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Habitat monitoring based on acoustics from fishing vessels

Chile

Habitat Monitoring of Chilean Jack Mackerel based on acoustics from fishing vessels 2020

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Abstract

Mean density estimates and spatial distribution obtained from acoustic data recorded by 4 vessels of the Chilean jack mackerel (CJM) fishing fleet in their usual fishing operations during the year 2020 are presented and compared with previous years. The abundance calculation was made only for the year 2020 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.

Unlike 2018 and 2019, when the CJM remained close to the coast between January and March, and then expanded its distribution to the west with respect to the port of discharge (Talcahuano), in 2020 the CJM stayed near the coast between January and May, only expanding its distribution in the latitudinal direction in April and May, reaching -32°00'S in the north and -40°00'S in the south.

Mean acoustic densities in m^2/nm^2 corresponding to the years 2018, 2019 and 2020 were calculated and the highest acoustic densities were registered in 2019. During 2020, a small increase was observed in the mean density of the schools of CJM compared to 2019 in the month of March, however, in the months of January, February and April the mean density of the schools detected the year 2020 was lower than 2019.

The total abundance of CJM was estimated in 2,476 millions of individuals that in biomass represents a total of 1,424,990 tons of CJM in the central-south zone of Chile, with a coefficient of variation of 4.17%. The abundance estimate obtained in 2019 was higher than that calculated for 2020, however, the biomass obtained in 2020 is greater than that of 2019, due to a greater effective area of distribution of CJM and the presence of larger fish compared to 2019. 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 CJM 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 4 fishing vessels of the national fleet during 2020, 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 scientific echo sounders were 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 were 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 mean 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 mean 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, $TS = 20 \text{ Log}_{10} (\text{LH}) - 68.91$; (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 mean 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 mean 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 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/nm^2 and 300,000 m^2/nm^2 respectively (Figure 2).

Unlike 2018 and 2019, when the CJM remained close to the coast between January and March, and then expanded its distribution to the west with respect to the port of landing (Talcahuano), in 2020 the CJM stayed near the coast between January and May, only expanding its distribution in the latitudinal direction in April and May, reaching -32°00'S in the north and -40°00'S in the south. Furthermore, in May one of the vessels sailed west, near to -76°00'W, without finding of commercial fishing zone. The highest densities were observed in the months of January and March with values close to 100,000 m^2/nm^2 and 300,000 m^2/nm^2 respectively (Figure 3).

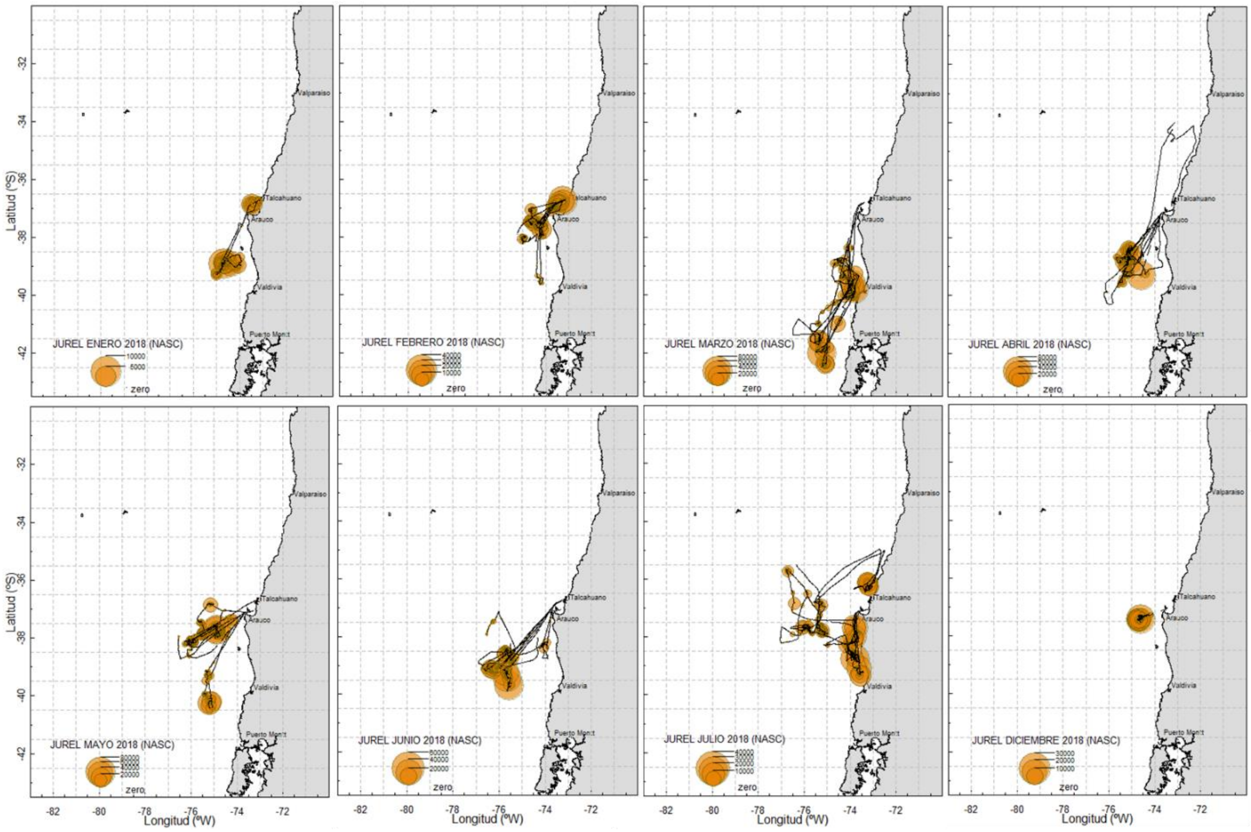

Figure 1. Spatial distribution of Chilean jack mackerel density during 2018.

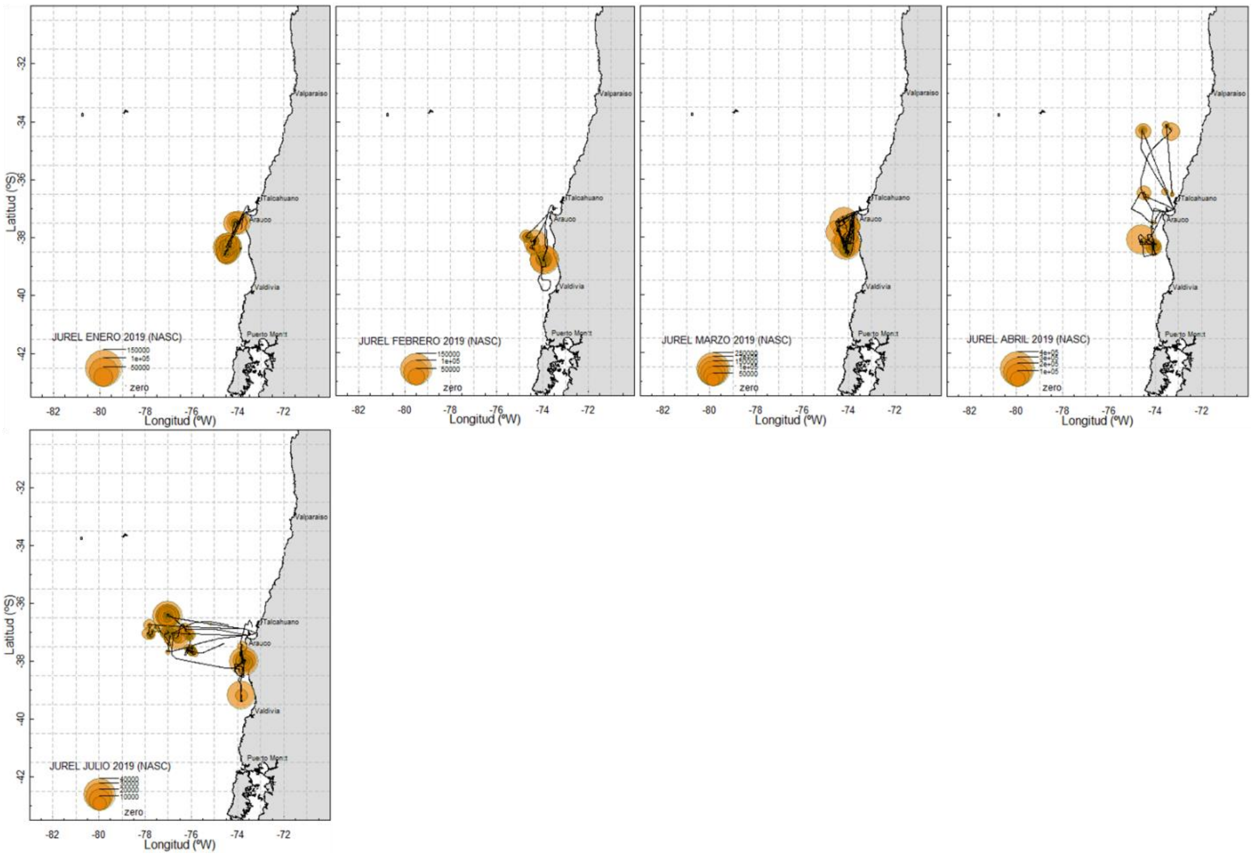

Figure 2. Spatial distribution of Chilean jack mackerel density during 2019.

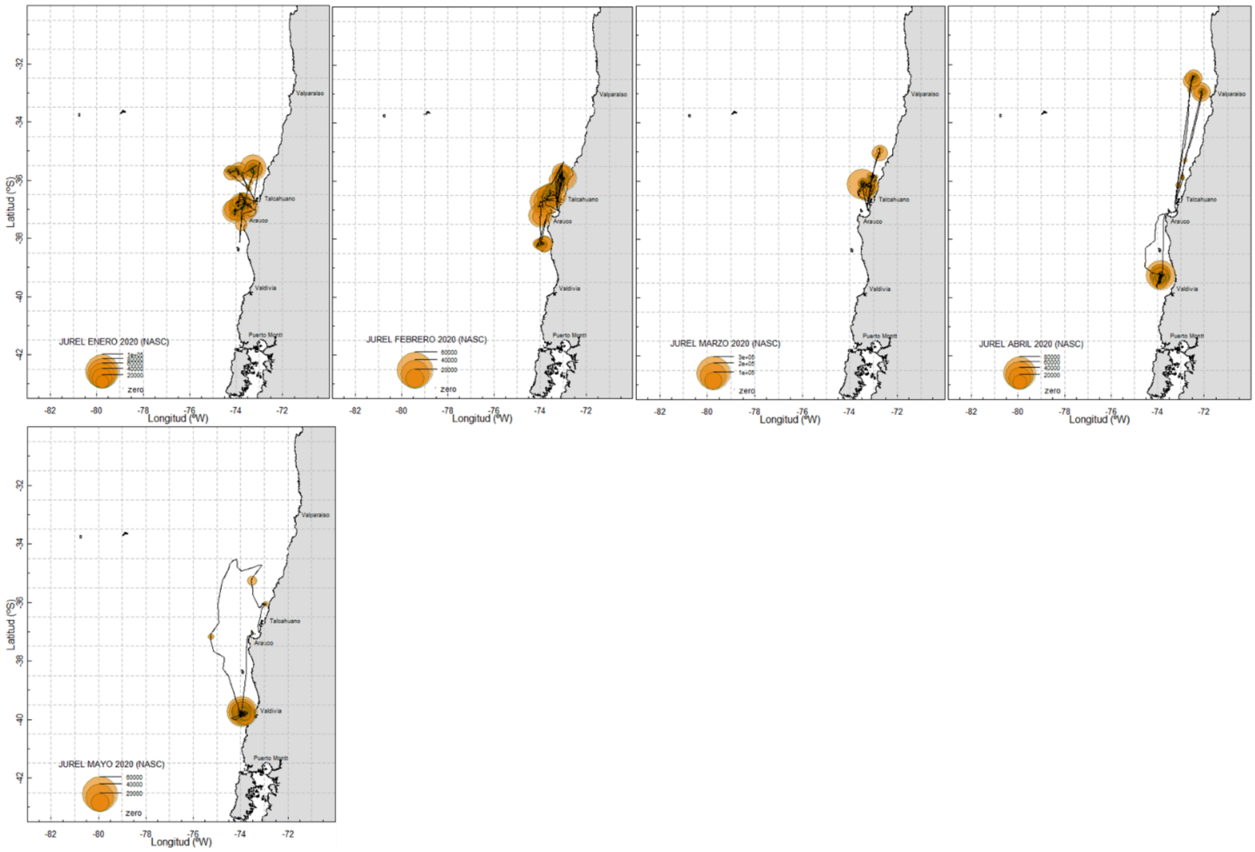

Figure 3. Spatial distribution of Chilean jack mackerel density during 2020.

Variations in Chilean jack mackerel density between 2004 and 2020

Table 1 shows the results of the CJM density calculations (ton/nm^2) during the month of May of each year, considering positive mean density (only values greater than zero) and the mean density including zeros. In addition, the results of the total of sum of the densities, the number of days with register and the number of schools detected for each year in the month of May are presented. In this regard, the highest mean densities occurred in the years 2005, 2009, 2018 and 2019, however, when comparing the mean 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 mean 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 mean 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. In 2020, a lower mean density was observed compared to 2019, however represents the third highest in the last 10 years. In addition, when comparing the number of schools detected, an increased number of schools in 2020 was observed.

Table 1. Annual Chilean jack mackerel density from 2004 to 2020.

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
2020	15	520	594.76	93.44	309,274

The comparison of monthly mean acoustic densities in m^2/nm^2 (Figure 4) corresponding to the years 2018, 2019 and 2020, 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. During 2020, a small increase was observed in the mean density of the schools of CJM compared to 2019 in the month of March, however, in the months of January, February and April the mean density of the schools detected in year 2020 was lower than 2019 (Figure 4).

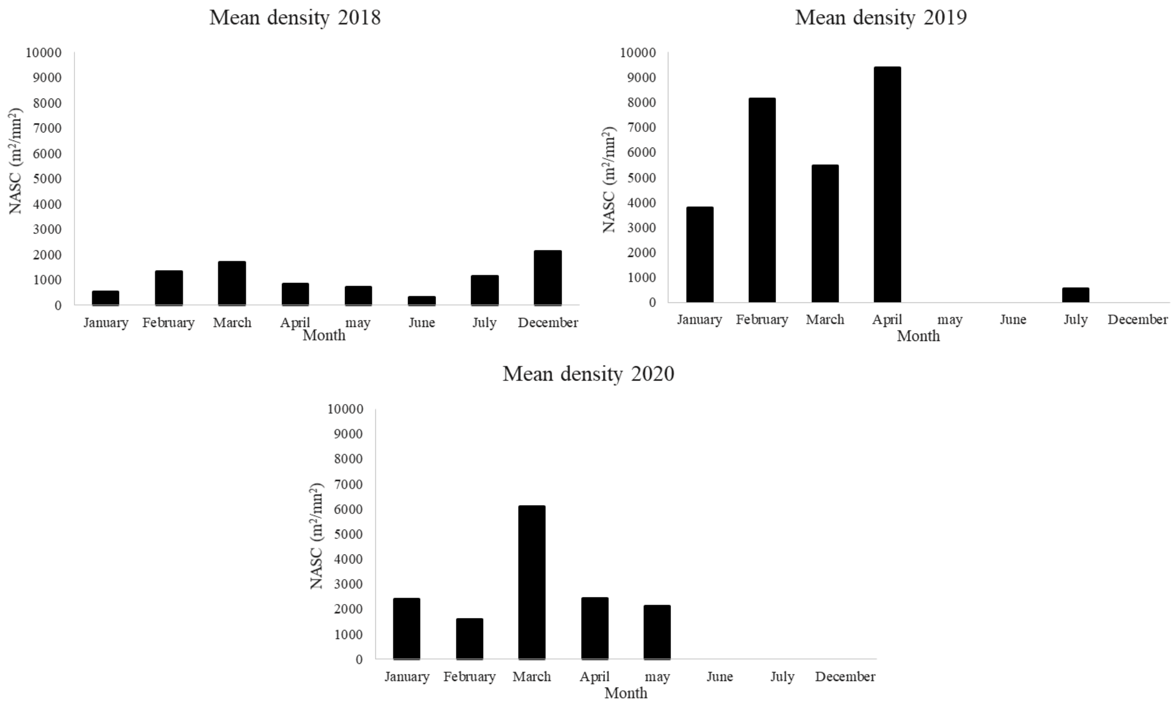

Figure 4. Mean monthly acoustic density during the years 2018, 2019 and 2020.

Chilean Jack mackerel abundance in year 2020

To estimate abundance and biomass of CJM, the data obtained between January and May 2020 were used. The geostatistical analysis obtained in 2019 compared with 2020 (Figure 5), show the best adjustment of the variogram considering a gaussian model with a range of 6.9 km in 2019, resulting in a mean density of 477.5 m^2/nm^2 in an effective distribution area of the resource estimated as 9,788.9 nm^2. On the other hand, in 2020 an exponential model was adjusted to the experimental variogram, obtaining a range of 2.2 km and a mean density of 200.9 m^2/nm^2 distributed in an effective area of 26,394.4 nm^2.

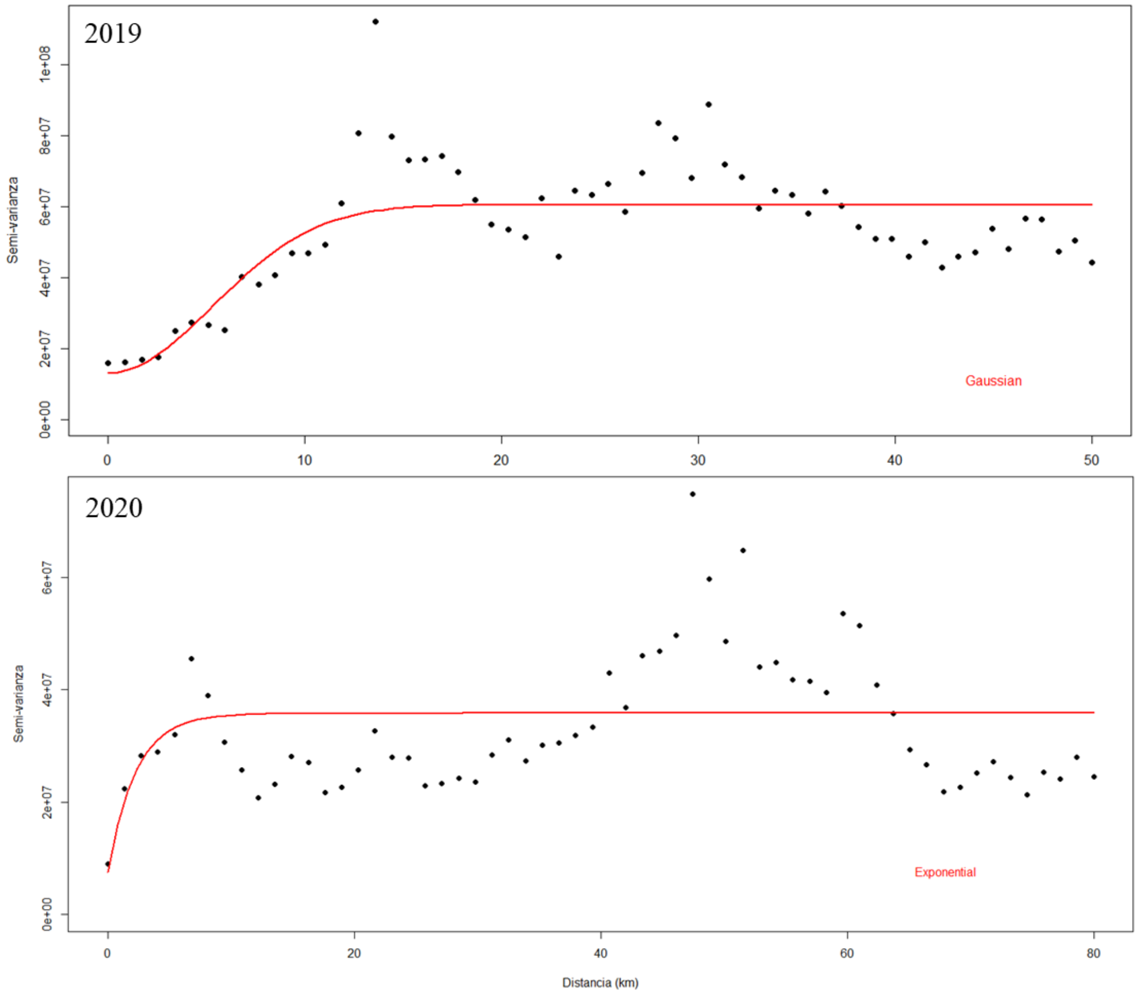

Figure 5. Geostatistical model adjustment for Chilean jack mackerel density. Experimental Variogram (points) and theoretical variogram (solid line) in year 2019 (gaussian) and 2020 (exponential).

Results of the estimations of abundance and biomass of CJM by length bins for 2019 and 2020 are presented in Table 2. Total abundance calculations for 2019 were about 2,664 million individuals, representing a total biomass of 1,081,072 tons in the south-central zone of Chile with a coefficient of variation of 4.96%. In 2020 the abundance calculation was 2,476 million individuals, representing a biomass of 1,424,990 tons of CJM, with a coefficient of variation of 4.17%.

Considering the size structure between 2019 and 2020, the abundance estimate (in number of individuals) obtained in 2019 was higher than the calculated in 2020 because of a contribution of individuals between 29 and 31 cm FL. However, a wider range of sizes was observed in 2020 between 24 up to 65 cm FL, dominating fish between 35 and 41 cm FL with a contribution of larger fish (Figure 6).

Table 2. - Results of the Chilean jack mackerel abundance and biomass estimate for the year 2019 and 2020.

Length (cm)	Abundance 2019 (ind)	Biomass 2019 (t)	Abundance 2020 (ind)	Biomass 2020 (t)
24	-	-	961,404	147
25	-	-	29,116,814	5,061
26	-	-	108,089,306	21,197
27	2,804,836	581	117,703,348	25,923
28	71,523,325	16,669	79,247,179	19,518
29	297,312,644	77,662	46,971,465	12,887
30	455,785,892	132,930	50,542,395	15,390
31	367,433,550	119,217	46,559,434	15,681
32	246,825,591	88,792	124,982,552	46,409
33	239,813,500	95,347	145,446,728	59,368
34	262,252,190	114,895	190,907,415	85,414
35	225,789,319	108,696	208,075,348	101,773
36	152,863,576	80,647	185,963,050	99,187
37	91,157,178	52,573	184,314,928	106,949
38	74,328,161	46,749	186,787,111	117,644
39	50,487,053	34,552	155,747,488	106,250
40	60,303,980	44,811	147,232,193	108,572
41	19,633,854	15,809	101,084,789	80,422
42	9,816,927	8,549	78,285,774	67,073
43	12,621,763	11,865	72,380,005	66,666
44	5,609,673	5,683	44,499,282	43,988
45	5,609,673	6,113	44,087,252	46,698
46	-	-	31,863,684	36,110
47	4,207,254	5,281	26,781,975	32,426
48	4,207,254	5,655	20,738,863	26,789
49	-	-	12,498,255	17,201
50	-	-	13,322,316	19,510
51	1,402,418	2,296	5,493,739	8,550
52	-	-	5,219,052	8,623
53	-	-	3,021,556	5,293
54	1,402,418	2,765	1,922,808	3,568
55	1,402,418	2,935	961,404	1,887
56	-	-	961,404	1,995
57	-	-	1,785,465	3,912
58	-	-	1,373,435	3,174
59	-	-	274,687	669
60	-	-	274,687	705
61	-	-	274,687	741
62	-	-	412,030	1,169
63	-	-	-	-
64	-	-	-	-
65	-	-	137,343	451
Total	2,664,594,448	1,081,072	2,476,302,652	1,424,990

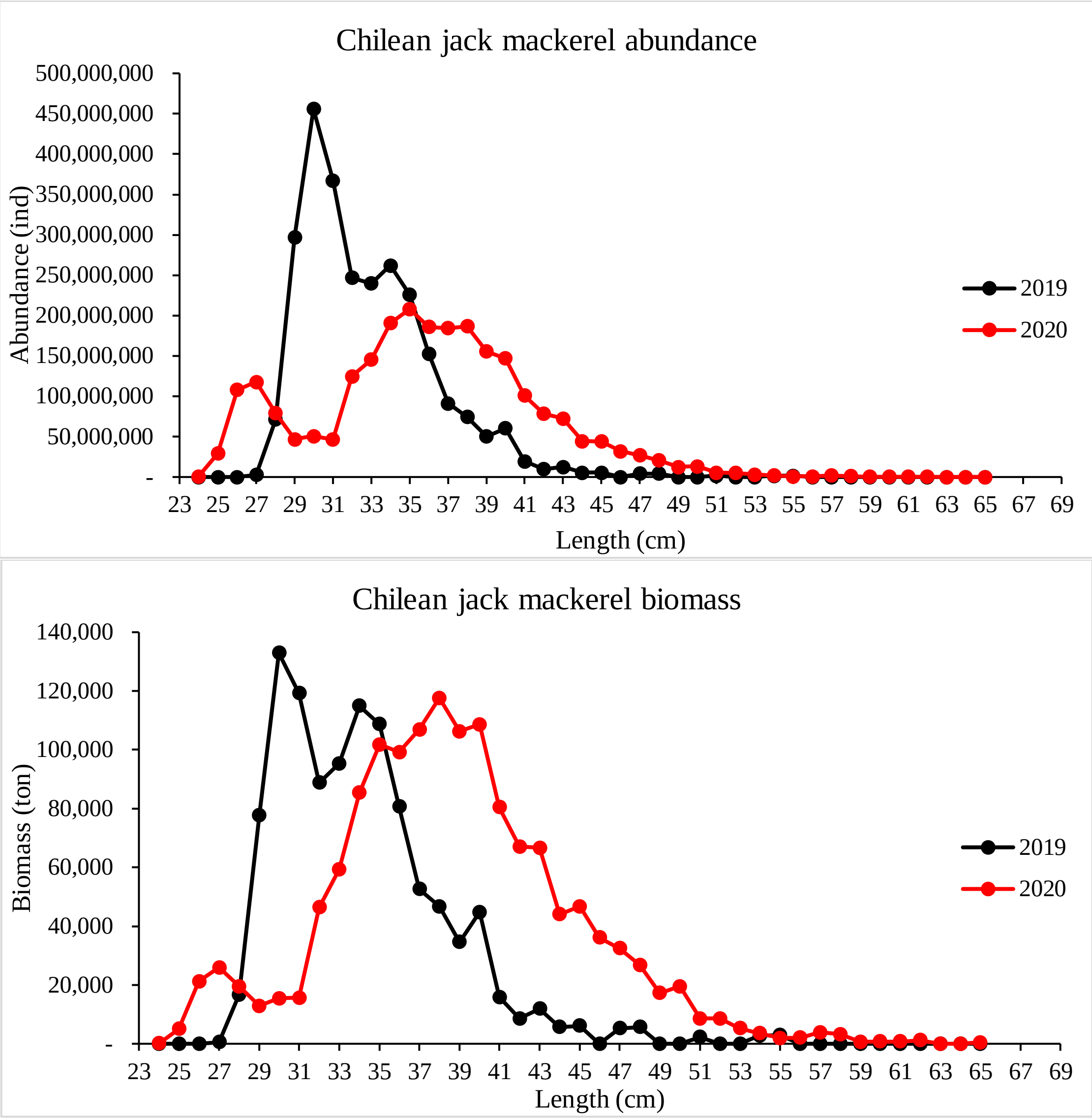

Figure 6. Abundance and biomass distribution during 2019 and 2020 by size.

Concluding remarks

- Despite 2018 and 2019 the CJM remained close to the coast between January and March, and then expanded its distribution to the west with respect to the port of landing (Talcahuano), in 2020 the CJM stayed near the coast between January and May, only expanding their distribution in the latitudinal range in April and May.
- In 2020, a lower mean density was observed compared to 2019, however it represents the third highest in the last 10 years.
- A slight increase in the average density of CJM schools was observed in 2020 compared to March 2019. However, in January, February and April, the average density of CJM schools in 2020 was lower than in 2019.

- The total abundance calculated in year 2020 was 2,476 million of individuals, which represent a total biomass of 1,424,990 tons of CJM in the central south zone of Chile with a coefficient of variation of 4.17%.

- Although the mean density (m^2/nm^2) and abundance (ind) values obtained for 2020 are lower than those obtained for 2019, the biomass (ton) obtained in 2020 is higher than that estimated for 2019. This situation is justified by two important aspects, the increase of almost 3 times in the size of the effective distribution area of CJM in 2020 compared to 2019, and the differences in the size composition between years where fish between 32 to 40 FL cm and larger are influencing the increase in biomass in this region.

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