Interannual variability in distribution, size structure, and biomass of Chilean jack mackerel (*Trachurus murphyi*) estimated from fishery-dependent acoustics

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Abstract

Acoustic data collected from fishing vessels operating off south-central Chile were used to evaluate the spatial distribution, acoustic density, and biomass of Chilean jack mackerel (*Trachurus murphyi*) during the first quarter of 2026, and to compare these patterns with historical observations. Abundance and biomass estimate for the period 2019–2025 were derived using geostatistical methods, specifically ordinary kriging, applied to opportunistic acoustic data.

Results indicate marked interannual variability in spatial distribution. The period 2018–2019 was characterized by a relatively broad and weakly structured distribution, followed by a progressive coastal organization during 2020–2023. A northward expansion of the stock was observed in 2024 and 2025, whereas early 2026 shows a re-concentration in nearshore areas. Monthly analyses indicate a consistent seasonal cycle, with peak acoustic densities occurring between February and May and minimum values during winter months.

Abundance and biomass estimated for 2019–2025 exhibited high interannual variability, strongly modulated by changes in size structure. A peak was observed in 2024 (3.24 billion individuals: 1.83 million tons), driven by strong recruitment of small individuals (~30 cm fork length). In contrast, 2025 showed a sharp decline (>70%) in both abundance and biomass across most size classes. This reduction likely reflects changes in population structure, spatial redistribution, and/or environmental conditions affecting aggregation behavior and acoustic detectability.

Overall, the results highlight the strong coupling between spatial dynamics, size structure, and biomass variability, emphasizing the importance of integrating fishery-dependent acoustic data as complementary indicators in stock assessment frameworks under highly variable environmental conditions.

Introduction

The Chilean jack mackerel (*Trachurus murphyi*) is a transboundary species with an extensive distribution across the South Pacific, from the Galapagos Islands to the southern region of Chile, inhabiting both oceanic and coastal waters (Serra, 1991). In international waters, it forms large schools and is primarily distributed between 33°S and 48°S, extending as far west as 160°W (Gretchina, 1992).

The migration patterns of this species are closely tied to its spawning and feeding behavior, following an annual cycle that includes an offshore migration in the spring to spawn in oceanic waters, followed by a return to the coastal areas of Chile and Peru during the summer and autumn in response to the availability of prey (Quiñones *et al.,* 1997; Miranda *et al.*, 1998). During autumn and winter, CJM schools aggregate into dense formations, which are highly accessible to the fishing fleet off the Chilean coast, particularly in the central-southern region

(Serra, 1991; Arancibia *et al.*, 1995a, b).

Historically, acoustic research aimed at estimating CJM abundance in the south-central zone of Chile has been conducted aboard scientific vessels. Currently, direct scientific surveys are performed biennially to assess the CJM stock, typically in June, under the National Research Funding framework. Despite these efforts, the estimated proportion of the population remains uncertain, and there are concerns regarding the timing of the surveys conducted. Furthermore, this resource may undergo changes in size structure and density within its primary fishing grounds.

To address these gaps, the need to obtain direct information by identifying and quantifying acoustic targets, together with the collection of biological and environmental information, requires specialized systems that 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 and supports this study.

This study aims to estimate CJM abundance and biomass levels in the south-central zone of Chile using acoustic data collected from opportunistic vessels within the CJM fishing fleet. Estimating available biomass is crucial for developing independent indices of annual biomass variation, which can be incorporated as supplementary indicators in the stock assessment of CJM (Sepúlveda *et al*., 2004).

Materials and Methods

Equipment and working platforms

For 2026, acoustic data were collected from fishing trips conducted by two vessels of the south-central Chilean fleet, equipped with echosounders that allow recording information (Table 1).

Table 1. Vessels and equipment used to record acoustic information.

Vessel name	Manufacture	Model	Frequency (kHz)
PAM Cazador	SIMRAD	EK60	38 and 120
PAM Don Julio	SIMRAD	EK60	38

Acoustic information analysis and abundance estimation

The acoustic information was processed using Echoview (v. 9.0), echogram analysis software. 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 analyzed 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 summatory 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, $\boldsymbol{\lambda} i$ is the weighting attributed to the sample xi, y:

$$\sum \lambda_i = 1$$

The N weights $\boldsymbol{\lambda}$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,

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

and the Target Strenght, $TS = 20 \log_{10}(FL) - 68.91$ (Lillo *et al*, 1996) where FL 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.

$$B_t = A_t \cdot W$$

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 catch,

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 2026

Figure 1 illustrates the spatial distribution of Chilean jack mackerel (CJM) schools, along with the navigation tracks of fishing vessels during catch trips conducted between 2018 and the first three months of 2026.

The spatial distribution of acoustic density of Chilean jack mackerel (*Trachurus murphyi*) between 2018 and the first three months of 2026 exhibits a consistent occupancy pattern in the central–southern region of Chile, primarily between 34°S and 40°S, with a clear affinity for nearshore areas. Throughout the entire period, spatial coverage is sufficiently continuous to allow the observed patterns to be interpreted as representative of the resource distribution off central–southern Chile. The spatial structure is markedly heterogeneous, characterized by discrete high-density aggregations embedded within areas of lower concentration, reflecting a patchy distribution typical of pelagic species.

At the interannual scale, 2018 and 2019 display a relatively broad distribution, with multiple density nuclei and some extension toward offshore areas, while maintaining a center of gravity within the central–southern band. In 2020 and 2021, the distribution becomes more clearly organized along the coastal zone, with more defined aggregations between 35°S and 38°S. This process consolidates in 2022 and 2023, when the distribution adopts a more structured configuration, latitudinally aligned and closely associated with the coastal domain, suggesting an increasing influence of oceanographic forcing on the spatial organization of the stock.

During 2024 and 2025, a notable shift is observed, characterized by a northward expansion of the distribution, reaching latitudes close to 33°S. This latitudinal displacement suggests a redistribution of the stock and/or changes in environmental conditions that expand suitable habitat. Despite this expansion, significant aggregations persist in the central–southern region, maintaining the overall patchy nature of the distribution.

In the first quarter of 2026, the distribution shows a greater concentration in coastal areas, with a main core around ~36°S. This pattern suggests aggregation in specific nearshore habitats, potentially associated with favourable environmental conditions as well as intrinsic spatial dynamics related to the schooling behavior of the species. The presence of well-defined

hotspots reinforces the interpretation of a structured and non-homogeneous distribution (Figure 1).

In synthesis, the spatial distribution of jack mackerel acoustic density between 2018 and the first quarter of 2026 exhibited marked interannual variability, while maintaining a persistent core between 36°S and 39°S along the central-southern Chilean coast. Early years (2018–2019) showed a broader and less structured distribution, followed by a progressive coastal organization during 2020–2023. A northward expansion was observed in 2024 and 2025, suggesting shifts in habitat use or environmental conditions. In early 2026, the distribution became more coastal, with well-defined aggregations. Overall, the distribution is highly patchy, with distinct high-density nuclei, consistent with schooling behavior and the influence of dynamic oceanographic processes.

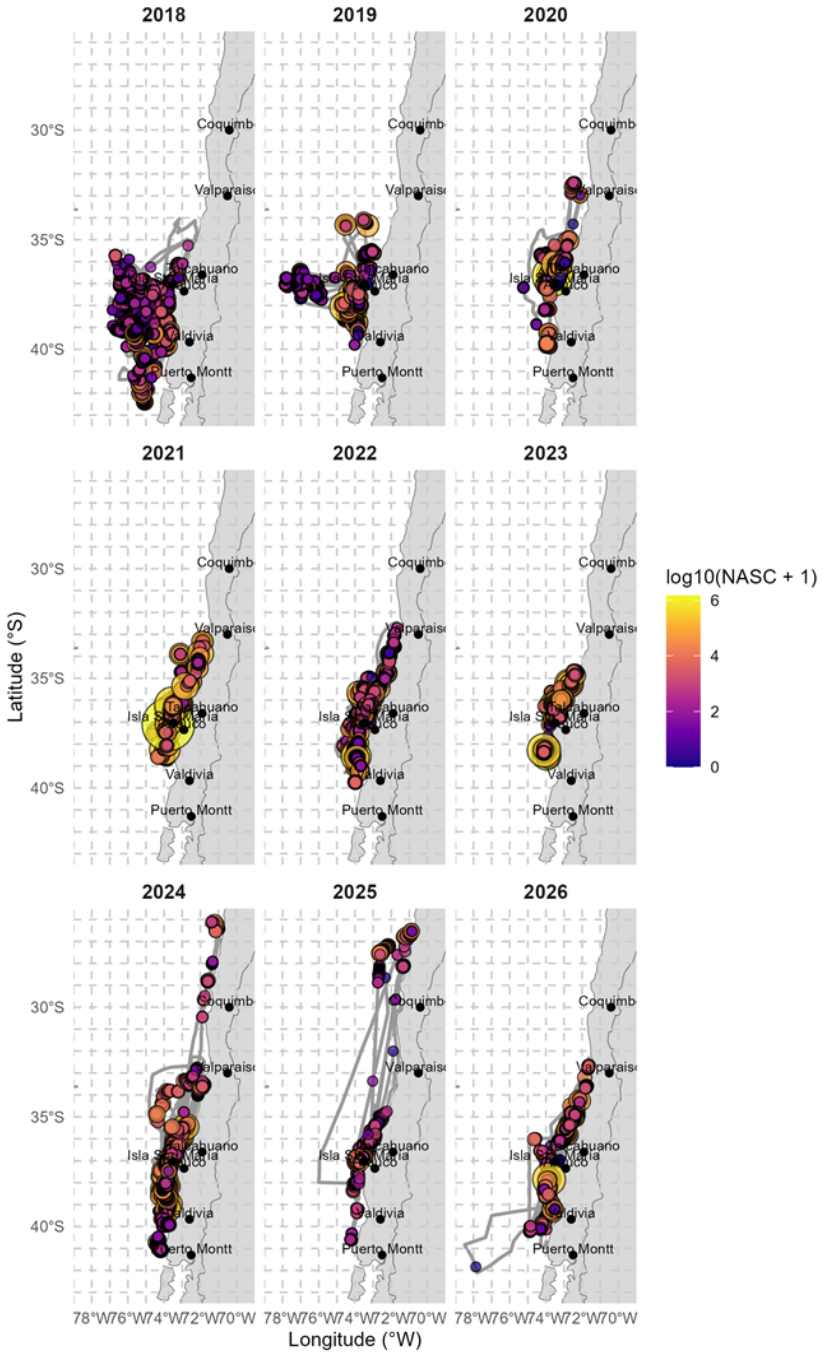


Figure 1. Spatial distribution of Chilean jack mackerel acoustic density between 2018 and 2026.

Between November 2025 and March 2026, the spatial distribution of Chilean jack mackerel (*Trachurus murphyi*) exhibited a transition from a partially dispersed pattern to a highly aggregated coastal configuration, followed by the onset of a new expansion phase. In November, the stock still showed residual dispersion with multiple nuclei, but already displayed clear signs of re-aggregation in the central–southern zone (32–38°S), particularly around ~36°S. By December, the distribution had contracted and became more localized within this latitudinal range, indicating a well-defined transition toward increased spatial coherence and structuring (Figure 2).

During January 2026, the distribution reached its highest level of organization, characterized by dense, continuous aggregations strongly aligned with the coastline. The main core was concentrated in the central–southern zone (33–36°S), consistent with the typical summer aggregation pattern described in recent years (Alegría and Sepúlveda, 2025), in which the stock exhibits high concentrations in specific coastal areas. In February and March 2026, the distribution entered a new expansion phase, evidenced by an increase in its latitudinal range—primarily toward the south—and by westward displacements (Figure 2). This pattern suggests enhanced stock mobility and a progressive spatial reorganization. Furthermore, an earlier onset of this expansion phase was observed, consistent with trends reported in recent years (Alegría and Sepúlveda, 2025), whereby this process has occurred progressively earlier: in 2024 it was recorded in May, in 2025 in April, and in 2026 it is already evident from February.

Overall, the dynamics described in recent years support the existence of a well-defined intra-annual cycle, characterized by a summer coastal aggregation phase in the central–southern zone (33–38°S), followed by a progressive spatial expansion toward other areas. This behavior is consistent with the high mobility of the species and its strong association with environmental variability, as well as with the spatial structure and dynamics of its habitat.

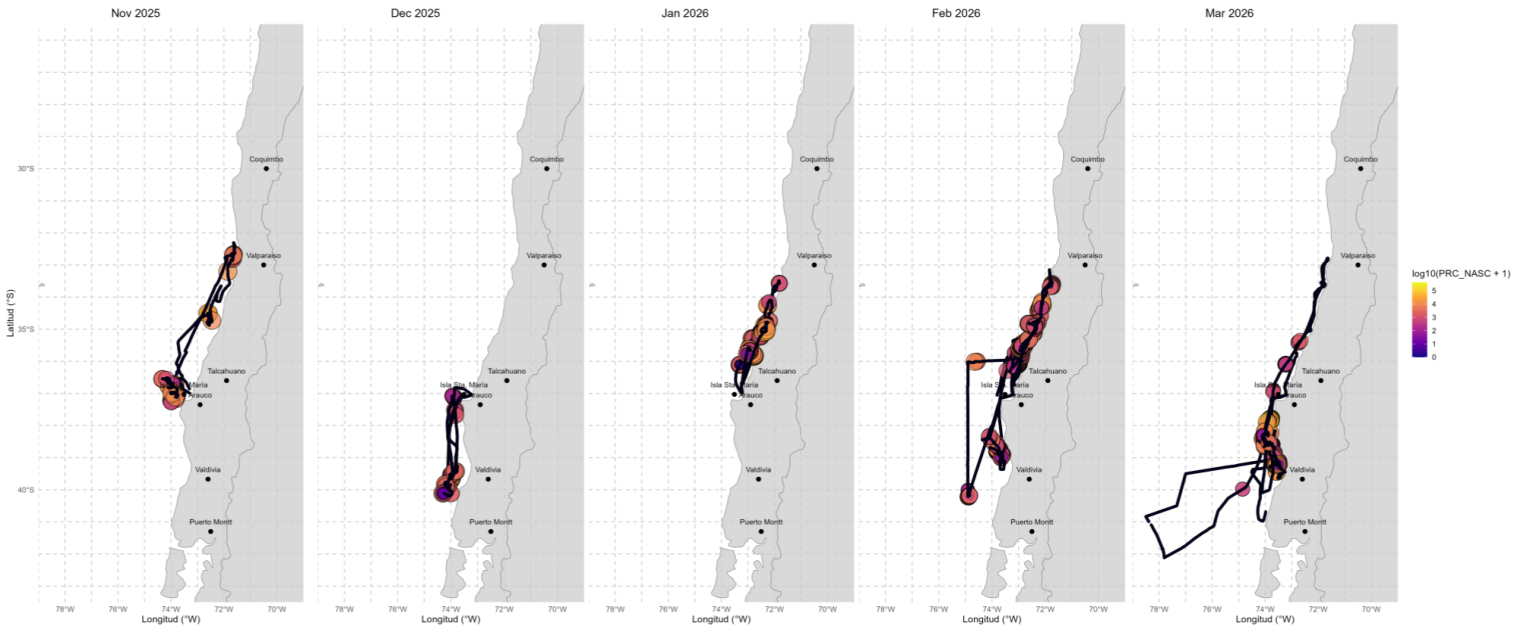


Figure 2. Spatial distribution of Chilean jack mackerel acoustic density by month between November of 2025 and March of 2026.

Variations in the monthly mean density of CJM between 2021 and 2026

The monthly variability of acoustic density of Chilean jack mackerel (*Trachurus murphyi*) between 2021 and 2026 reveals marked interannual differences, while maintaining a broadly

consistent seasonal pattern. As previously reported, March 2022 exhibits the highest value across the entire series, whereas 2021 shows the highest overall densities when considering the full annual cycle (Alegría and Sepúlveda, 2021). These results reinforce the importance of late summer–early autumn as the period of maximum aggregation intensity (Figure 3).

Across most years, peak acoustic densities are concentrated between February and May. In 2021, high values are sustained from February through June, indicating a prolonged period of elevated aggregation. In contrast, 2022 displays a sharp and pronounced peak in March, followed by a rapid decline in subsequent months. The year 2023 shows a more gradual seasonal decrease, with relatively high densities between January and March, followed by a steady decline toward minimal values in June and July. Similarly, 2024 presents moderate densities with a less pronounced peak, suggesting a weaker aggregation phase compared to earlier years.

Consistent with the general pattern, June and July represent the lowest-density months across the time series, particularly evident in 2023 and 2024, where values approach minimal levels. This seasonal decline likely reflects a transition toward a more dispersed spatial configuration of the stock, consistent with post-summer redistribution processes.

A notable shift is observed in 2025, where acoustic densities are substantially lower than in previous years across all months. This reduction suggests a significant change in schooling behavior and/or aggregation intensity, potentially linked to environmental variability or changes in habitat conditions. Preliminary data for 2026 indicate a partial recovery in January, followed by lower values in February and March, although the limited temporal coverage precludes definitive conclusions.

Overall, the results indicate a recurring seasonal cycle characterized by peak aggregation during late summer and early autumn (February–May), followed by a marked decline in winter months (June–July). However, the reduced densities observed in 2025 and the altered pattern in early 2026 suggest increasing interannual variability, potentially associated with changing oceanographic conditions influencing the spatial organization and behavior of the stock.

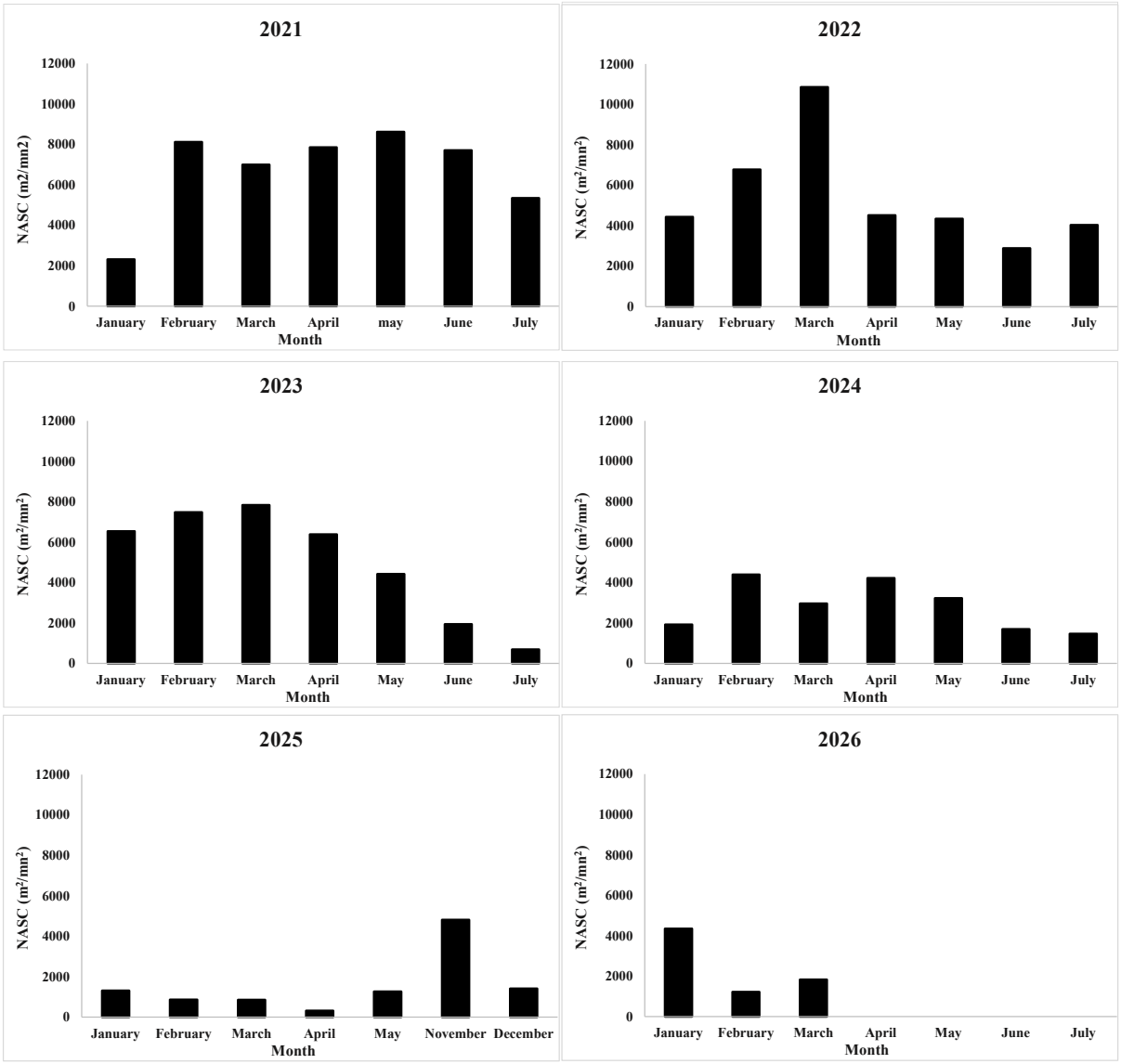


Figure 3. Mean monthly acoustic density between 2021 and 2026.

Interannual variability in Chilean jack mackerel density (2004 and 2025)

Table 2 presents the acoustic density indicators of Chilean jack mackerel (CJM) schools for May from 2004 to 2025, including mean densities (with and without zeros), total density, number of sampling days, and the number of detected schools. The highest mean density values were observed in 2005, 2009, 2018, 2019, 2021, 2022, 2023, and 2024. Among these, 2021 and 2023 exhibited particularly elevated mean densities despite a low number of detected schools, suggesting the presence of large, highly aggregated schools within a restricted spatial extent.

A similar pattern was observed in 2012, 2013, 2014, and 2019, where high positive mean densities coincided with fewer schools, potentially reflecting extensive search effort and a high proportion of zero observations. In 2021, mean density reached a maximum of 337.55 ton/nm², while total density peaked at 1,356,291 ton/nm², indicating a strong concentration of biomass.

Although 2022 showed slightly lower values than 2021, it remained among the highest in the series, consistent with a broader spatial distribution and a higher proportion of smaller

individuals. In 2023, all density indicators increased again, reinforcing the pattern of dense aggregations within a limited area. In contrast, 2024 showed a decrease in mean density but a substantial increase in the number of schools, ranking second in total density, which suggests higher overall biomass with a more dispersed spatial structure.

In 2025, all indicators declined markedly, including mean density, total density, and number of schools, pointing to a more diffuse distribution and/or changes in schooling behavior.

For 2026, the available data correspond to March rather than May and are therefore not directly comparable with the historical series. The increase in mean density (126.8 t/nm²) and total density (~599 thousand t/nm²) relative to 2025 may be influenced by a higher seasonal concentration in March and does not necessarily reflect a structural recovery of the stock. Although these values could suggest a partial increase in acoustic biomass and aggregation levels, they are likely driven, at least in part, by seasonal variability in distribution and schooling behavior. Consequently, the 2026 estimates should be considered preliminary, and a consistent interannual comparison will only be possible once May data are available, ensuring continuity with the time series.

Table 2. Annual Chilean jack mackerel density from 2004 to 2026 (march).

Year	Analyzed days	Schools Number	Mean Density positive (t/mn^2)	Mean Density (t/mn^2)	Total density (t/mn^2)
2004	6	99	366.3	66.8	36,264
2005	15	1,098	462.4	122.8	507,722
2009	25	1,350	462.9	119.4	623,553
2010	24	1,474	70.0	38.2	103,182
2011	22	42	792.1	15.6	33,270
2012	18	62	1,714.6	71.6	106,308
2013	7	21	1,045.9	70.3	106,248
2014	7	24	1,526.7	42.4	36,642
2015	25	592	190.8	27.8	112,943
2016	35	655	341.0	42.1	223,365
2017	7	123	439.9	72.4	54,103
2018	19	2,871	168.1	106.1	482,744
2019	15	173	3,046.9	268.5	527,110
2020	15	520	594.8	93.4	309,274
2021	23	503	2,696.4	337.6	1,356,291
2022	22	1011	1,008.2	249.2	851,579
2023	20	593	2,126.4	531.4	1,260,948
2024	31	1051	1,254.8	305.2	1,318,738
2025	28	534	677.0	57.9	361,534
2026	24	484	1,238.6	126.8	599,472

Abundance and Biomass of Chilean Jack Mackerel between 2019 and 2025

Between 2019 and 2025, the abundance and biomass of Chilean jack mackerel (*Trachurus murphyi*) in the central–southern region of Chile (Table 3 and Figure 4) exhibited marked interannual variability. During 2019–2020, relatively high levels of abundance (≈2.5–2.7 billion individuals) and biomass (≈1.1–1.4 million tons) were recorded. From 2021 to 2023, a general declining trend in abundance was observed, while biomass remained relatively stable or even increased in 2022, suggesting a shift in size structure toward larger individuals.

In 2024, both abundance and biomass reached their highest values in the time series, primarily driven by a strong contribution of smaller individuals (27–33 cm). However, in 2025, a sharp

decline occurred, with reductions exceeding 70% in both indicators, affecting nearly all length classes. This decrease may reflect changes in population structure, a more dispersed spatial distribution, or unfavorable environmental conditions influencing acoustic detectability.

Biomass estimates for 2026, based on June survey data to ensure consistency with the historical time series, will be presented at the Scientific Committee meeting in September.

Table 3. CJM abundance (millions) and biomass (ton) estimated between 2019 and 2025.

Year	2019	2020	2021	2022	2023	2024	2025
Abundance	2,665	2,476	1,857	1,506	1,328	3,240	822
Biomass	1,081,072	1,424,990	1,295,440	1,527,320	1,210,359	1,826,276	493,822
CV%	12.29	15.08	15.23	13.26	17.95	13.54	16.74

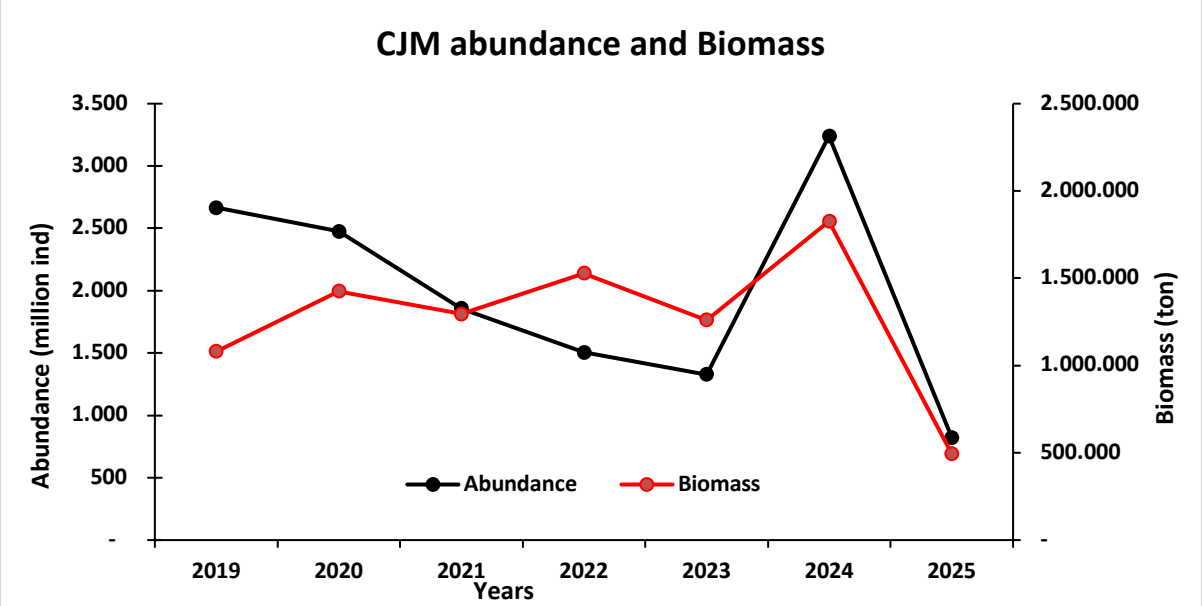


Figure 4. Comparison between CJM abundance and biomass estimates from 2019 to 2025.

The length structure of Chilean jack mackerel (*Trachurus murphyi*) between 2019 and 2025 (Figure 5 and 6) reveals a clear relationship between interannual variability in abundance and biomass and shifts in size composition. Overall, the period 2020–2023 is characterized by a decline in total abundance that was partially offset by an increased contribution of larger individuals, whereas 2024 exhibits a marked increase driven by a strong influx of small fish.

Maximal abundances were recorded in 2019 and 2024, both associated with a dominant size range of 27–33 cm fork length (FL) and a modal length of approximately 30 cm. In contrast, from 2020 to 2023 the population displayed a broader size spectrum (24–65 cm FL), dominated by medium to large individuals (35–51 cm FL). During this period, the increase in mean size contributed to relatively high biomass estimates despite reduced abundance, indicating a population composed of fewer but larger individuals.

In 2023, biomass declined relative to 2022 despite the continued prevalence of large fish, likely reflecting a contraction in the spatial extent of the stock. A pronounced shift occurred in 2024, when both abundance and biomass reached peak values, exceeding 3 billion individuals and 1.8 million tons, respectively. This increase was driven by a strong recruitment event, as evidenced by the dominance of small individuals (~30 cm FL).

In 2025, both abundance and biomass declined sharply to the lowest levels in the time series. Although small individuals (mode ~32 cm FL), likely originating from the 2024 cohort, remained dominant, the reduced presence of larger fish resulted in a substantial decrease in total biomass. This pattern highlights a decoupling between numerical abundance and biomass.

Length-structure analyses for 2026, based on June survey data to ensure consistency with the historical time series, will be presented at the Scientific Committee meeting in September.

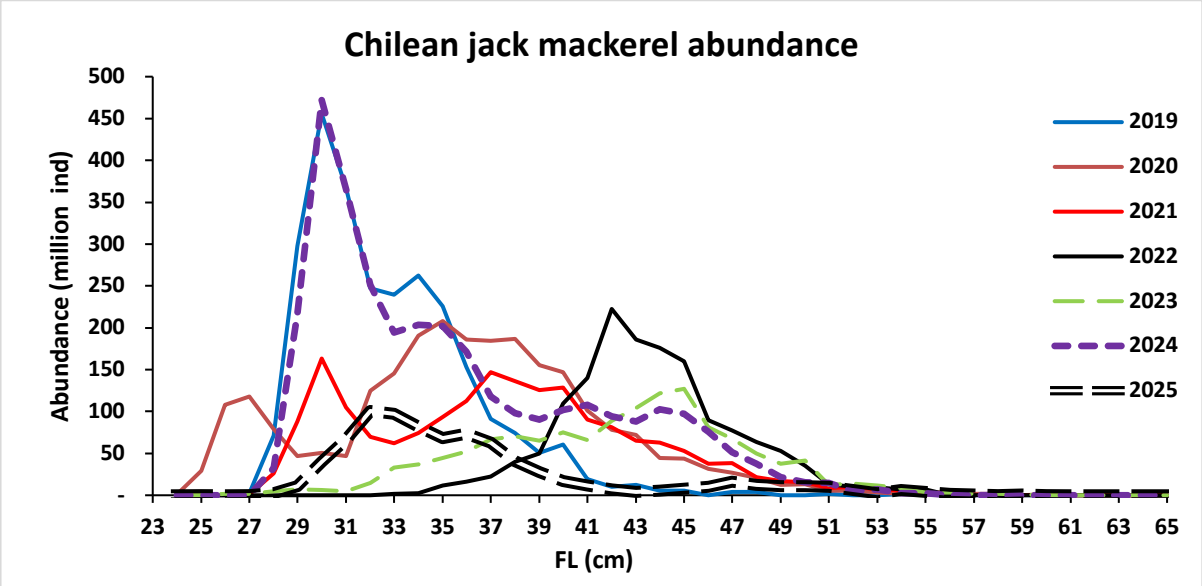


Figure 5. CJM abundance distribution by length (2019 – 2025).

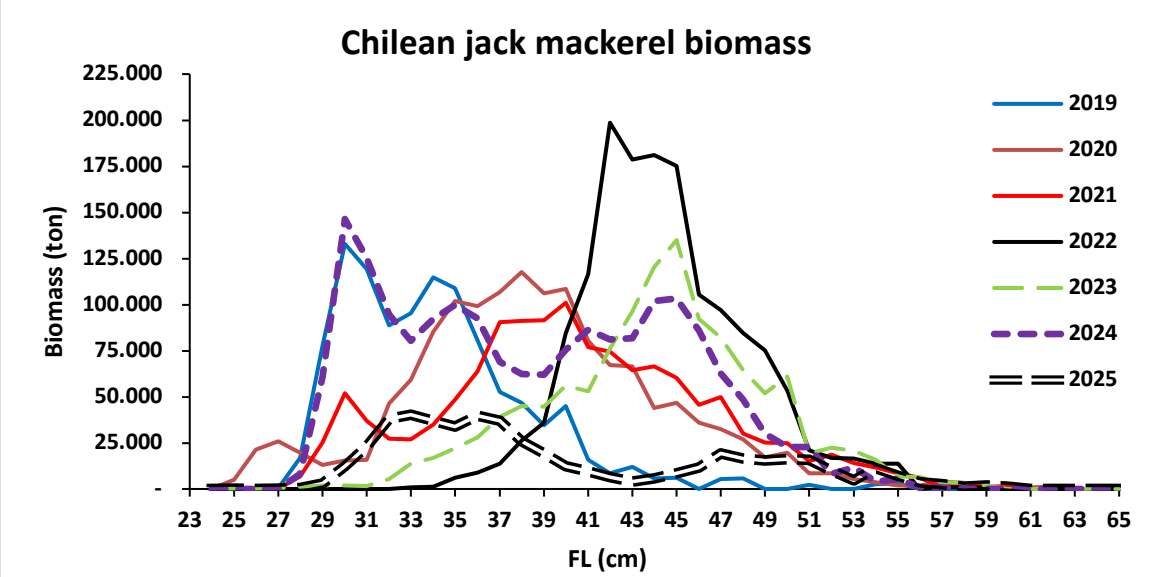


Figure 6. CJM Biomass distribution by length (2019 - 2025).

Concluding remarks

Spatial dynamics and habitat use: Between 2018 and early 2026, Chilean jack mackerel (*Trachurus murphyi*) exhibited pronounced spatial variability, while maintaining a persistent core distribution in the central–southern Chilean region (36°S–39°S). The transition from a relatively broad distribution (2018–2019) to a more coastal and spatially structured configuration (2020–2023), followed by a northward expansion (2024–2025) and a subsequent coastal re-concentration in early 2026, indicates a highly dynamic spatial regime likely driven by environmental forcing and variability in habitat suitability.

Seasonal aggregation patterns: A consistent intra-annual cycle was identified, characterized by peak aggregation during late summer to early autumn (February–May) and reduced densities during winter (June–July). However, recent years—particularly 2025—deviate from this pattern, suggesting changes in aggregation intensity and/or schooling behavior.

Size structure and population dynamics: Substantial shifts in size composition were observed across years. The period 2020–2023 was dominated by larger individuals, supporting relatively high biomass despite declining abundance. In contrast, 2019 and especially 2024 were dominated by small individuals (~27–33 cm FL), indicating strong recruitment events. The 2025 population was characterized by a narrow size structure dominated by small fish, with a notable absence of larger individuals.

Abundance–biomass decoupling: The results demonstrate a clear decoupling between abundance and biomass, driven by changes in size structure. Years with lower abundance but larger individuals (e.g., 2022–2023) maintained relatively high biomass, whereas 2025 showed low biomass despite the presence of small fish, highlighting the importance of size composition in stock assessments.

Interannual variability and uncertainty: The time series (2004–2025) reveals alternating periods of highly aggregated biomass and more dispersed distributions. The sharp decline observed in 2025 across all indicators suggests a major shift in population state, potentially linked to environmental variability, changes in behavior, or reduced acoustic detectability.

Implications for monitoring and assessment: These findings underscore the need to incorporate fishery-dependent acoustic data as complementary indicators in stock assessment models. The high variability observed in spatial distribution, aggregation patterns, and size structure highlights the importance of adaptive monitoring strategies, particularly under changing oceanographic conditions.

References

Alegría & Sepúlveda, 2021. Spatial Distribution and Acoustic Habitat Monitoring of Chilean Jack Mackerel from Fishing Vessels 2021. SC9-HM08. 9th meeting of the scientific committee SPRFMO. 16pp.

Alegría & Sepúlveda, 2024. Spatial distribution and biomass estimate of Chilean jack mackerel off South- central Chile based on acoustic records from fishing vessels, year 2024. SC12-HM04. 12th meeting of the scientific committee SPRFMO. 16pp.

Alegría & Sepúlveda, 2025. Spatial distribution and biomass estimate of Chilean jack mackerel off South- central Chile based on acoustic records from fishing vessels, year 20245 SC13-JM05. 13th meeting of the scientific committee SPRFMO. 22pp.

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.

Córdova, J., B. Leiva, V Catasti y C Valero. 2022. Evaluación hidroacústica de jurel entre las Regiones de Valparaiso y Los Lagos, año 2021. IT/ASIPA/2021. Instituto de Fomento Pesquero. Valparaíso, Chile (116 p) +figs. y anexos.

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.