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Space-time Dynamics of the Jack mackerel Fishery off South Central Chile 2004-2021

Chile

Space-time dynamics of the Jack mackerel fishery off south-central Chile in 2004-2021

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Summary

During the year 2021 (January-July) there was a strong concentration of fishing activity of Chilean jack mackerel (*Trachurus murphyi*) within the coastal area of 60 nm of the coast as well as that recorded in 2020 from where 97% of the total industrial landing were landed, this was allowed by: a) the high level of commercial aggregation presented by the schools of jack mackerel near the coast; (b) the high recurrence of school sighting areas throughout this strip; c) the high abundance of schools, caused largely by the presence of areas of high biological productivity, and d) also because these specimens captured during this year largely met the requirements (size and quality) of the industry for the production of by-products for human consumption, as observed in 2020. The few incursions into the ocean sector did not yield positive results, also the presence of a small fleet of trawlers outside the EEZ that searched for jack mackerel and finally maintained its operation between High Sea waters off Iquique and Antofagasta, and the results of the direct evaluation of jack mackerel 2021 that indicated that the resource was distributed mainly within the 60 nm strip confirming its coastal distribution, this breaks in part with the space-temporal dynamics traditionally recorded in past decades, in which commercial schools were observed to migrate to the ocean sector during June and July approaching the limit of the EEZ and outside it, which was registered in previous years by the national fleet and by the international fleet.

Biological-fishing background of the Jack mackerel fishery (2004 to 2021).

Landings

During the last 17 years, jack mackerel landings in the south-central region of Chile have registered a significant decrease during the period 2004 to 2011, decreasing from 1,261,000 t to 192,000 t (Figure 1). This is due to a lower availability of the resource at sea and on the other hand to the implementation of management measures that regulated the fishing effort, in order to facilitate a recovery process. During the following years, landings have been registering a progressive increase based on the increase in the annual quota that this fishery has been experiencing, due to the favorable signals that have been observed in the population indicators, this has caused that from 2011 to 2020 there has been an approximate increase of 150% in the landing of this resource. On the other hand, it is observed that the main species associated with this purse seine fishery have been mackerel (*Scomber japonicus*), jumbo squid (*Dossidicus jigas*) and hoki (*Macruronus magellanicus*). Mackerel showed a negative trend in landings as well as jack mackerel from 2004 to 2011 with values of 367,800 t and 10,300 t for both years, subsequently remained at values below 15,000 t, except for the period 2016 to 2019, where landings fluctuated between 16,000 t and 48,000 t, and then decline again in the years 2020 and 2021. Secondly, the jumbo squid was observed, a resource that has been present throughout the period analyzed, as well as mackerel, this resource registered more relevant values from 2004 to 2011, mainly under 7,000, only the years 2007 and 2010 stood out with high values of 39,700 t and 129,900 respectively, from 2012 to 2021 the jumbo squid has registered values mainly below 1,000 t. In relation to hoki, this resource has not been constant during this period, only landings were recorded until 2013 and in this period the years 2005 and 2011 stood out with values of 15,200 t and 13,400 t in the other years values below 2,300 t were recorded.

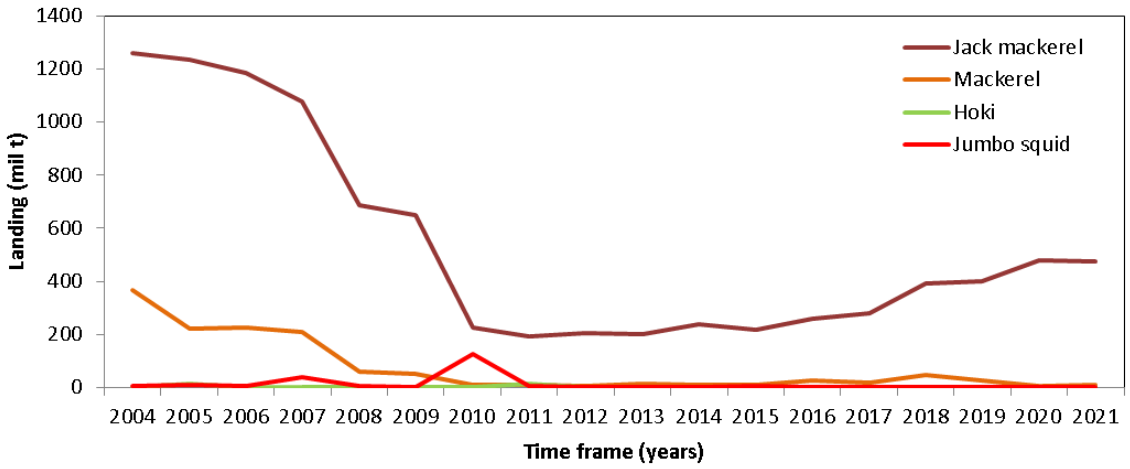
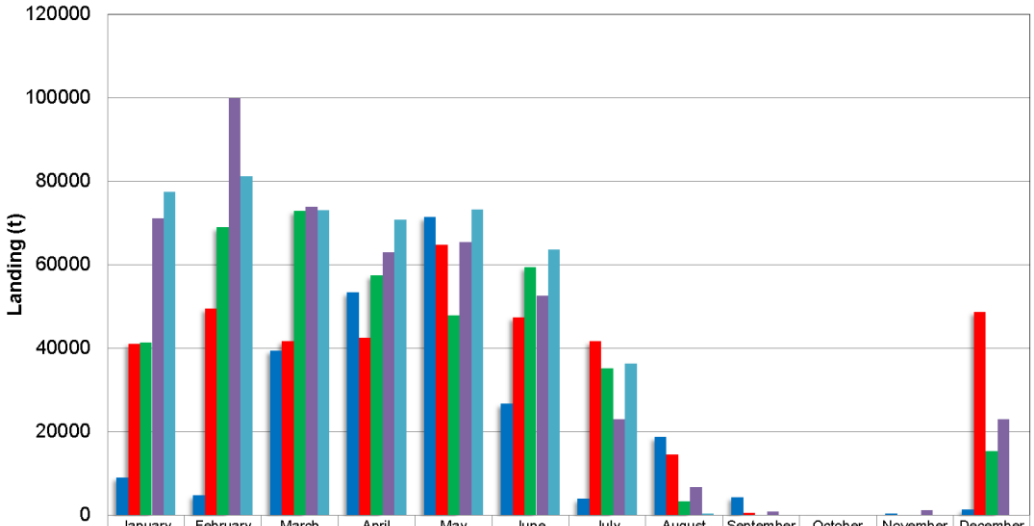


Figure 1. Annual landing of jack mackerel and its accompanying fauna registered during the period 2004 to august 2021 (Source: Inpesca-Sernapesca).

Monthly landings of jack mackerel in the region of central-south Chile registered between January and August 2021 (Figure 2), were clearly higher than the landings registered for a similar period (January-August) in the years 2017 to 2020, with a higher magnitude of 109%, 39%, 23% and 4.5% in the years 2017, 2018, 2019 and 2020 respectively. In February 2021 the highest monthly landing

with a value of 81,151 t was observed, and in second place March and January in which landings were above 70,000 t respectively, so the first quarter represented 49% of total landed until August 2021. Later in the course of autumn and winter entry, landings had a behavior similar to that registered in the period 2017-2020.



	January	February	March	April	May	June	July	August	September	October	November	December
2017	9055	4817	39454	53292	71332	26683	3963	18694	4356	159	344	1392
2018	41074	49511	41743	42481	64749	47407	41636	14511	468	0	0	48710
2019	41296	68916	72884	57401	47789	59401	35153	3272	0	0	0	15341
2020	71155	99911	73946	62989	65370	52569	23026	6715	893		1199	22982
2021	77402	81151	73103	70758	73287	63715	36283	356				

Figure 2. Monthly landings of jack mackerel from the industrial fleet of central-south Chile from 2017 to until August 2021 (source of data: Sernapesca).

Fishing yields

By observing the fish yields of jack mackerel for a long-term period between 199 to 2021 (Figure 3), it is noted that these declined as did the yields of jack mackerel + mackerel in two periods, in 1995-1998 and in 2006-2011, registering a general negative trend, highlighting that in 2011 the lowest value (2.7) was observed for the total period. On the contrary, from 2012 to 2021, jack mackerel fishing yields showed a positive net trend, highlighting high values close to 20% in 2020 and 2021, similar to what was recorded in the mid-90's, despite with hauls of 2.6 and 2.5 respectively. On the other hand, it is important to note that in 2012, carrying capacity (hold capacity by days out of port) registered the lowest value of the total analysis period (2.4 million m^3), from then on this parameter has remained under 5 million m^3, this associated mainly with the strong regulation of fishing effort that affected this fishery, from 2011 onwards, carried out in conjunction with the SPRFMO (SSPA 2017). On the other hand, it is important to note that in 2012, carrying capacity registered the lowest value of the total analysis period (2.4 million m^3), from then on this parameter has remained under 5 million m^3, this associated mainly with the strong regulation of fishing effort that affected this fishery, from 2011 onwards, carried out in conjunction with the SPRFMO (SSPA 2017).

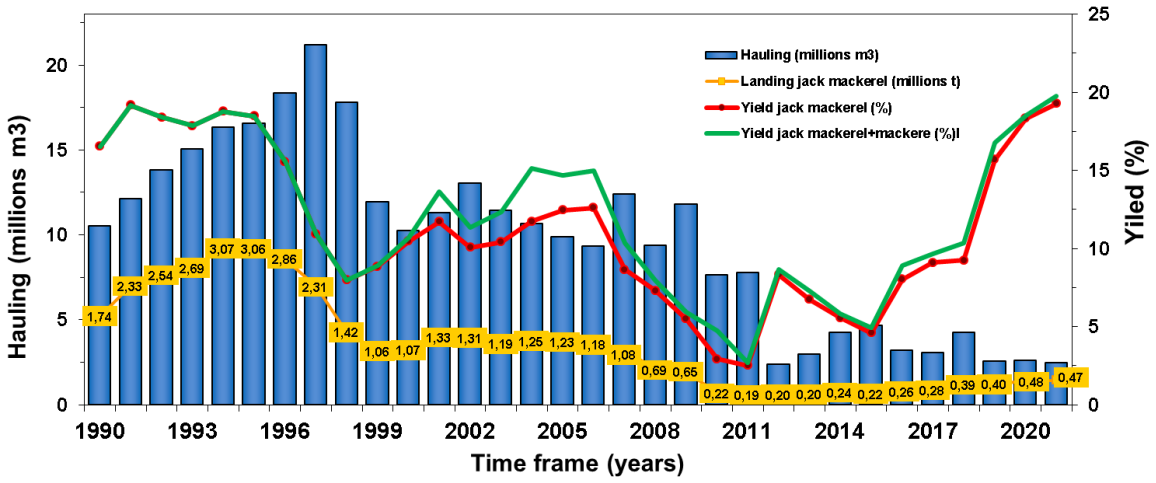


Figure 3. Annual dynamics of landings, carrying capacity and yields of the industrial fleet of central-south Chile that operates in jack mackerel and mackerel between the years 1990-2021 (until July).

Length frequencies of Chilean jack mackerel

The Fisheries Research Institute (Inpesca) carries out a permanent biological monitoring of the jack mackerel fishery at the landing ports of the purse seine vessels that operate in this resource and also there are scientific observers continuously on board to support the registration of biological information, this has allowed to form an important biological database of this resource over the years. In this sense, the annual and expanded jack mackerel size structures to the catch (Figure 4), according to analysis of progression of the modal classes (blue lines) (Pauly, 1983), indicate the presence of different cohorts that have been present in the area of the fishery of Central-South Chile during the time period analyzed. During the period of years analyzed, the presence of a structure made up mainly of adults stood out, with a low presence of juvenile specimens or low legal minimum size (<26 cm FL), in most of the period this fraction did not exceed 4%, only in the years 2004 and 2010 was registered 8.4% and 9.1% respectively. On the other hand, as a recurrent pattern during the fishing season, there has been a greater recurrence of modal groups less than 30 cm FL in the sampling of fishing sets, mainly during the summer season and part of the autumn season, to give way later until the end of the fishing season to a greater recurrence of modal groups greater than 30 and 40 cm FL

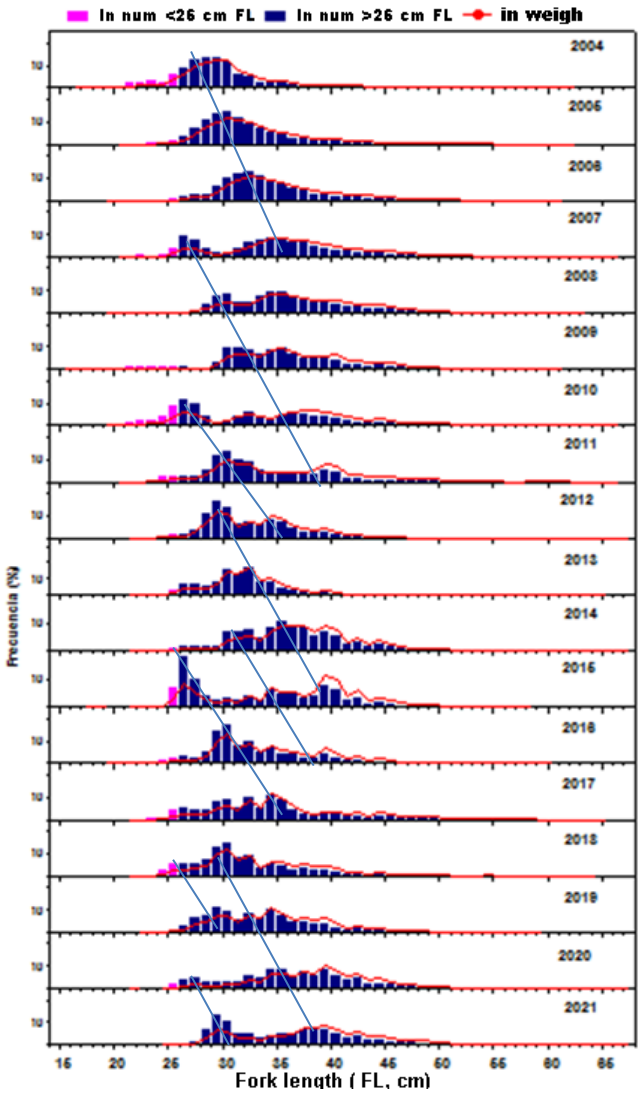


Figure 4. Length frequencies of Chilean jack mackerel sizes in the landings of the Chilean fleet during the years 2004-2021.

Spatial distribution of the fishing operation 2004 to 2021

From 2004 to 2007, the fishery of this resource registered a coastal-oceanic distribution (Figure 5) characterized by a displacement of the fleet to inside of the EEZ, generally attached to the coast during the summer period and later towards the autumn the fleet developed a gradual displacement towards the northwest or southwest outside the EEZ, achieving extreme lengths in the years 2006 and 2007 established at 97°W and 99°W respectively, with an impact on navigation, not recorded before in the history of the purse seine fleet of central-south Chile, which caused a maximum route of 1,160 nautical miles and approximately 1,240 nautical miles to reach these fishing areas.

During the period 2008 to 2019 the fleet distributed its operation mostly to the interior of the EEZ, evidencing a coastal displacement with a northern orientation of the BíoBío Region during the

summer period, later during the autumn and winter the fleet distributed its operation towards the most oceanic region gradually, either to the west or southwest managing to reach in some years the surroundings of the limit of the EEZ, in the longitudinal direction, maximum displacements of about 650 nautical miles were observed. However, during years 2020 and 2021 the fleet experienced a highly coastal operation mainly within the strip of 60 mn of the coast in the order of 99% and 97%, respectively. This operation presented maximum displacements of approximately 440 nautical miles of port in the longitudinal direction, this represents an extraordinary condition for the period analyzed (2004-2021).

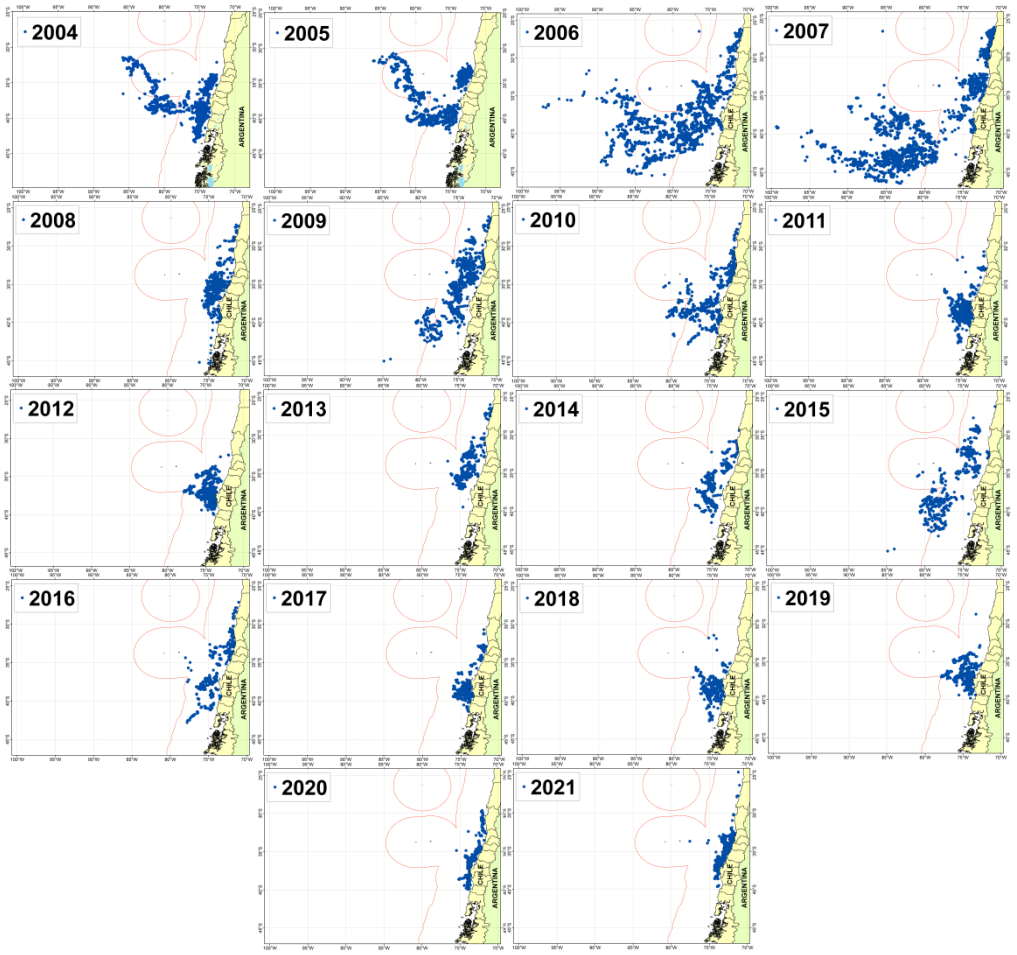


Figure 5. Location of Chilean jack mackerel fishing sets of the Central-South fleet from 2004 to 2021.

Historical analysis of the jack mackerel fishing operation inside the coastal strip of 60 nautical miles.

In order to characterize the fishing operation within the coastal strip of 60 nm of the coast and establish the impact it has had in recent years on the fishing operation in jack mackerel in central-south Chile, a spatial analysis of the georeferenced catch data corresponding to the fishing operation of the central-south Chile purse seine fleet was carried out.

For the extraction of the spatial data of jack mackerel capture, a mask was designed in a geographic information system (GIS), which allowed to extract the spatial data located inside the 60 nm strip of the coast for the period from 1994 to 2021 (Figure 6).

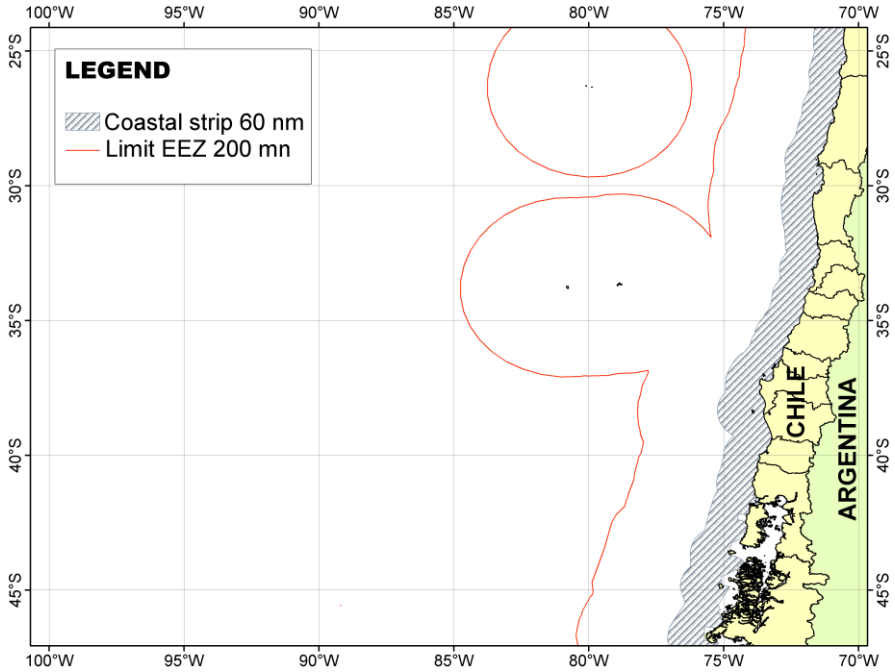


Figure 6. Representation of the boundaries used to differentiate the coastal region from the oceanic for the spatial analysis of catch data from 1994 to 2021.

The information used for this analysis corresponded to georeferenced data of the jack mackerel catches, which contained the date and time of the catch, recorded by the scientific observers of Inpesca and by self-sampling procedures implemented with skipers of the purse seine fleet of the BíoBío Region (Figure 7). Importantly, this information has represented a proportion of more than 30% of the total catches made by the fleet. From this information, the fraction of the operation that took place within the coastal strip was determined and the representation of this fraction in corresponding percentage of the total landing for each year analyzed is presented in Figure 8.

The results of this analysis indicate that the coastal strip during the period analyzed (1994-2021) has had a participation close to 90% in the mid-90's, however, towards the end of this decade this participation presented a decreasing trend until 2006, largely determined by the oceanic distribution of the fishing operation. From 2015 to 2021, the contribution of this coastal strip in

jack mackerel catches presented an incremental trend, established by the concentration of the fishing operation within it, which was more extreme during the years 2020 and 2021 where 99% and 97% of the total operation within this strip was reached, these results are consistent with comments made by experienced skipers of the purse seine fleet, in which they have indicated the presence of highly concentrated shoals inside the coastal sector during these two years compared to previous years.

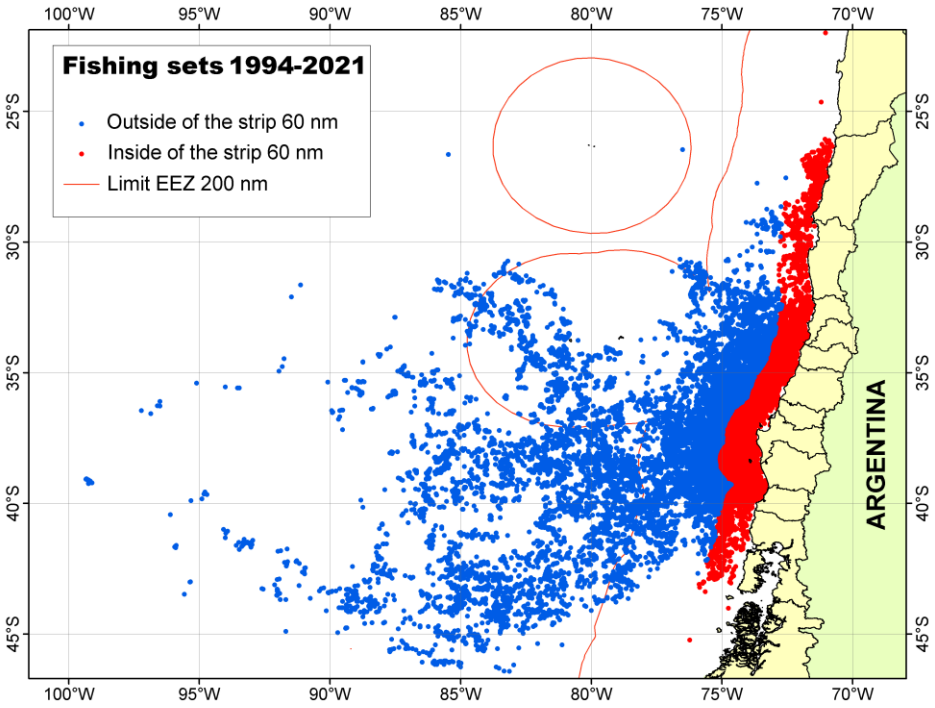


Figura 7 Spatial representation of the jack mackerel fishing sets carried out inside the coastal strip (red) and outside (blue), during the years 2017 to 2020.

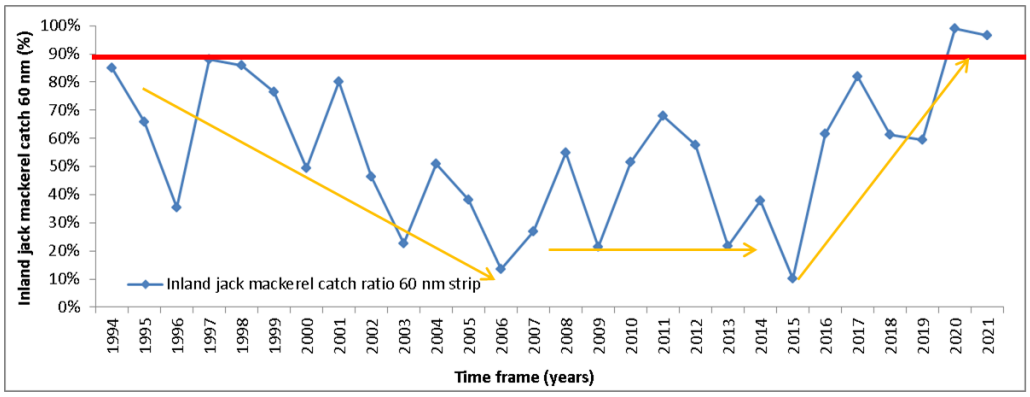


Figura 8. Contribution of coastal catch as a percentage to the total landed in central-south Chile during the years 1994 to 2021.

Dicussion and conclussion

Within the last two decades, the jack mackerel fishery in Central-South Chile has undergone significant regulation of fishing effort to prevent it from collapsing, determining a drop in landings under 200,000 t in 2011, this value corresponds to the lowest recorded in the recent history of the jack mackerel fishery. Coincidentally, the species associated with this fishery such as mackerel and jumbo squid also recorded a decline in the same year.

This condition of low availability of the jack mackerel during this period has been linked, on the one hand, to the high level of exploitation that this fishery has suffered in the 90's and on the other hand, to a change of population phase from expansion to a population phase of contraction (Mccall, 1990), as indicated by Klyashtorin (2001) and Sharp (2004) and that would correspond to the period after 90's of low productivity regime of this resource.

In this period the purse seine fleet of the BíoBío Region that operates in jack mackerel developed in an unprecedented way an extreme ocean fishing activity, which involved reaching high sea areas sharing its operation with the midwater fleet in international waters, this determined a low operation in the coastal region, despite the intense searches for schools of jack mackerel in this region, this was indicating low availability in the coastal region. It is relevant to mention that the commercial aggregations of jack mackerel found in the oceanic region were exceptionally suitable for purse seine fishing, which is why the fleet developed intense navigations to the west, also considering that in the coastal region the results were not favorable.

During the last 6 years, favorable environmental and feeding conditions have been observed and increased fishing activity of jack mackerel, such as the incremental trend of fishing yields, which has been favored by a progressive concentration of the resource in the coastal zone, this determined in an unprecedented way that the total annual catches during 2020 and 2021 have been generated mainly inside the coastal strip of 60 mn (99% and 97%) for the period analyzed. It is likely that this coastal distribution of jack mackerel schools is linked to their preference for areas with high levels of food supply and a low presence of predators such as jumbo squid that has decreased its presence in recent years in the coastal area. To this are added the results of the acoustic surveys carried out in 2020 in this region where a biomass of 1,548,640 t was determined, which was concentrated above 90% inside the coastal strip of 60 mn. These results are relevant considering that the estimate made in the last survey carried out in 2017, a biomass of 431,469 t was obtained (Ifop 2021).

In relation to jack mackerel sizes, it is highlighted that in these years the development of multiple modal progressions has been observed, thus determining the presence of cohorts that have been the basis of the landings generated. However, a low presence of juvenile specimens were registered in the landings. It is noted that during these years there has been a greater presence of specimens with a size of 30 cm FL during the summer period to the north of the BíoBío Region in a coincident way with the advance of subtropical waters to the south which causes a greater warming of the intermediate zone and that in combination with the presence of coastal upwelling processes generates thermal fronts associated with areas of high biological productivity (Gretchina *et al*. 2019), which would facilitate the approach of these schools to the intermediate and coastal region during the summer period (Figure 9). In the last 4 years, sampling information for the regions located northern of Valparaíso, indicate the presence of modal groups less than 30 cm FL (Böhm 2018, Böhm 2019, Böhm 2020, Böhm 2021).

Considering the results obtained from the fishing operation, it is likely that the pattern of displacement of these schools is southward in the summer season and then the fleet follows them north in the autumn in an apparent return to this region, unlike what was recorded in the previous decades in which the monitoring of these shoals traditionally went west during the winter and that it has been described as the beginning of the process of reproductive migration that this resource has developed historically, which has not been observed especially in the last two years, where the fleet has ended its operation in August due to the fulfillment to a large extent of the assigned quotas. This is reinforced considering that the acoustic survey of jack mackerel carried out in 2021, again is registering commercial shoals mainly associated with the coastal strip of 60 mn in the period that previously the jack mackerel began its reproductive migration to the ocean sector. On the other hand, the operation described by three vessels outside the EEZ during 2021, was focused on the northern part of Chile, between Iquique and Antofagasta north of the "La Bota" region, despite having begun its search for jack mackerel in front of the central-southern Chile region (traditional fishing area of the High sea fleet), apparently without favorable results.

This strong retreat of jack mackerel schools inside the coastal strip may obey as a strategy of this species in periods of low abundance that allow it to increase its biomass if environmental conditions facilitate this situation as it has apparently happened, this coastal pattern of the fishery was detected in its beginning in the late 70s and in the early 80's in the which the fleet landed during the year 1985 up to 1,000,050 t in an operation that was developed with a greater haul than the current one within the 60 mn in front of the Maule and Biobío regions, in a more restricted area than that registered in recent years (Böhm *et al.*, 1996).

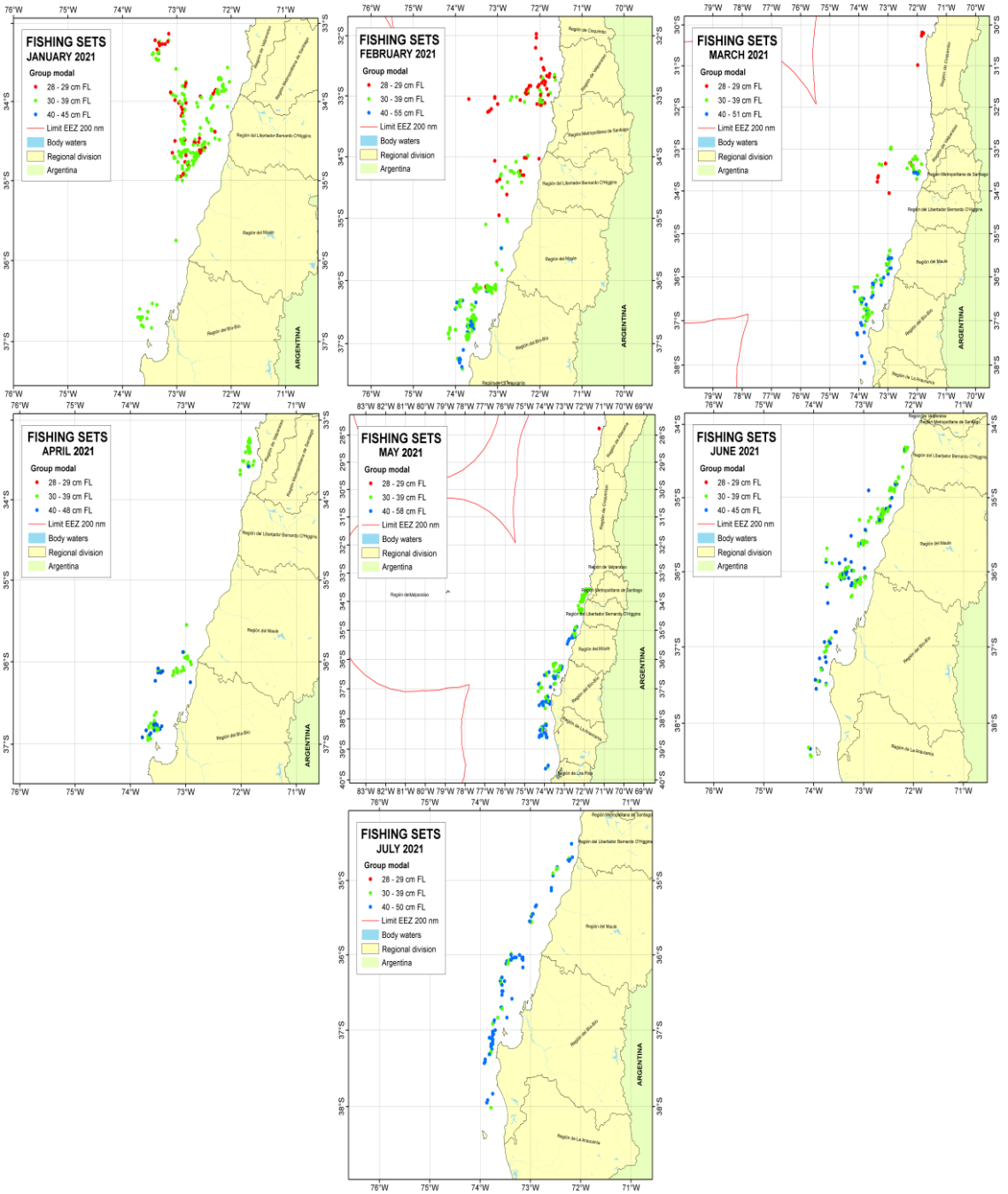


Figure 9. Monthly spatial distribution of modal groups registered in year 2021.

References

Böhm M.G. 2018. Boletín Semanal N°37. (XV, I, II, III, IV Regiones) (10 al 16 Septiembre 2018). Convenio de desempeño 2018. Programa de Seguimiento de las principales pesquerías pelágicas de la zona norte de Chile. XV-IV Regiones. Subsecretaría de Economía y EMT. 12 p.

Böhm M.G. 2019. Boletín Semanal N°30. (XV, I, II, III, IV Regiones) (22 al 28 Julio 2019). Convenio de desempeño 2019. Programa de Seguimiento de las principales pesquerías pelágicas de la zona norte de Chile. XV-IV Regiones. Subsecretaría de Economía y EMT. 12 p.

Böhm M.G. 2020. Boletín Semanal N°40. (XV, I, II, III, IV Regiones) (28 septiembre al 04 octubre 2020). Convenio de desempeño 2020. Programa de Seguimiento de las principales pesquerías pelágicas de la zona norte de Chile. XV-IV Regiones. Subsecretaría de Economía y EMT. 12 p.

Böhm M.G. 2021. Boletín Semanal N°30. (XV, I, II, III, IV Regiones) (26 julio al 01 agosto 2021). Convenio de desempeño 2021. Programa de Seguimiento de las principales pesquerías pelágicas de la zona norte de Chile. XV-IV Regiones. Subsecretaría de Economía y EMT. 12 p.

Böhm G., Barbieri M.A., Yáñez E., Catasti V., y A. González. 1996 Fip-It 93-22. Análisis de la captura y el esfuerzo de pesca de las unidades de pesquería de jurel de la Centro-Sur y norte. Instituto de Fomento Pesquero y Universidad Católica de Valparaíso. Informe final. 154 p

Gretchina, A., C. González & A. Sepúlveda. 2019. Space-time dynamics of Chilean jack mackerel fishery from South-central Chile in 2019. SPRFMO, 7 th Meeting of the Scientific Committee La Havana, Cuba, 7 - 12 October 2019. SC7-JM02

Ifop. 2021. Taller presentación resultados: “Evaluación hidroacústica de jurel entre las regiones de Valparaíso y Los Lagos, año 2020”

Klyastorin, LB. 2001. Climate change and long-term fluctuations or commercial catches: the possibility of forecasting. FAO Fisheries Techinical paper. N°410. Rome. 96 p

Mccall, A. D. 1990. Dynamic Geography of Marine Fish Populations. Seattle 153pp

Pauly, D. 1984. Fish population dynamics in tropical waters a manual for use with programable calculators. ICLARM Studies an Reviews 8, 325p. International Center for Living Aquatic Resouces Managemente, Manila, Phlippines.

Sharp, G.D. 2004. Cambio climático y pesquerías regionales en el futuro: análisis en colaboración. FAO Documento Técnico de Pesca. N°452. Roma, FAO. 2004. 84 p

SSPA, 2017. Plan de manejo para la pesquería de Jurel XV a X Regiones. Subsecretaría de Pesca y Acuicultura. 99 p