SPRFMO
South Pacific Regional Fisheries Management Organisation

11th MEETING OF THE SCIENTIFIC COMMITTEE

11 to 16 September 2023, Panama City, Panama

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Habitat conditions of jack mackerel (*Trachurus murphyi*) and chub mackerel (*Scomber japonicus*) in the Peruvian sea between 2021 and 2023

Republic of Peru

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HABITAT CONDITIONS OF JACK MACKEREL (TRACHURUS MURPHYI) AND CHUB MACKEREL (SCOMBER JAPONICUS) IN THE PERUVIAN SEA BETWEEN 2021 AND 2023

by

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This report contains information on the Jack mackerel fish stock and fishery in Peruvian jurisdictional waters that, we reiterate, the delegation of Peru, in use of its discretionary powers, voluntarily provides for the purpose of information and support to the scientific research work within the Scientific Committee of the SPRFMO. In doing so, while referring to Article 5 of the Convention on the Conservation and Management of High Seas Fishery Resources in the South Pacific Ocean and reiterating that Peru has not given the express consent contemplated in Article 20 (4) (a) (iii) of the Convention, Peru reaffirms that the decisions and conservation and management measures adopted by the SPRFMO Commission are not applicable within Peruvian jurisdictional waters.

2023

Summary

An update of the analysis on changes in the habitat of jack mackerel (*Trachurus murphy*) and chub mackerel (*Scomber japonicus*) has been made, with emphasis on what was observed between summers 2021 and 2023. The summer of 2023 has been characterized by being dominated by negative temperature anomalies until the beginning of February when there was rapid warming of the sea from north to south, up to approximately the latitude of Callao; at the end of February, ENFEN officially announced the development of conditions for the Coastal El Niño. In this context, and regarding the habitat, it was observed that during the summer 2023 the presence of jack mackerel and chub mackerel has again occurred in a typical way, that is, along the fronts between oceanic and coastal waters, unlike the year 2020 in which they were observed in oceanic waters, which was considered unusual at least for that season. From the analysis of the various variables analyzed regarding the habitat of these species, it is concluded that there have been different conditions in recent years, where the only parameter analyzed that remained within a narrow range is salinity. Another aspect to notice is that both species have been available for fishing in areas with low chlorophyll concentration and with relatively high values of altimetry and sea surface anomaly. In the case of jack mackerel, its main distribution area closer to the coast in the center-south zone is remarkable, while in the north it was less abundant. In the case of chub mackerel, a latitudinally wider availability was observed compared to jack mackerel.

TABLE OF CONTENTS

1. Introduction

The Scientific Research Committee (CIC) of the National Fisheries Society (SNP), in cooperation with the Humboldt Institute for Marine and Aquaculture Research (IHMA) organized the **Eleventh SNP Workshop on the habitat conditions of jack mackerel and other species of the Peruvian Current in the Humboldt System**, which was held virtually from 26 to 30th June 2023. It has counted, as usual, with the valuable participation and contribution of researchers from the Institute of Sea Research of Peru (IMARPE). This activity is a contribution to the national and international effort to research and diagnose the changing conditions of jack mackerel and chub mackerel populations, as well as other important species of the South Pacific, with particular emphasis on aspects related to their habitats since the first workshop in 2011.

2. Description of jack mackerel and chub mackerel habitats using oceanographic satellite and fisheries data

Various oceanographic parameters are described for the summers (January, February, March) of years 2021, 2022 and 2023 with an indication of the fishing sets made on jack mackerel (*Trachurus murphy*) and chub mackerel (*Scomber japonicus*). In Figures 2.1.1 to 2.1.5. The oceanographic parameters of January 15, February 15, and March 15 of each year are presented, in order to appreciate the changes that have occurred in the oceanic conditions during the last three years, with a description of the relationship with the distribution of jack mackerel and chub mackerel.

2.1. Sea surface temperature between 2021 and 2023

In the described period, the presence of jack mackerel and chub mackerel has been observed along the thermal fronts between cold coastal and subtropical water masses; the fishing sets made on jack mackerel were carried out outside the continental shelf. It is considered that, in general, the moderate thermal conditions of the last four years (since 2019) have led to a higher concentration of jack mackerel, especially in the south. Chub mackerel, on the other hand, has tended to be distributed – as usual – further north to the extent that in that area the presence of Equatorial Surface Waters predominated during summers (Figure 2.1.1).

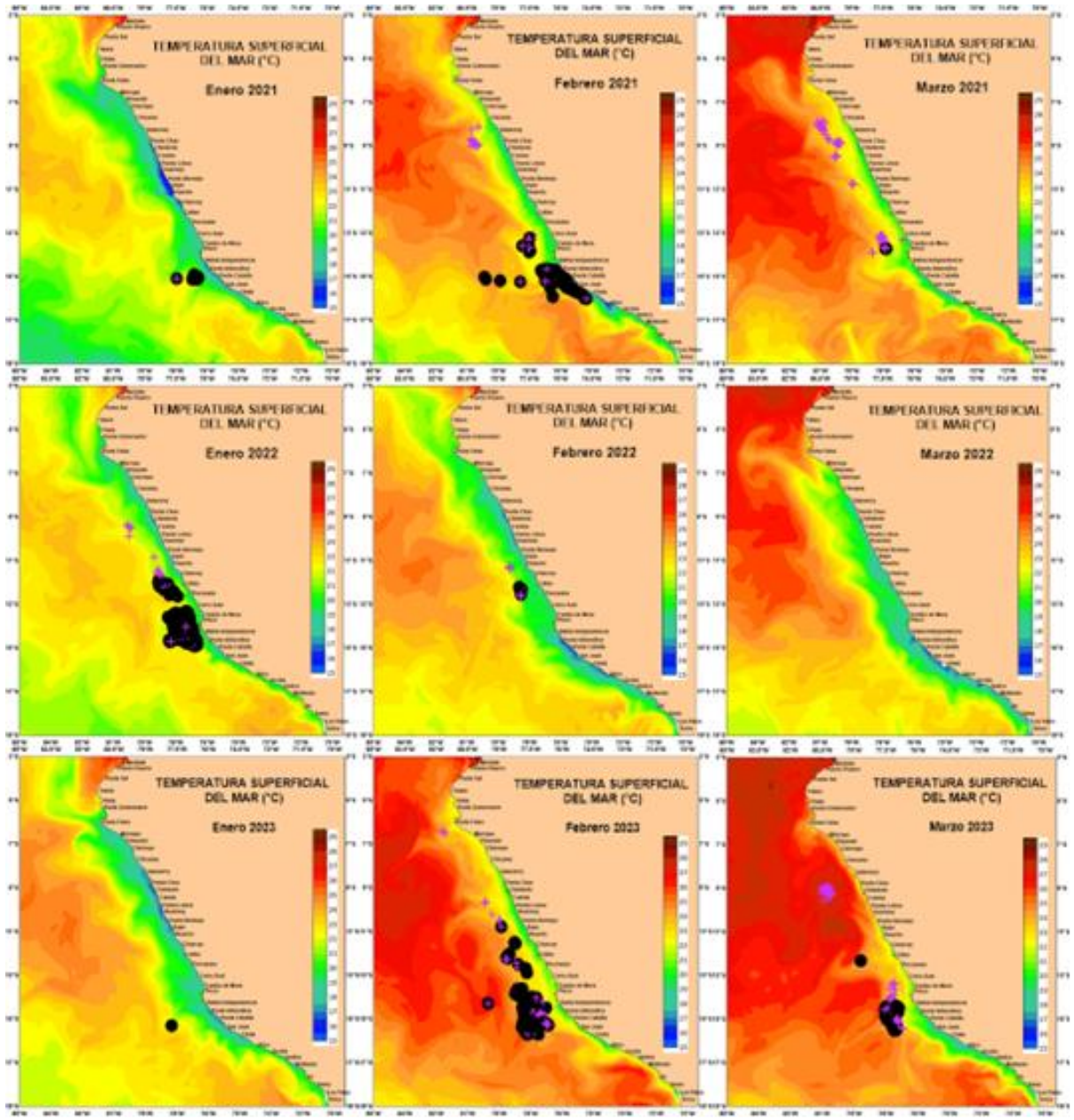

Figure 2.1.1. Sea surface temperature (SST°C) during the summer months of years 2021, 2022 and 2023. Jack mackerel fishing sets are indicated by black circles, and chub mackerel ones are indicated by purple crosses. In March 2022, no catches are observed because the industrial fishing quota was reached at the beginning of February.

2.2. **Sea surface temperature anomaly (ATSM, °C) between 2021 and 2023**

Between January 2021 and January 2023, there were higher negative anomalies than in previous years. Under these conditions, the main jack mackerel fishing zones were distributed south of the Paracas peninsula, where negative thermal anomalies were higher during 2021. Chub mackerel instead had some distribution areas in the north and center, but also in areas where it coincided with jack mackerel in the south. The conditions under which jack mackerel was caught during January 2022 are similar to those of February 2021. In February 2023 warmer conditions typical of a coastal El Niño begin to develop (Figure 2.2.1).

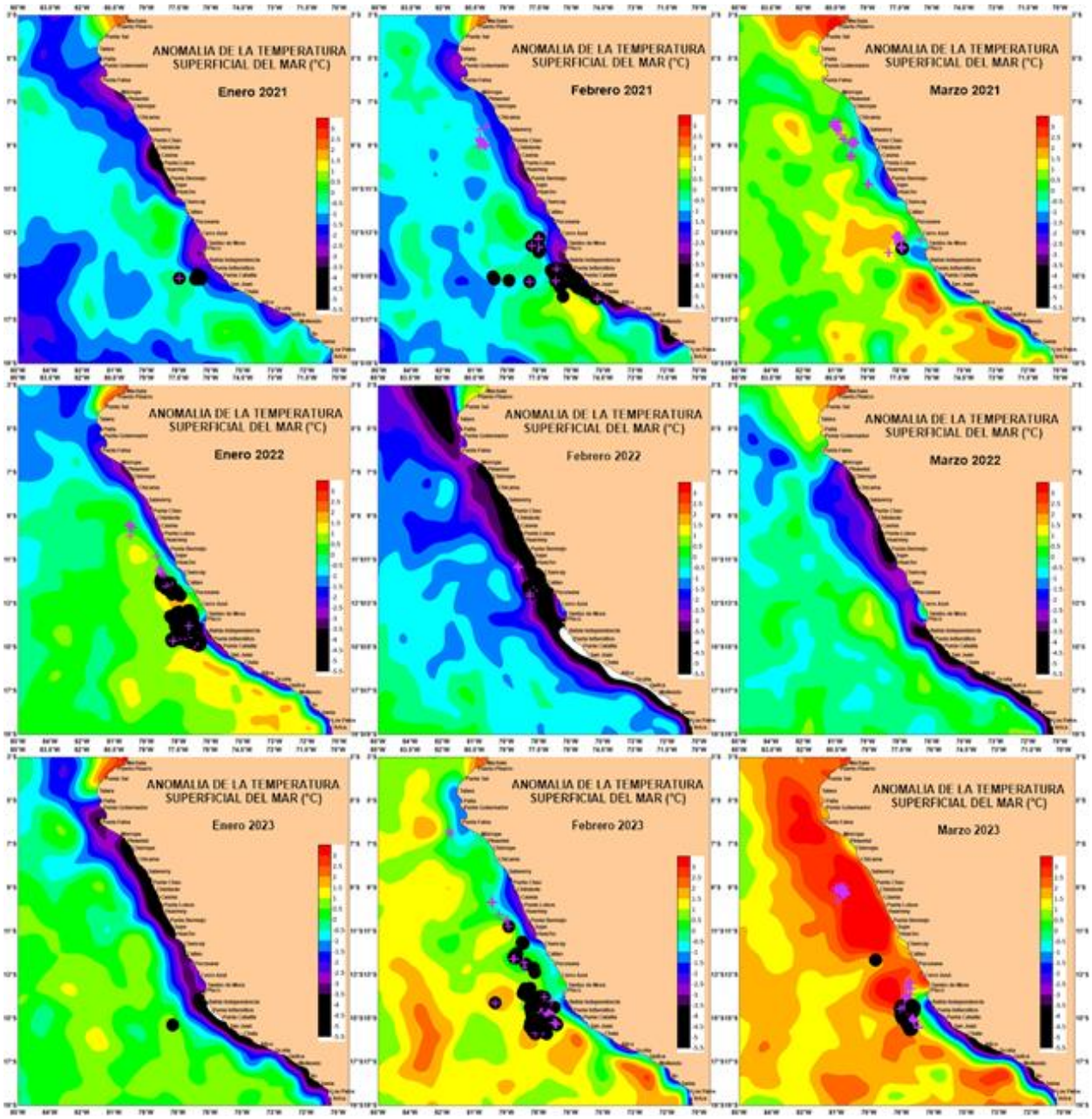

Figure 2.2.1. Sea Surface Temperature Anomaly (ATSM, °C) during the summers of years 2021, 2022, and 2023. Jack mackerel fishing sets are indicated by black circles, and chub mackerel are indicated by purple crosses. In March 2022, no catches are observed because the industrial fishing quota has been completed.

2.3. Sea surface salinity (SSM, ups) between the years 2021 and 2023

Between 2021 and 2023 chub mackerel fishing sets were distributed both in the center and south along the front between cold coastal waters (CCW) and subtropical surface waters (SSA); in the case of jack mackerel, in 2021 its fishing zones grounds have been located approximately in the same as previous years, that is, south of the Paracas Peninsula along the front between CCW and SSA (Figure 2.3.1).

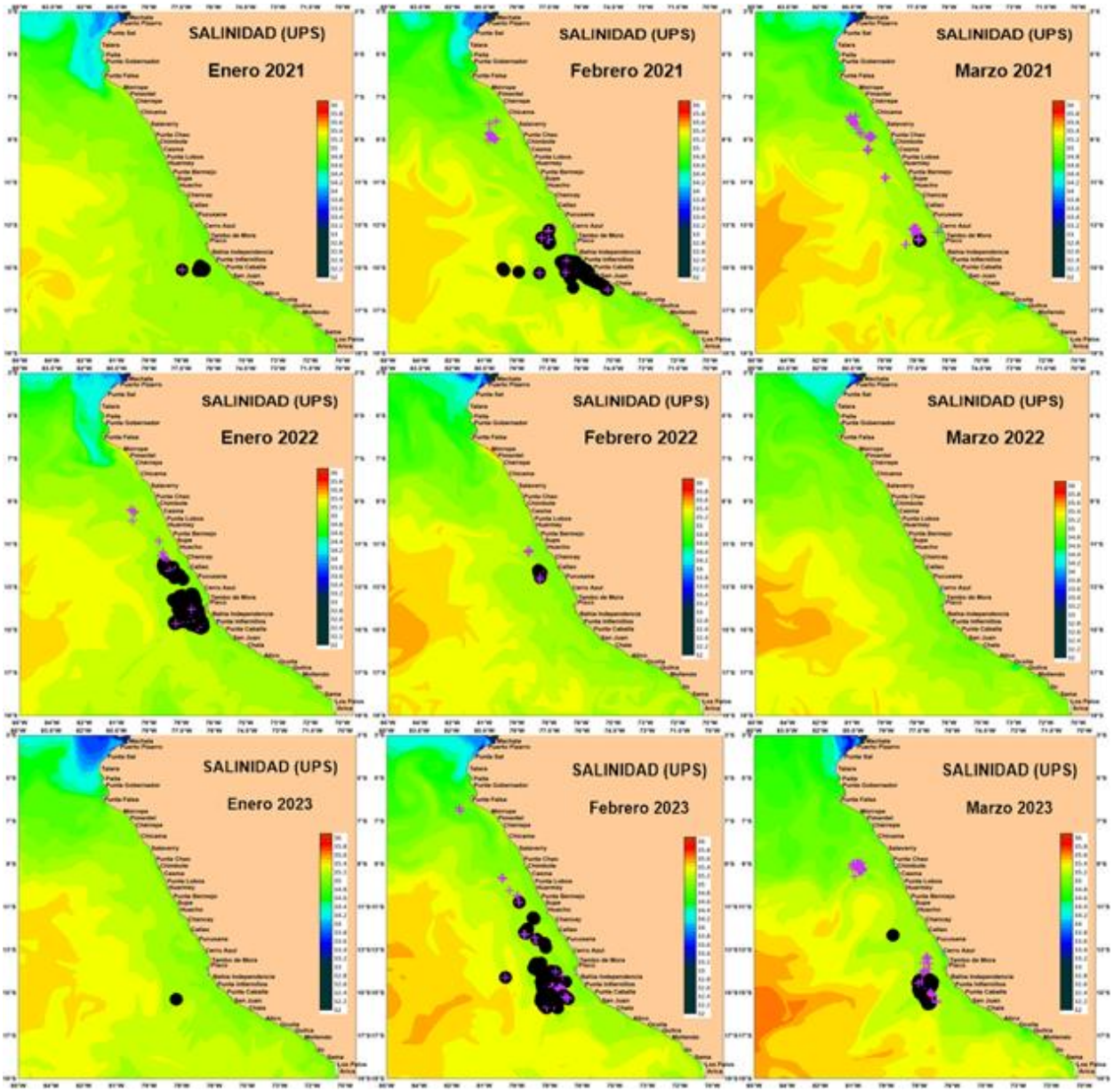

Figure 2.3.1. Sea surface salinity (SSS, ups) for the summer season during 2021, 2022 and 2023. Jack mackerel fishing sets are indicated by black circles, and mackerel ones are indicated by purple crosses. In March 2022, no catches are observed because the industrial fishing quota was completed at the beginning of February.

2.4. Sea surface chlorophyll (ug/Lt) between 2021 and 2023

Between 2021 and 2023, jack mackerel and chub mackerel were found on the outer edges of the highest concentration of chlorophyll in the central and southern zones. By 2023, lower primary productivity is evident, which use to be the case when El Niño events develop (Figure 2.4.1).

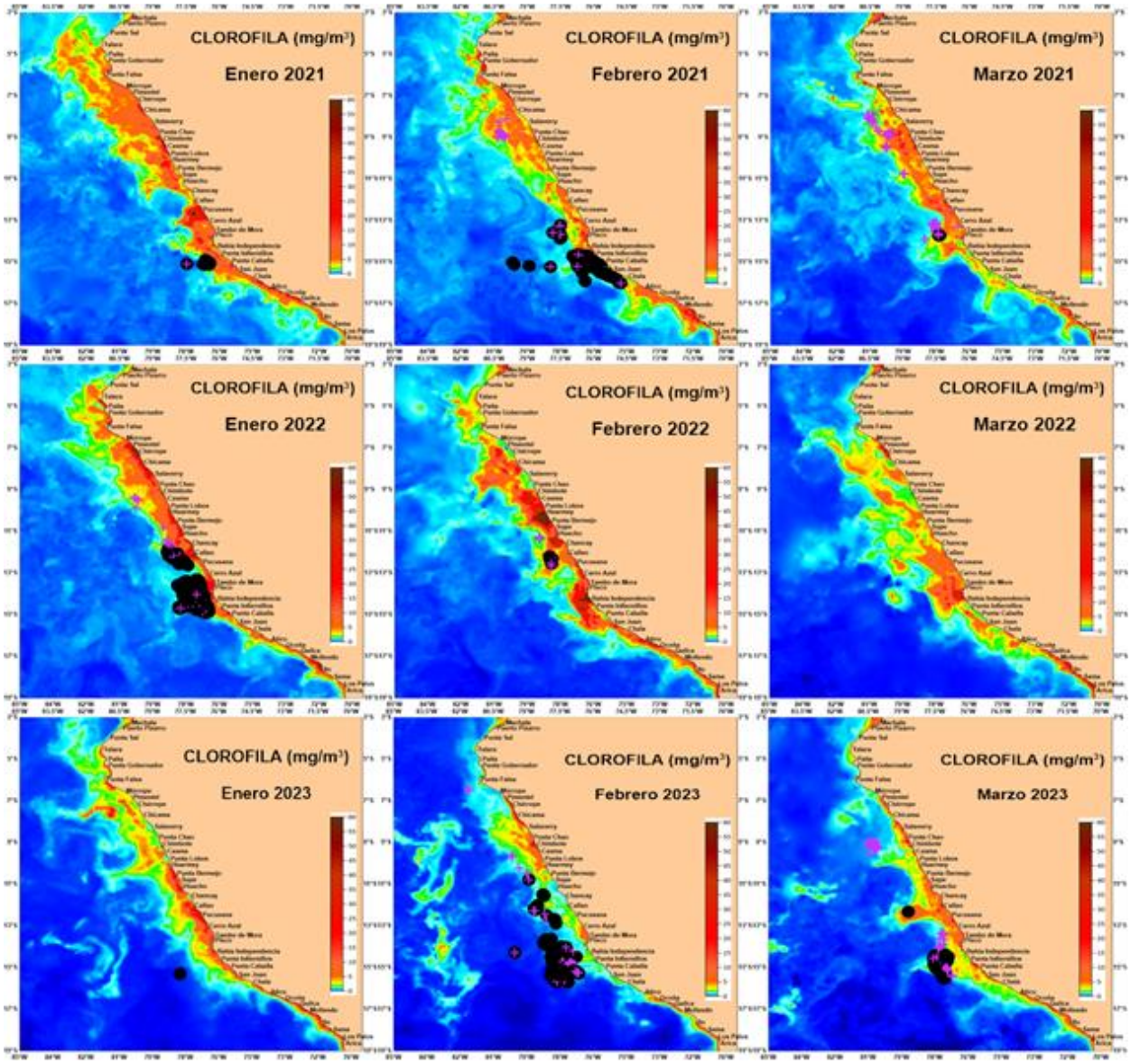

Figure 2.4.1. Sea surface chlorophyll (SSC, ug/L) during the summer of years 2019, 2020 and 2021. Jack mackerel fishing hauls are indicated by black circles, and chub mackerel ones are indicated by purple crosses. In March 2022, no catches are observed because the industrial fishing quota has been reached.

2.5. Sea Level Anomaly (SLA, cm) between 2021 and 2023

The summer months of years 2021 to 2023 – except January 2021 – presented higher oceanic dynamics than in previous years, which is associated with a denser availability of jack mackerel and chub mackerel, but mainly in the south. More specifically, the presence of jack mackerel and chub mackerel has been related to intermediate to high sea level anomalies (SLA) values. (Figure 2.5.1).

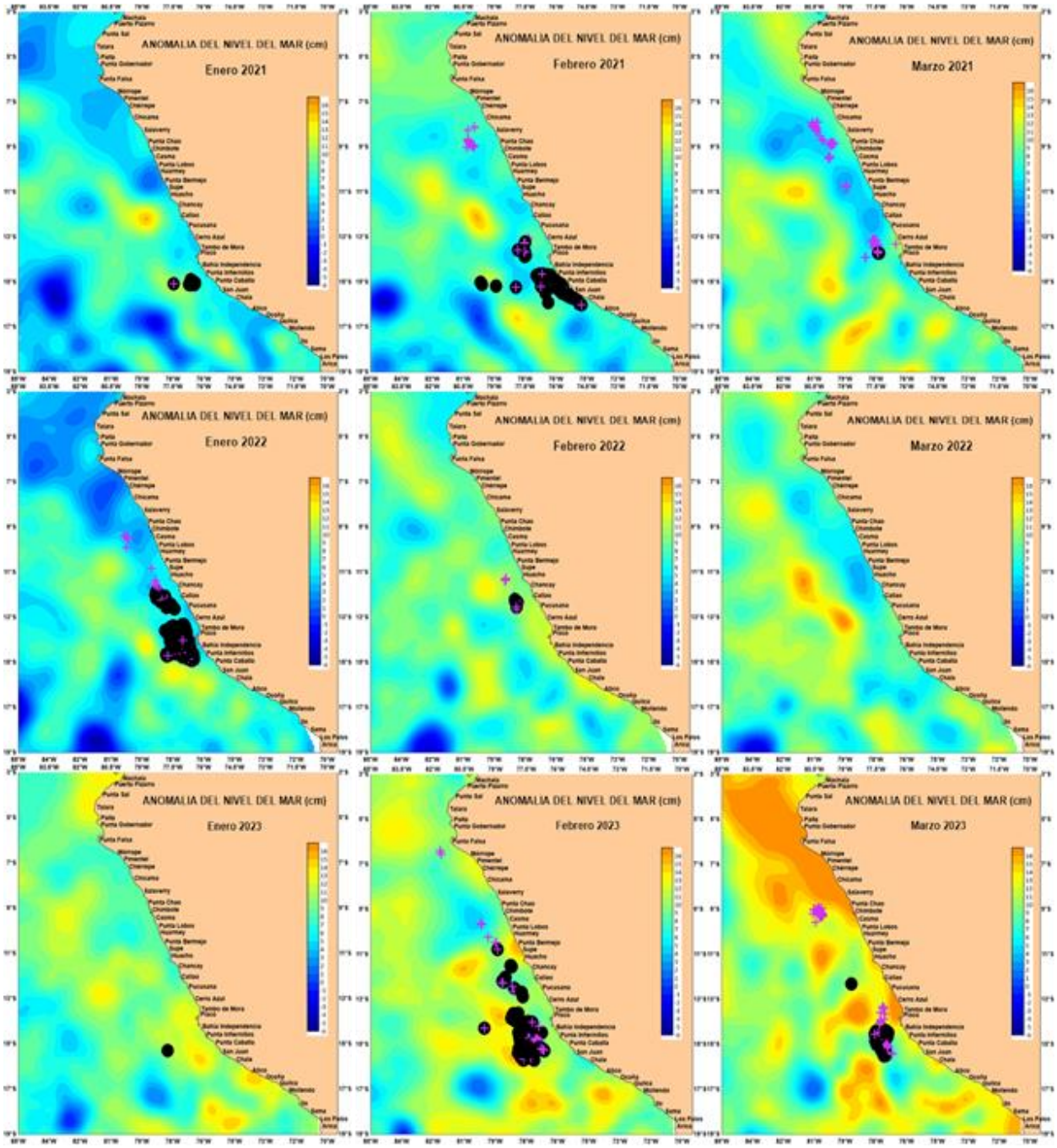

Figure 2.5.1. Sea level anomaly (SLA, cm) during the summer of years 2021, 2022 and 2023. Jack mackerel fishing sets are indicated by black circles, and chub mackerel ones are indicated by purple crosses. In March 2022, no catches are observed because the industrial fishing quota reached at the beginning of February.

3. Analysis of variability of parameters for jack mackerel and chub mackerel according to fishing sets carried out during the years 2019 to 2023 in relation to satellite oceanography variables.

Figures 3.1.1 and 3.2.1. shows the comparative results of the analysis of variability of parameters relevant to the distribution of jack mackerel and chub mackerels between 2019 and 2023. The analyzed parameters are: Sea Surface Temperature (SST, °C), Sea Surface Temperature Anomaly (ATSM, °C), Sea Surface Salinity (SALINITY, ups), Chlorophyll (ug/Lt), Sea Level Anomaly (SLA, cm), Sea Surface Altimetry (ALT, cm), latitude (LAT), distance to the coast (DC) and month of the year (MESES).

3.1. Variability in the case of jack mackerel

In the case of jack mackerel, Figure 3.1.1 shows notable differences between several parameters for the years 2019 to 2023. For the sea surface temperature (TSM), a wide range of thermal values can be seen (between 18 and 25°C), with a preference for relatively high temperatures during the years 2019, 2020 and 2023; in the years 2021 and 2022 the thermal values have been below average. As for the ATSM (in a range between -4 to +2°C), there has been a higher presence of jack mackerel in slightly positive values except for 2021 in which all catches were made in zones with negative values. On the other hand, salinity remained in a discrete range of values (35 to 35.4 ups) and low chlorophyll concentration values (< 4 ug / Lt) except for the year 2021 when the highest values were observed. As for SLA and ALT, the presence of jack mackerel is almost entirely limited to positive values, but not beyond values of 10 cm. Latitudinally the distribution of jack mackerel presented a range restricted to the center-south zone. As for its distribution according to its distance from the coast, jack mackerel was at relatively close distances, around 50 nm from the coast on average between 2019 and 2023, except for 2020 when it was located at more than 100 nm on average. Finally, the timing of the distribution of fishing sets made on jack mackerel is limited to the summer months, during which the issued fishing quota has been completed (Figure 3.1.1.).

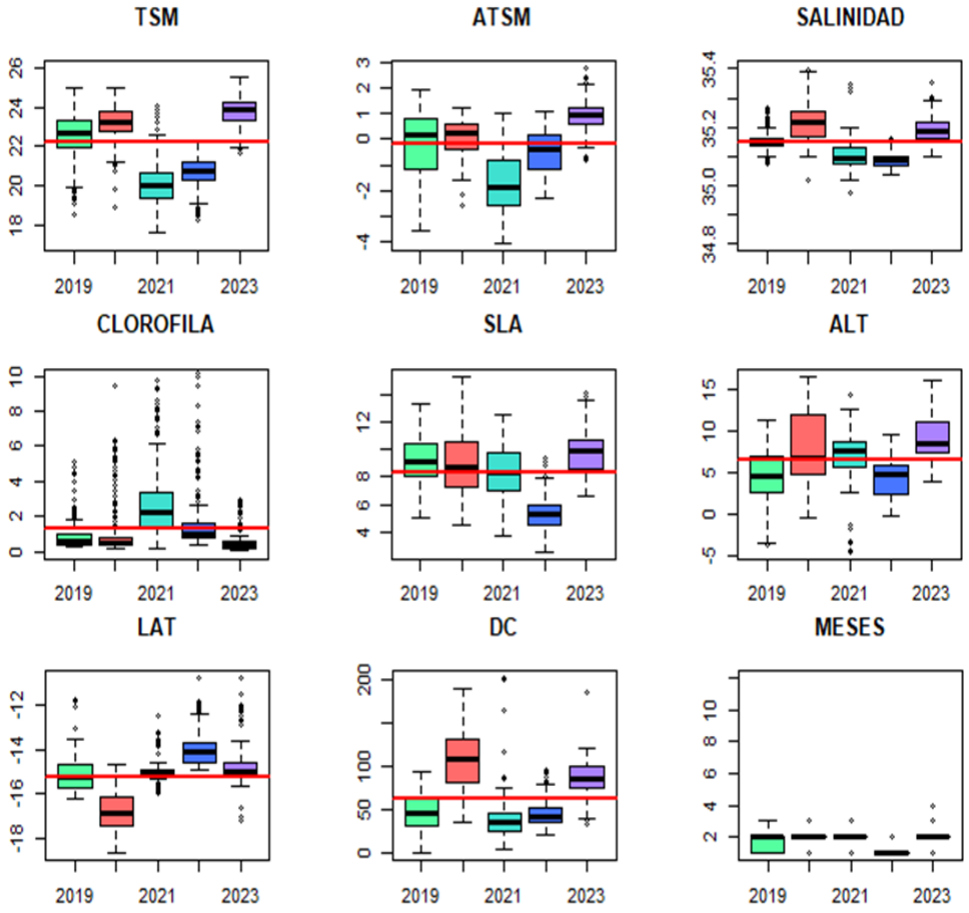

Figure 3. 1.1. Boxplots on the variability of parameters in the case of jack mackerel between years 2019 and 2023: Sea Surface Temperature in °C (TSM), Sea Surface Temperature Anomaly in °C (ATSM), Sea Surface Salinity in ups (SALINIDAD), Chlorophyll (Clorofila) in ug/lt, Sea Level Anomaly (SLA) in cm, Altimetry (ALT) in cm, latitude (LAT) in south degrees, distance to the coast (DC) in nautical miles, and months (MESES). The red line on each box indicates the average value of all measurements.

3.2. Variability in the case of chub mackerel

For the sea surface temperature (TSM), different ranges of thermal values can be seen (between 18 and 24 ° C), having been distributed in warmer conditions in years 2019, 2020 and 2023, and in colder conditions during 2021 and 2022. Likewise, the distribution of chub mackerel is related

to a rather wide range of ATSM (between -4 to +2 ° C), but discrete in the case of salinity (34.9 to 35.4 ups), and with low chlorophyll concentration values (< 4 ug / Lt) except for 2021 when the highest values are observed. As for SLA and ALT, the presence of chub mackerel is almost entirely limited to positive values, but not beyond values of 10 cm. Latitudinally, the distribution of chub mackerel was wide during 2019, trending south in 2020, and with a higher presence in the center during 2021, 2022 and 2023. As for its distribution according to its distance from the coast, chub mackerel was relatively close to the coast during 2019, 2021 and 2022, and further away in years 2020 and 2023. Finally, the timing of the distribution of chub mackerel is the same fleet targeting jack mackerel (Figure 3.1.2.).

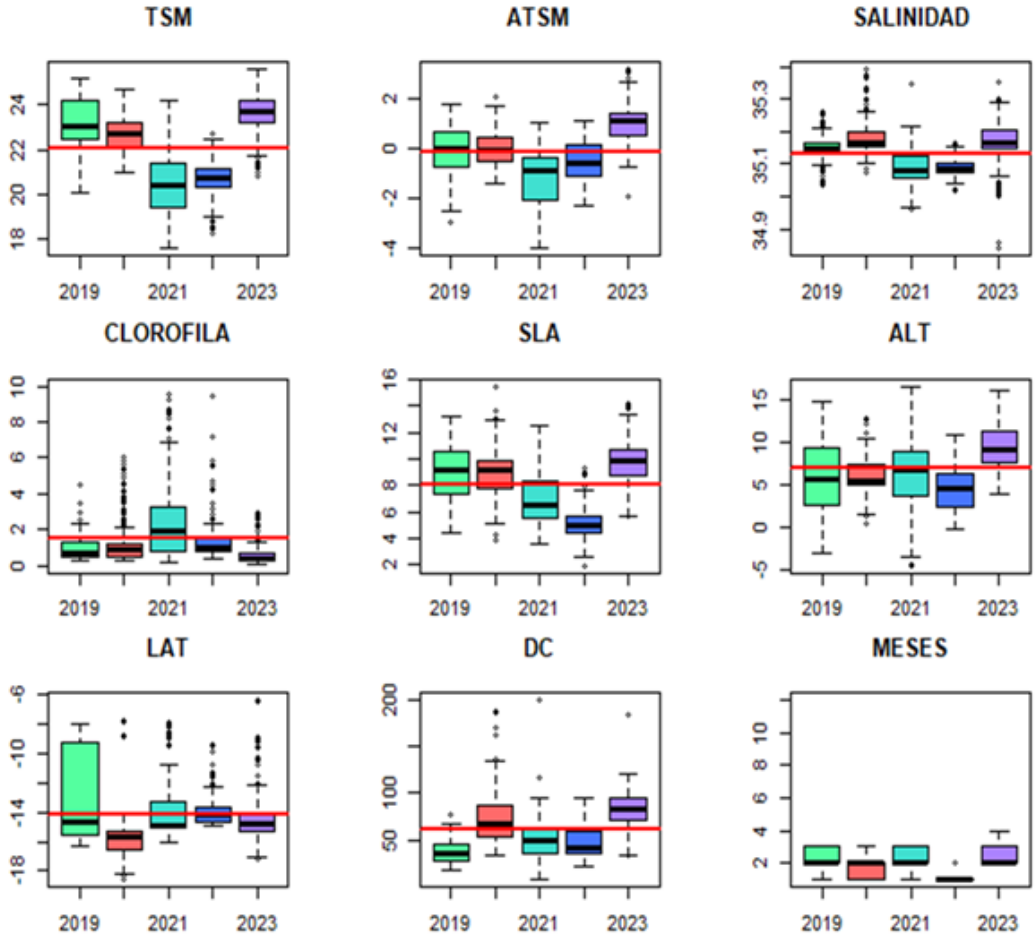

Figure 3. 1.2. Boxplots on variability of parameters (boxplot) related to the presence of chub mackerel between years 2019 to 2023. Sea Surface Temperature in °C (TSM), Sea Surface Temperature Anomaly in °C (ATSM), Sea Surface Salinity in ups (salinity), Chlorophyll (Clorofila) in ug/lt, Sea Surface Anomaly (SLA) in cm, Altimetry (ALT) in cm, latitude (LAT) in south degrees, distance to coast (DC) in nautical miles, and months (MESES). The red line on each box indicates the average value of all measurements.

4. Distribution of ichthyoplankton by Spring 2022

Ichthyoplankton data come from samples collected by the fishing fleet during the operations of the industrial fleet during September to October 2022. The sampling stations come from two zones, one in the north, between Talara and Salaverry, and the other in the south between Callao and Atico. The samples were collected using Baby Bongo nets with meshes of 300 and 500 microns, and implemented with a Hydrobios brand flowmeter, in order to know the amount of filtered water. The sampling was made through oblique pulls from 100 meters deep to the surface, while the vessel was moving at minimum speed; the average speed of descent and ascent was 1 m.sec-1. The samples were fixed and preserved in 2% formaldehyde. Figure 4.1.

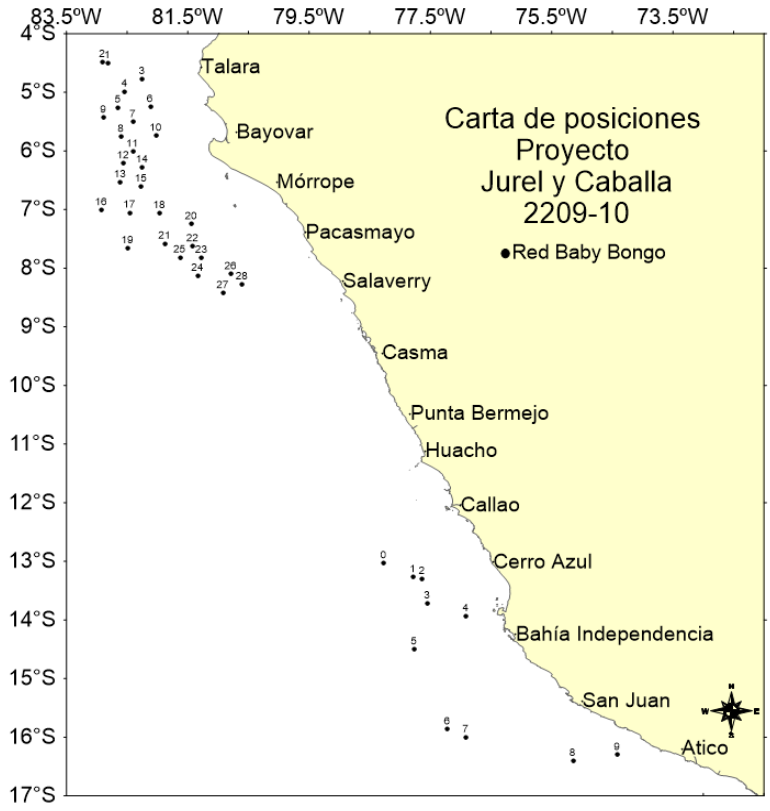

Figura 4.1. Sampling locations for ichtioplankton 2022.

Ichthyoplankton density was determined by at least 24 species/genus, of which the most abundant and frequent were the eggs and larvae of anchovy *Engraulis ringens, followed by eggs and larvae of* mesopelagic fish *Vinciguerria lucetia*, as well as myctophids and eggs and larvae of jack mackerel *Trachurus murphyi.* The presence of eggs and larvae of jack mackerel, was detected in the southern zone only, the eggs were observed between San Juan and Marcona in both coastal and oceanic stations, with levels of abundance between 8 and 41 eggs/100 m^3. The larvae occurred in the stations furthest from the coast between Cerro Azul and Atico, with abundance levels between 4 and 33 larvae/100 m^3 (Figure 4.2).

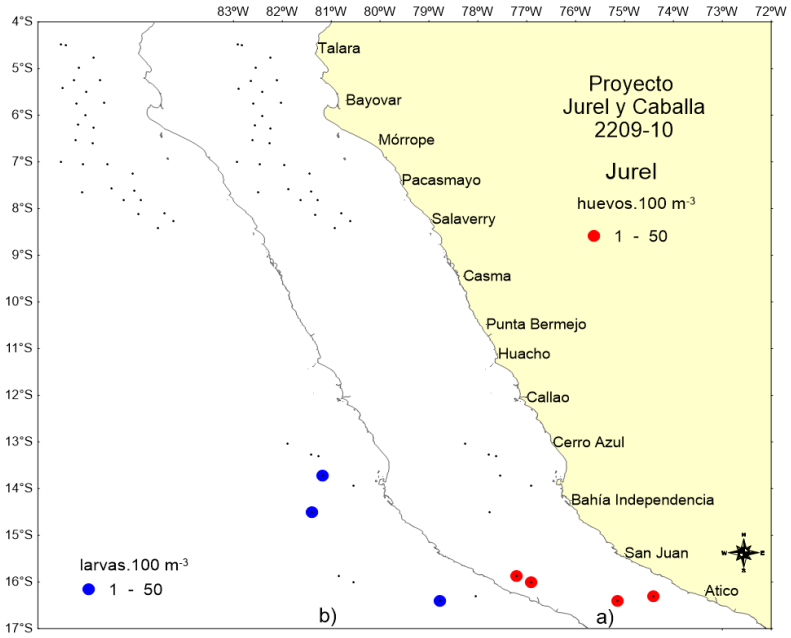

Figure 4.2. Distribution and abundance of eggs and larvae of jack mackerel (*Trachurus murphyi*) between September and October 2022.

5. Potential habitat model for jack mackerel (MHPJ)

Valdez *et al.* (2015) developed an empirical, deterministic and probabilistic 2D model (MHPJ) to describe the potential habitat of jack mackerel (*Trachurus murphyi)* using six variables on satellite oceanography information and positional variables. However, because of the high cloudiness in the coastal zone it was decided to exclude chlorophyll, which is affected by these conditions. Jack mackerel catches were better correlated with the model when it reached probabilities higher than 0.3 (in a range of 0 to 1). The used satellite oceanographic were downloaded from the HYCOM website (salinity and temperature), and the thermal anomalies were obtained from the annual pattern. The MHPJ was run weekly between the months of February to April 2023, which corresponds to the industrial fishing season for jack and chub mackerel.

The models' results are shown in Figure 5.1. Regarding the areas represented by the model, between weeks 1 and 3 (as of February 1, 2023) a great amplitude and high density (> 0.75) is observed between degrees 6 and 16 of south latitude; in those weeks the habitat conditions for jack mackerel have been optimal along the entire coast. By weeks 4 and 5 the area reaches the southern coast. Between weeks 6 and 7 the habitat spanned from degree 12 to the south, out until 100 n.mi. from San Juan de Marcona. Between weeks 8 and 10 the habitat was observed from Pisco to the border with Chile. In addition, it was observed that the highest probabilities (~0.75) were found in front of San Juan de Marcona. The rather sudden variation in the jack mackerel habitat during the fifth week is due to the increase in temperature in northern Peru after the beginning of the coastal El Niño. To visualize the assertiveness of the model, the fishing sets were plotted on the results of the MHPJ model. It is observed that the location of the fishing sets matched the areas of intermediate probability values. In addition, it was calculated the average probability of the model, being it 0.55.

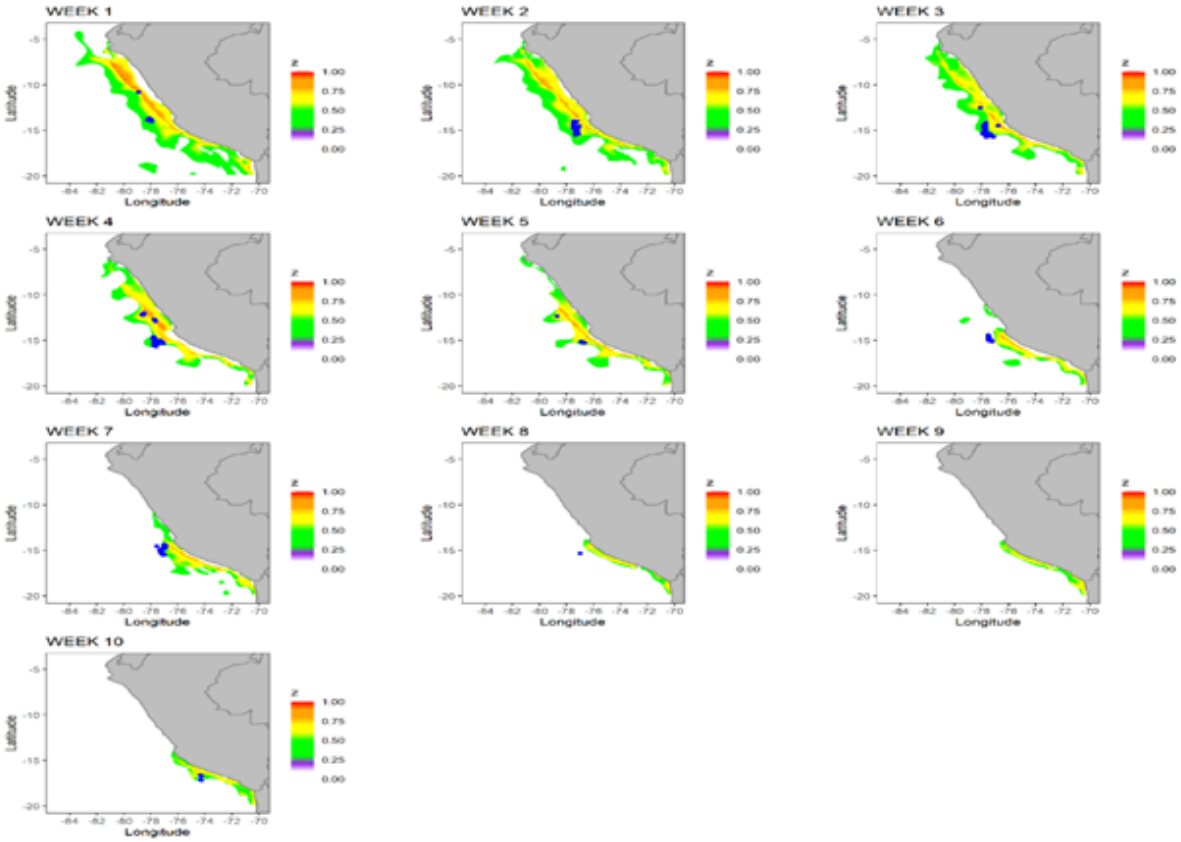

Figura 5.1. Resultados de diez semanas del MHPJ entre febrero y abril del 2023. Los puntos azules marcados en los mapas indican las capturas efectuadas por los barcos industriales. La escala de color indica probabilidad de encontrar jurel (valores de 0 a 1).

5.1. **Modelling the distribution of jack mackerel**

The modeling of the jack mackerel habitat during 2020 and 2023 has been carried out using data on the environmental conditions (habitat) for the adult segment of the population. It must be noticed that the commercial fishery is aimed at adult individuals of jack mackerel only. It is a pending task to model the habitat for individuals in the juvenile or larval stage. In both cases, it is a challenge to identify and model the factors that potentially influence the habitat. In the present case, the used data included the years 2020 to 2023.

The proposed Response Variable was the catch. The candidate covariates were: chlorophyll concentration (as an indicator of the presence of macrozooplankton, CHL), latitude, longitude, time of day, month, sea surface temperature (SST), sea surface salinity (SSS), thermal anomaly (ATSM), altimetry (ALT), sea surface anomaly (SLA), and year.

Before the modeling exercise, exploratory data analysis was carried out to reveal possible aggregations or relationships between environmental variables. To this end, a Principal Component Analysis (PCA) was performed to explore the relationship between environmental variables during summers (Figure 5.1.1.). The first three components were selected, which explains 85.99% of the variability between the parameters (Figure 5.1.1a). Based on what was observed in the PCA analysis, a clustering analysis was carried out in order to describe the observed environmental characteristics. Thus, 3 clusters were identified (Figure 5.1.1b). It can be observed that cluster 1 was associated with higher values of temperature, salinity, and thermal anomalies farther from the coast, and with lower values in chlorophyll and sea level anomalies. Cluster 2 has inverse characteristics to Cluster 1. Finally, cluster 3 is associated with chlorophyll.

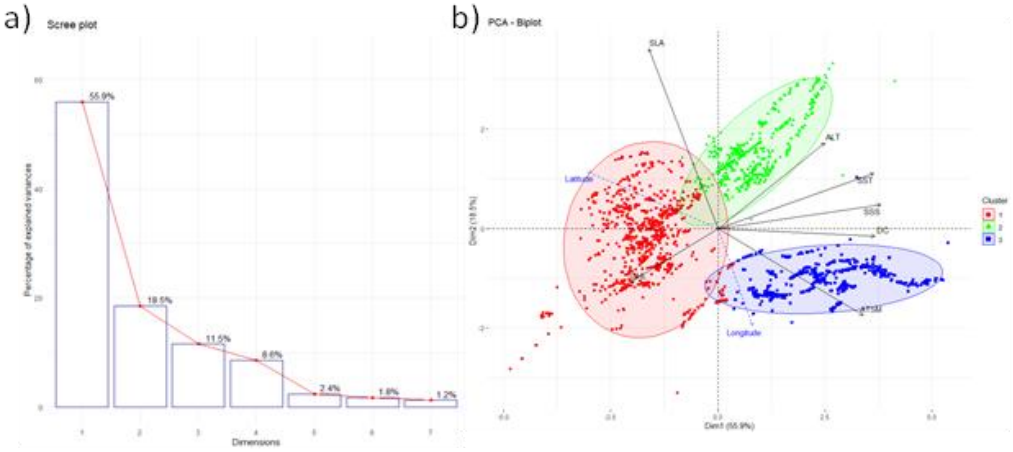

Figure 5.1.1. Principal Components Analysis (PCA) of the environmental conditions associated to jack mackerel during fishing set made between 2020 and 2023. a) Bar graph of the percentage of the explained variance by dimension; (b) PCA biplot. TSM: sea surface temperature (°C); ALT: altimetry (cm); SLA, sea surface anomaly (cm); DC: distance to the coast (n.mi.); CHL, chlorophyll (ug/L); ATSM, sea surface thermal anomaly (°C); SSS: salinity at the sea surface.

Regarding the spatial distribution of jack mackerel, It can be seen that during 2020 clusters 1 and 3 were found with a larger predominance of cluster 3. Furthermore, the distribution of cluster 3 was observed between latitudes 15 and 19°S and far from the coast, while cluster 1 this year was closer to the coast and near San Juan de Marcona. In 2021 there was a larger predominance of cluster 1 between Pucusana and San Juan de Marcona, with few cluster 2 values. during 2022, only cluster 1 between Callao and Bahía Independencia was observed. Finally, in 2023 there was a predominance of cluster 2 with little presence of cluster 1 between Callao and Atico was observed (Figure 5.1.2.).

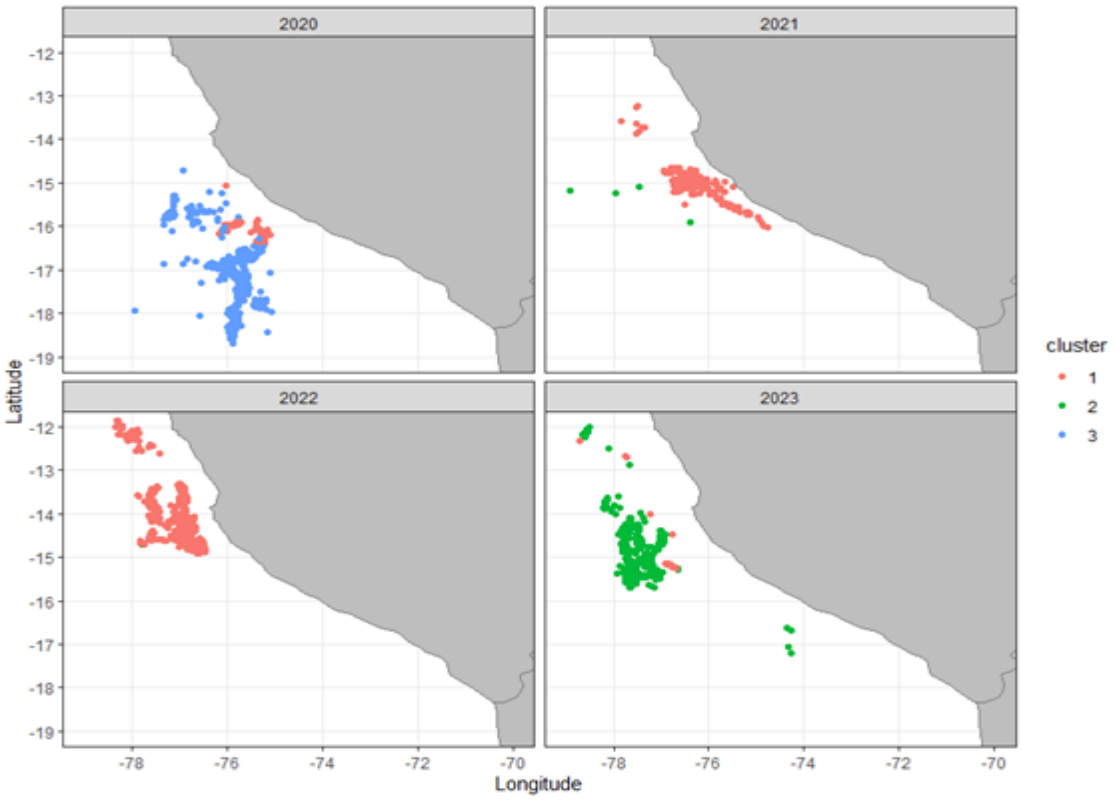

Figure 5.1.2. Distribution of clusters according to oceanographic variables. 3 clusters were observed, which were also identified according to environmental characteristics and distance to the coast.

6. Conclusions

- Thermal conditions of the last four years have led to a larger availability of jack mackerel, especially in the Peruvian south, while chub mackerel has tended to be distributed northwards, sharing some distribution areas with jack mackerel.

- During summer 2023, jack mackerel fishing sets were made farther from the coast than in 2022; however, south degrees 13 and 14 are the ones that concentrated the largest catches in the last two years along the front between cold coastal and subtropical water masses.

- Summers 2019 to 2023 -except January 2021- presented higher oceanic dynamics than in previous years, which is associated with a denser availability of jack mackerel and chub mackerel, mainly south of Callao. The availability of jack mackerel and chub mackerel has been related to intermediate SLA values.

- Jack mackerel eggs and larvae were observed in the southern zone between San Juan de Marcona in both coastal and oceanic stations, with abundance levels varying between 8 and 41 eggs/100 m^3. The larvae were presented in the stations furthest from the coast between Cerro Azul and Atico, with densities between 4 and 33 larvae / 100 m^3.

- At the time of the workshop, no major indications of coastal El Niño impacts had been detected on the usual distribution of jack mackerel and chub mackerel.

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