons of CJM in the central south zone of Chile, with a coefficient of variation of 4.96%.

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