South Pacific Regional Fisheries Management Organisation

9th MEETING OF THE SCIENTIFIC COMMITTEE

Held virtually, 27 September to 2 October 2021

SC9-HM08_rev1

Spatial Distribution and Acoustic Habitat Monitoring of Chilean Jack Mackerel from Fishing Vessels 2021

Chile

Spatial distribution and acoustic habitat monitoring of Chilean jack mackerel from fishing vessels 2021

Nicolás Alegría and Aquiles Sepúlveda

Instituto de Investigación Pesquera. Talcahuano, Chile.

Abstract

Mean density estimates and spatial distribution obtained from acoustic data recorded by 6 vessels of the Chilean jack mackerel (CJM) fishing fleet in their usual fishing operations during the year 2021 are presented and compared with previous years. The abundance calculation was made for the years 2019, 2020 and 2021 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 fishing season of 2021 and unlike previous years, the CJM was located near the coast. Also, it was observed that the distribution of CJM expanded towards the north during the months of January, March, April and May, arriving near to Valparaíso. In June, July and August, CJM was observed near the port of Talcahuano. The highest acoustic densities were observed during the months of May and July. Mean acoustic densities (in m^2/nm^2) for the years 2018, 2019, 2020 and 2021 were calculated and the highest acoustic densities were registered in 2020. In 2021, the average densities obtained during almost every month were the highest in the series, except for 2019 with higher values in April. A bimodal condition was observed in the size structure of CJM with modes at 30 and 37 cm FL and a large contribution of specimens over 40 cm FL, evidencing a significant increase in specimen size of CJM, compared to previous years.

An estimated abundance of 4,612 million individuals was calculated in 2021 representing a biomass of 3,217,169 tons (CV 3.79%). Estimated abundance and biomass represent a significant increase compared to 2020 that can be explained by a high density of schools in a reduced area of distribution and the increase in fish size. A comparison with the results obtained from the scientific acoustic survey conducted in the Central-South area between June and July 2021 was considered. An important decrease depending on the period considered for the estimation of biomass was obtained, in this case a decrease in the average densities between June and July of the year 2021 was observed. The estimated abundance of CJM only in June and July of 2021 was 1,857 million individuals, which represents a biomass of 1,295,440 tons (CV 3.77%).

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 to estimate 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 National Research Funding. Despite the existence of this study, it is still unknown to what fraction of the population it is estimated and there are considerations about the time window in which surveys are carried out. Also, this resource could change their structure of sizes and density of its main fishing grounds.

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 of 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 or during the fishing season 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 opportunity vessels 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 5 fishing vessels of the national fleet during 2021, all equipped with echosounders that allow recording information. Some of the echosounders were previously calibrated following the recommendations of their manufacturer. Only data obtained by scientific echosounders 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 based on 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 from 2018 to 2021

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 CJM began to migrate slowly westward acquiring an oceanic distribution. In July, an important change was observed, CJM adopted a wider distribution, moving from coastal areas to the oceanic 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 CJM 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).

In 2021, schools of CJM were located near of the coast between January and August, unlike previous years, where the schools of CJM were located near the coast during the first months of the year, mainly near Talcahuano, to later expand its distribution longitudinally. Also, it was observed that the distribution of CJM expanded towards the north during the months of January, March, April and May, achieving the area off Valparaíso (33°00 "S). In June, July and August, CJM was observed near the port of Talcahuano. The highest acoustic densities were observed during the months of May and July (Figure 4).

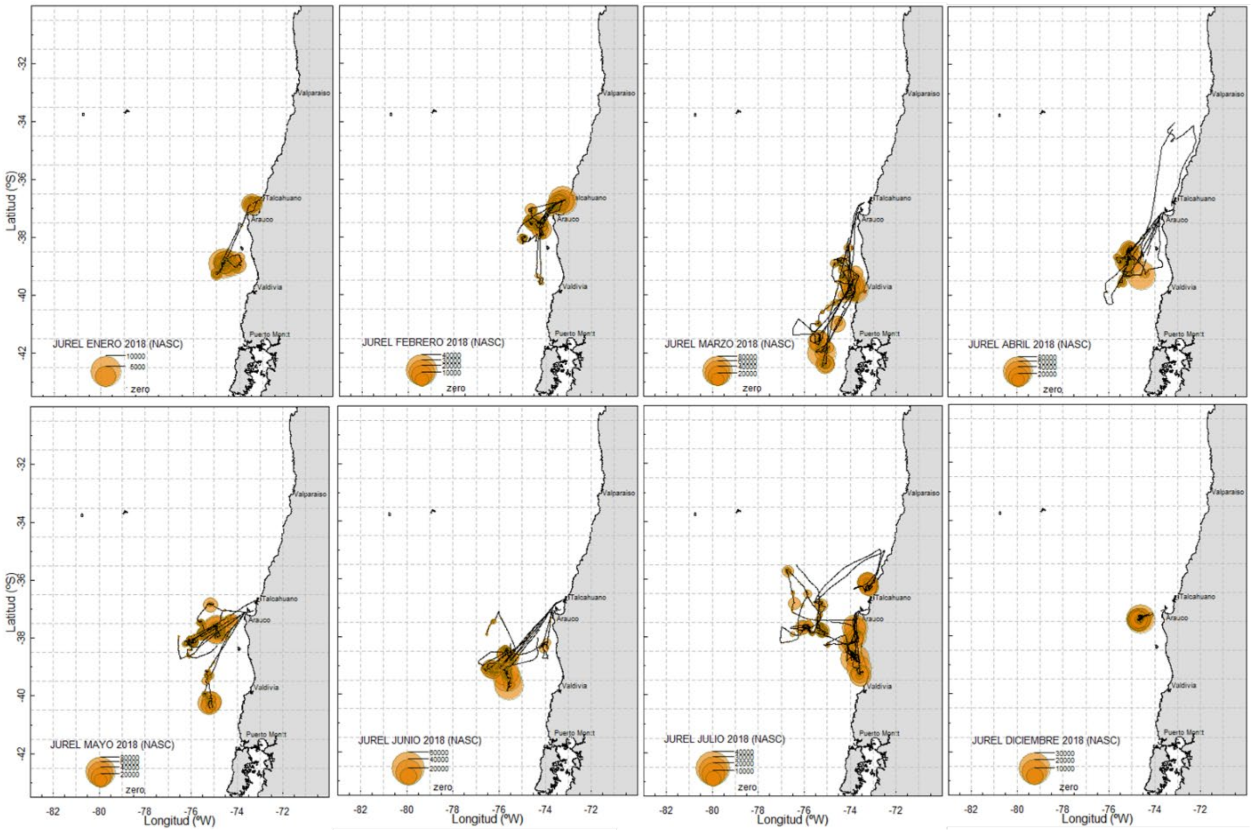


Figure 1. Spatial distribution of Chilean jack mackerel density by months during 2018.

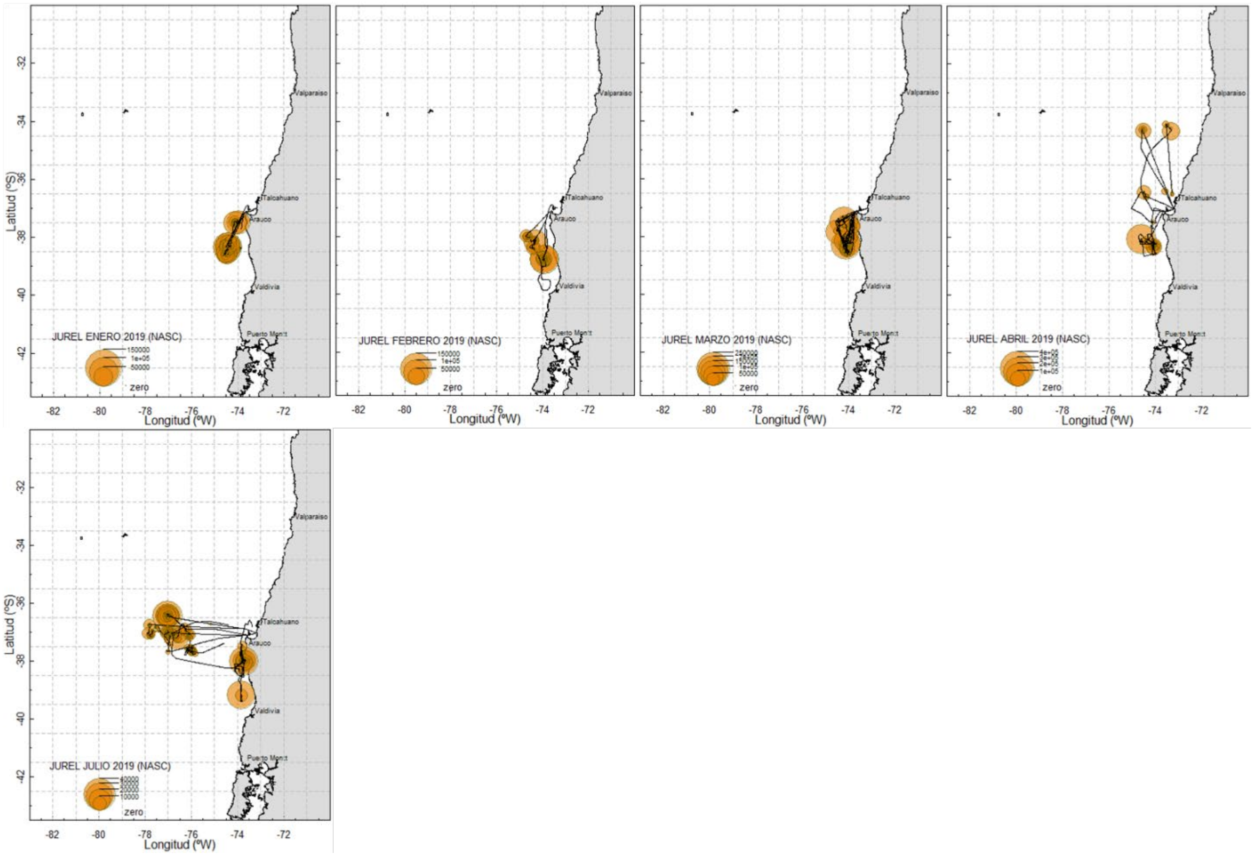


Figure 2. Spatial distribution of Chilean jack mackerel density by months during 2019.

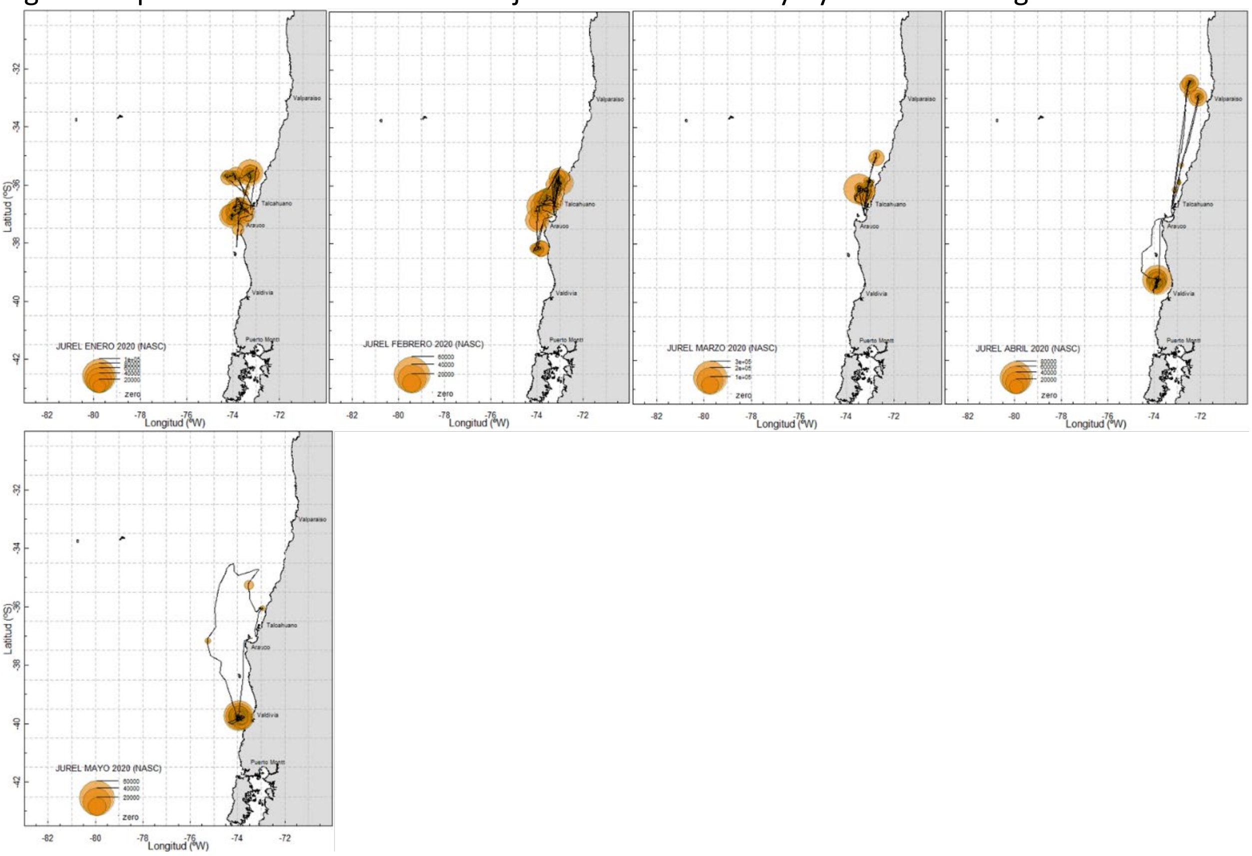


Figure 3. Spatial distribution of Chilean jack mackerel density by months during 2020.

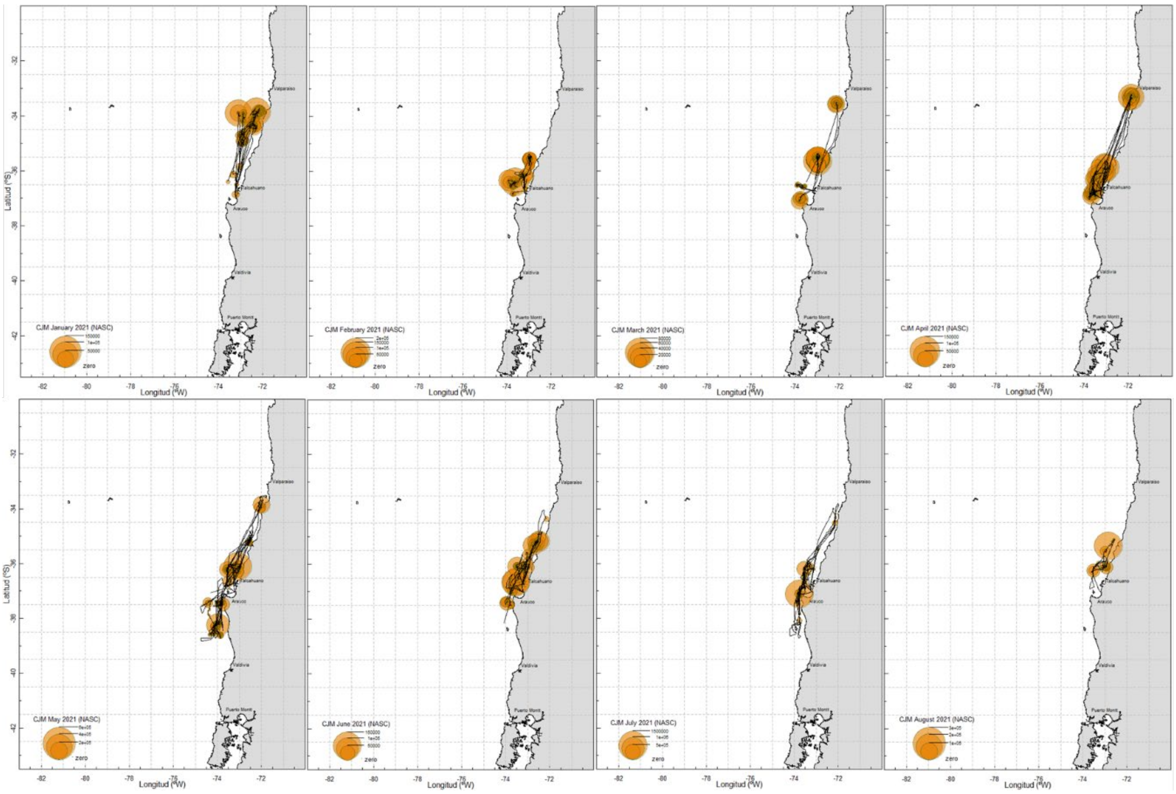


Figure 4. Spatial distribution of Chilean jack mackerel density by month during 2021.

<u>Variations in Chilean jack mackerel mean density between 2018 and 2021</u>

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. Finally, if we compare average densities by months of 2021 with the last three years, the values obtained during almost every month were the highest in the series, except for 2019 that exhibit the highest values in April (Figure 5).

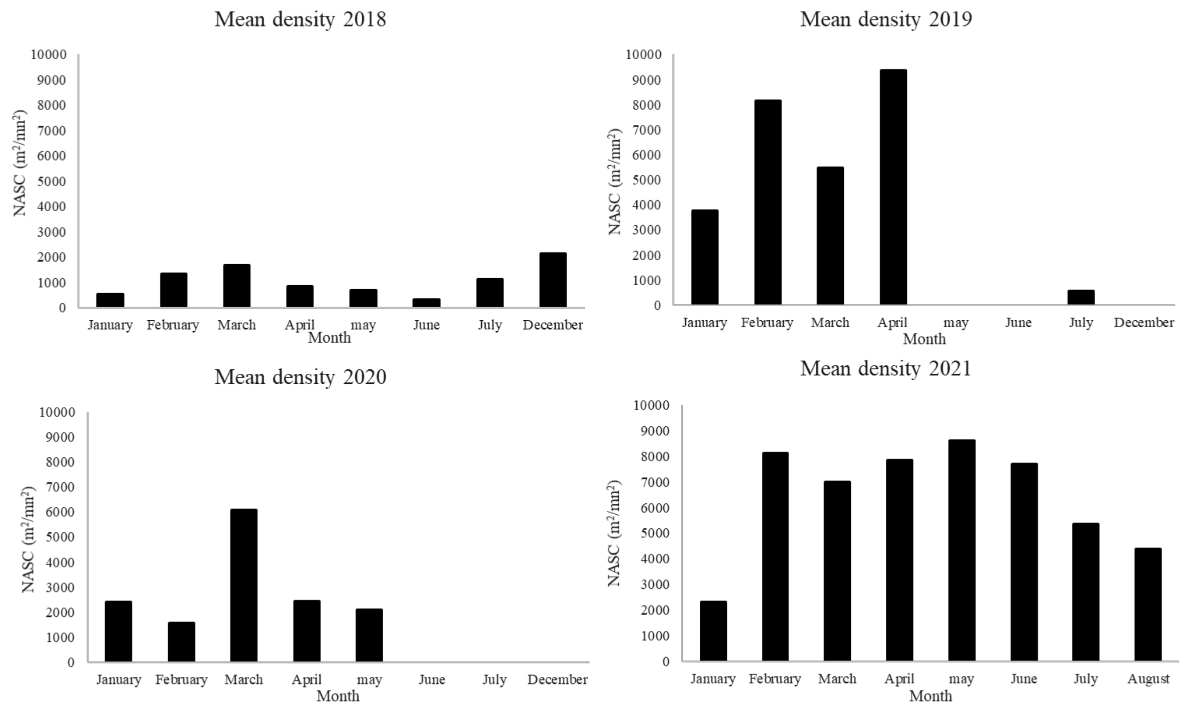


Figure 5. Mean monthly acoustic density during the years 2018, 2019, 2020 and 2021.

<u>Variations in Chilean jack mackerel density between 2004 and 2021</u>

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 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. In 2021 an increase in the average density of CJM was observed, achieving the highest value of the series with 337.55 (ton/nm^2), the average density considering only positive values presented a value of 2,696.40 (ton/nm^2) positioning itself as the second highest value of the series. Schools registered in 2021 showed a high density because the sum of the densities represent the highest value of the series (1,356,291 ton/nm^2) with a low number of schools (503). The increase in CJM densities in 2021 can be explained by the presence of dense schools in a small area of distribution.

Table 1. Annual Chilean jack mackerel density from 2004 to 2021.

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
2021	23	503	2,696.40	337.55	1,356,291

Chilean Jack mackerel abundance from 2019 to 2021

To estimate abundance and biomass of CJM, the data obtained between January and August 2021 were used. The geostatistical analysis obtained in 2019 compared with 2020 (Figure 6), 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. For the 2021 year, a gaussian model was adjusted, obtaining a range of 0.64 km and an acoustic mean density of 540.74 m^2/nm^2 in an effective distribution area of 19,865.25 nm^2.

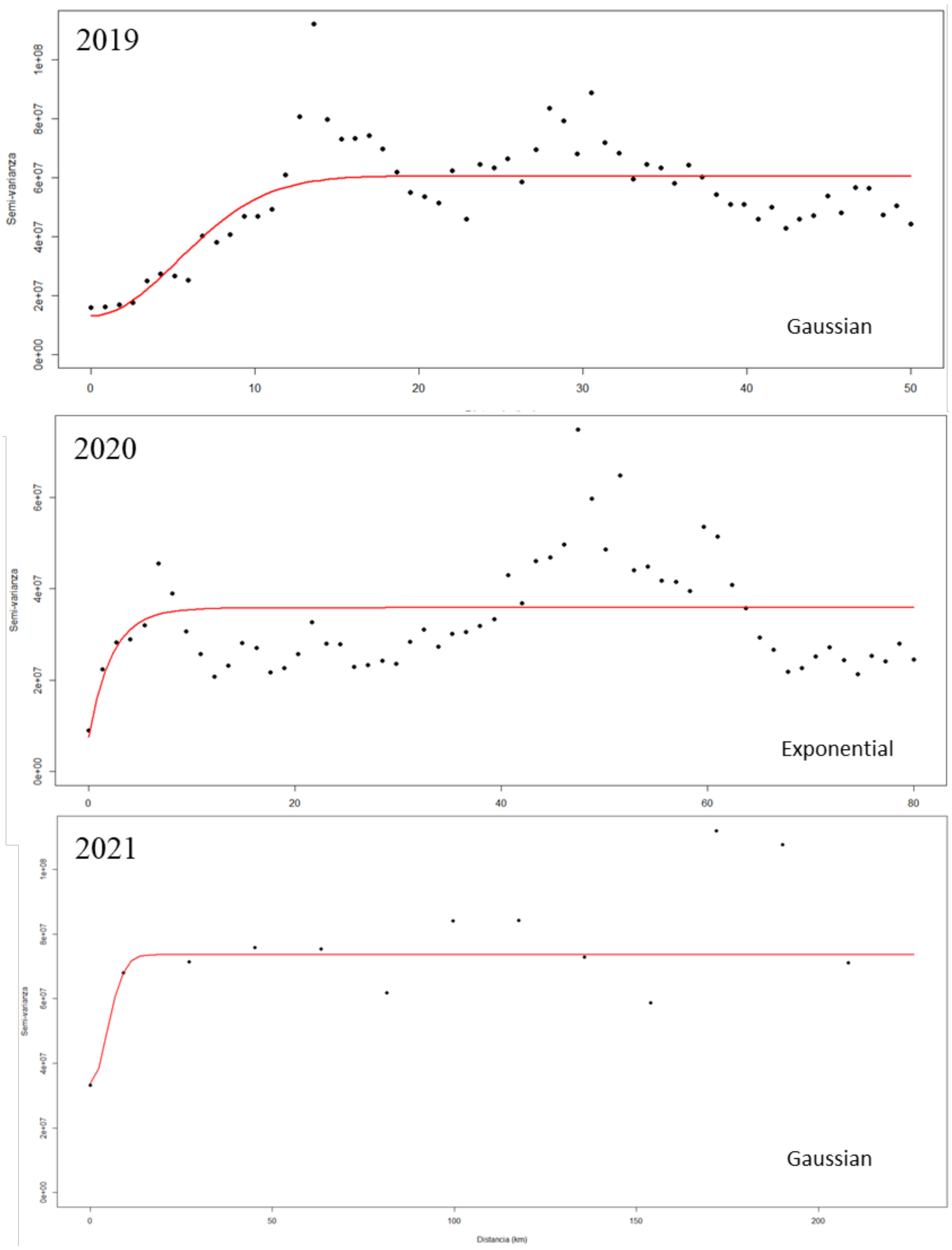


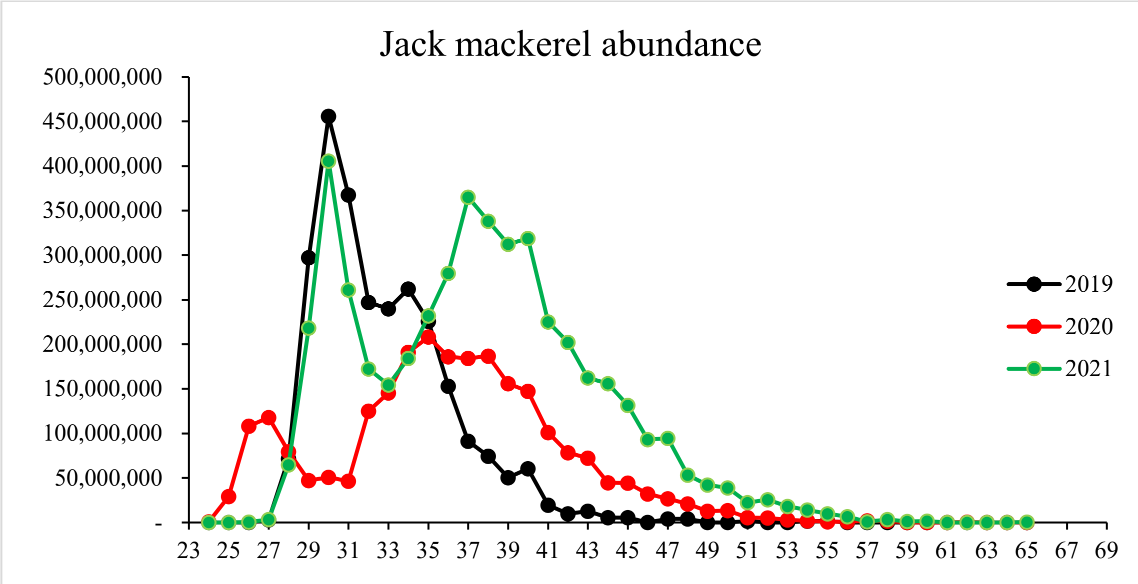
Figure 6. Geostatistical model adjustment for Chilean jack mackerel density. Experimental Variogram (points) and theoretical variogram (solid line) in year 2019, 2020 and 2021.

Results of the estimations of abundance and biomass of CJM by length bins for 2019, 2020 and 2021 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%. In 2021 the abundance was 4,612 million individuals, which represents a biomass of 3,217,169 tons (CV= 3.79%). The estimated abundance and biomass represent an important increase compared to 2020.

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. In 2021, a bimodal size structure was observed, with modes at 30 and 37 cm FL and a large contribution of specimens over 40 cm FL, evidencing a significant increase in size of CJM compared to previous years. This increase in fish size is directly related to the abundance and biomass results obtained (Figure 7).

Table 2. Results of the Chilean jack mackerel abundance and biomass estimate for the year 2019, 2020 and 2021.

Length (cm)	Abundance 2019 (ind)	Biomass 2019 (t)	Abundance 2020 (ind)	Biomass 2020 (t)	Abundance 2021 (ind)	Biomass 2021 (t)
24	-	-	961,404	147	-	-
25	-	-	29,116,814	5,061	-	-
26	-	-	108,089,306	21,197	288,297	59
27	2,804,836	581	117,703,348	25,923	3,171,270	726
28	71,523,325	16,669	79,247,179	19,518	64,578,584	16,581
29	297,312,644	77,662	46,971,465	12,887	218,241,017	62,558
30	455,785,892	132,930	50,542,395	15,390	405,634,229	129,329
31	367,433,550	119,217	46,559,434	15,681	260,909,010	92,203
32	246,825,591	88,792	124,982,552	46,409	172,401,755	67,310
33	239,813,500	95,347	145,446,728	59,368	154,527,325	66,449
34	262,252,190	114,895	190,907,415	85,414	184,221,942	86,999
35	225,789,319	108,696	208,075,348	101,773	232,079,285	120,040
36	152,863,576	80,647	185,963,050	99,187	279,648,331	158,016
37	91,157,178	52,573	184,314,928	106,949	364,984,317	224,757
38	74,328,161	46,749	186,787,111	117,644	338,172,673	226,427
39	50,487,053	34,552	155,747,488	106,250	312,225,920	226,813
40	60,303,980	44,811	147,232,193	108,572	318,856,757	250,788
41	19,633,854	15,809	101,084,789	80,422	225,160,151	191,364
42	9,816,927	8,549	78,285,774	67,073	202,096,371	185,258
43	12,621,763	11,865	72,380,005	66,666	162,311,351	160,192
44	5,609,673	5,683	44,499,282	43,988	155,968,812	165,451
45	5,609,673	6,113	44,087,252	46,698	131,463,545	149,648
46	-	-	31,863,684	36,110	93,120,011	113,571
47	4,207,254	5,281	26,781,975	32,426	94,561,498	123,383
48	4,207,254	5,655	20,738,863	26,789	53,334,991	74,345
49	-	-	12,498,255	17,201	42,091,398	62,595
50	-	-	13,322,316	19,510	38,920,129	61,668
51	1,402,418	2,296	5,493,739	8,550	22,198,888	37,429
52	-	-	5,219,052	8,623	25,658,455	45,981
53	-	-	3,021,556	5,293	18,162,727	34,554
54	1,402,418	2,765	1,922,808	3,568	14,126,565	28,499
55	1,402,418	2,935	961,404	1,887	9,802,106	20,947
56	-	-	961,404	1,995	6,630,837	14,995
57	-	-	1,785,465	3,912	864,892	2,068
58	-	-	1,373,435	3,174	3,171,270	8,006
59	-	-	274,687	669	1,153,189	3,072
60	-	-	274,687	705	1,441,486	4,048
61	-	-	274,687	741	-	-
62	-	-	412,030	1,169	-	-
63	-	-	-	-	-	-
64	-	-	-	-	-	-
65	-	-	137,343	451	288,297	1,041
Total	2,664,594,448	1,081,072	2,476,302,652	1,424,990	4,612,467,684	3,217,169



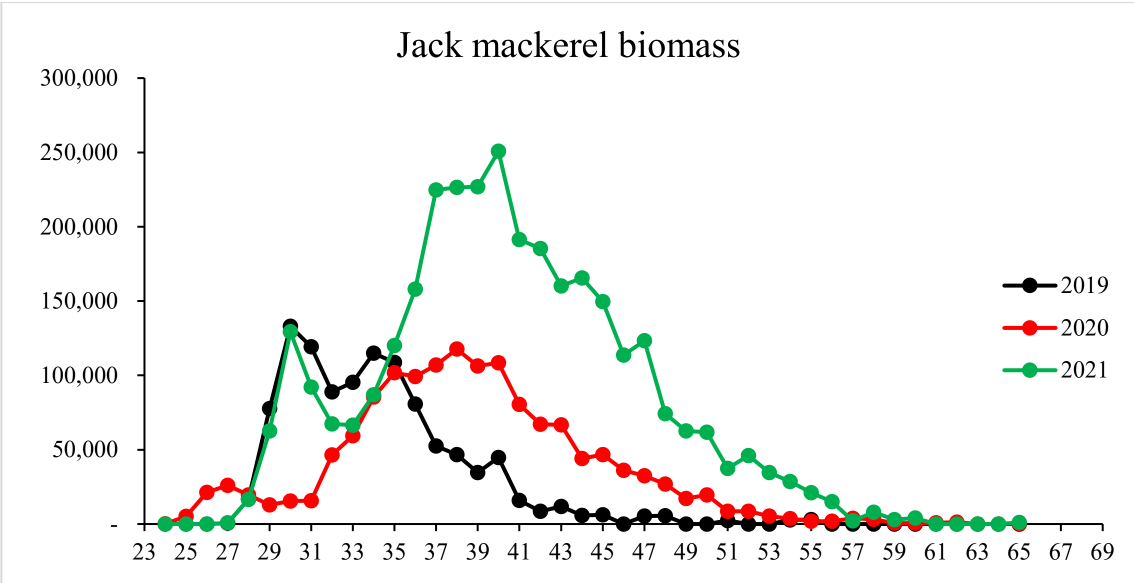


Figure 7. Abundance and biomass distribution by size during 2019, 2020 and 2021.

The hydroacoustic survey of CJM carried out by the Fisheries Development Institute (IFOP) for the year 2021 off Central-South Chile was carried out between June 18 and July 15. To compare the results obtained in the present study with those obtained by the survey carried out by IFOP, the data recorded by the vessels of the fleet only in the months of June and July 2021 were analysed. Table 3 shows the results from the estimation of CJM abundance and biomass for the months of June and July and a marked decrease is observed in the quantification of CJM compared to that obtained with the data of the entire fishing season (Table 2). This is justified by the decrease in the average densities obtained in the months of June and July of the year 2021 (Figure 5). The estimated abundance of CJM only in June and July of 2021 was 1,857 million individuals, which represents a biomass of 1,295,440 tons (CV= 3.77%).

Table 3. Results of the Chilean jack mackerel abundance and biomass estimate for the month June and July, year 2021.

Abundance June-July 2021 (ind)	Biomass June-July 2021 (t)
-	-
-	-
116,087	24
1,276,958	292
26,003,506	6,676
87,877,919	25,190
163,334,521	52,076
105,058,807	37,127
69,420,074	27,103
62,222,675	26,757
74,179,644	35,032
93,450,099	48,336
112,604,467	63,628
146,966,243	90,502
136,170,144	91,174
125,722,307	91,329
128,392,310	100,983
90,664,009	77,056
81,377,043	74,597
65,357,026	64,504
62,803,110	66,621
52,935,708	60,258
37,496,127	45,731
38,076,562	49,682
21,476,110	29,936
16,948,714	25,205
15,671,756	24,831
8,938,705	15,071
10,331,750	18,515
7,313,486	13,914
5,688,267	11,476
3,946,961	8,435
2,670,003	6,038
348,261	833
1,276,958	3,224
464,348	1,237
580,435	1,630
-	-
-	-
-	-
-	-
116,087	419
1,857,277,184	1,295,440

Concluding remarks

- In 2021, unlike previous years, CJM was located near the coast all the fishing season. Also, it was observed that the distribution of CJM expanded towards the north during the months of January, March, April and May, achieving up to the area of Valparaíso (33°00'S). The highest acoustic densities were observed during the months of May and July.

- In 2021, the average densities obtained during almost every month were the highest in the last four years.

- In 2021 an increase in the average density, average density considering only positive and the sum of densities of CJM was observed. The increase in CJM densities in 2021 can be explained by a high density in schools in a small area of distribution.

- In 2021, a bimodal condition was observed in the size structure, with modes of 30 and 37 cm FL and a large contribution of specimens over 40 cm FL, evidencing a significant increase in size compared to previous years. This increase in fish size is directly related to the abundance and biomass results obtained.

- In 2021, the estimated abundance of CJM was 4,612 million individuals representing a biomass of 3,217,169 tons (CV = 3.79%). These estimates represent a significant increase compared to 2020.

- The estimated abundance based only on June and July of 2021 was 1,857 million individuals representing a total biomass of 1,295,440 tons (CV = 3.77%). There is an important decrease depending on the period considered for the estimation of biomass. In this case, a decrease in the average densities between June and July of the year 2021 was observed.

References

Arancibia, H., Cubillos, L., Grechina, A., Arcos, D., Vilugrón, L., 1995a. The fishery of horse mackerel (Trachurus symmetricus murphyi) in the south Pacific Ocean, with notes on the fishery off central-southern Chile. Scientia Marina 59(3/4), 589-596.

Arancibia, H., Alarcón, R., Cubillos, L., Arcos, D., 1995b. A landing forecast for horse mackerel, Trachurus symmetricus murphyi (Nichols, 1920) off Central Chile. Scientia Marina 59(2), 113-117.

Cressie, N.A.C. 1993. Statistics for spatial data. Wiley, New York.

Deutsch, C.V. & A.G. Journel. 1998. GSLIB: Geostatistical Software Library and User's Guide. 2nd Ed. Oxford University Press, New York. 369 p.

Gretchina, A. 1992. Historia de investigaciones y aspectos básicos de la ecología del jurel (*Trachurus symmetricus murphyi* (Nichols) en alta mar del Pacífico Sur. Doc. Téc. Inst. Invest. Pesq, (INPESCA), Talcahuano, 1(2): 1-47.

Journel, A.G. & C.J. Huijbregts, 1978. Mining geostatistics. Academic Press, London.

Lillo, S., J. Córdoba. y A. Paillaman. 1996. Target-strength measurements of hake and jack mackerel. ICES J. Mar. Sci., 53: 267-271.

Miranda, L., Hernández, A., Sepúlveda, A. y M. Landaeta. 1998. Alimentación de jurel y análisis de la selectividad en la zona centro-sur de Chile. *In*: Arcos, D. (ed.), Biología y ecología del jurel en aguas chilenas, Instituto de Investigación Pesquera, Talcahuano, Chile, p. 173-187.

Petitgas, P. 1993. Geostatistics for fish stock assessments: a review and an acoustic application. ICES. J. Mar. Sci., 50: 285 – 298.

Quiñones, R., Serra, R., Núñez, P., Arancibia, H., Córdova, J. y F. Bustos. 1997. Relación espacial entre el jurel y sus presas en la zona centro-sur de Chile. In: Tarifeño, E. (ed.), Gestión de sistemas oceanográficos del Pacífico oriental, UNESCO COI/INF – 1046, p. 187-202.

Sepúlveda, A., R. Alarcón, C. González. 2004. Evaluación de la biomasa de jurel con embarcaciones de la flota pesquera 2004. Doc. Téc. Inst. Invest. Pesq. (IIP), Talcahuano, 13(7):1-42.

Serra, R. 1991. Important life history aspects of the Chilean jack mackerel, *Trachurus murphyi*. Invest. Pesq., Chile, 36: 67-83.symmetricus.