SPRFMO
South Pacific Regional Fisheries Management Organisation

11th MEETING OF THE SCIENTIFIC COMMITTEE

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Republic of Peru

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Peru National Report No. 2

NATIONAL REPORT ON THE SITUATION OF THE PERUVIAN STOCK OF JACK MACKEREL (FAR-NORTH STOCK) AND THE PERUVIAN FISHERY IN NATIONAL JURISDICTIONAL WATERS, PERIOD JANUARY 2022 – JUNE 2023

by

IMARPE - PRODUCE

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

The Peruvian marine environment is characterized by its high productivity and high variability and is particularly exposed to the effects of the opposed significantly warm (El Niño) and cold (La Niña) climatic patterns in the Pacific Ocean that alternate with relatively short periods of close to neutral conditions. Between 2013 and the first part of 2018, these changing environmental conditions caused a more dispersed distribution, reduced availability, lower abundance indexes and consequently lower catches of Jack mackerel. This has been followed by an expanded distribution in denser concentrations farther offshore, much higher abundance indexes, increased availability to the industrial and artisanal purse seine fleet and higher catches of Jack mackerel during the second half 2018 and throughout 2019, 2020, 2021 and the first half of 2022. From summer 2023 until June 2023, a Coastal Niño event was registered along the Peruvian coast, as a consequence, during this period, a displacement of Jack mackerel fishing areas to the south of Peruvian coast was observed, as well as a dispersion of its schools. The poor 2018-2019 reproductive cycle has been followed by almost normal 2019-2020, and well above normal 2020-2021, 2021-2022, and 2022-2023 reproductive cycles. The fishery, between January 2022 - June 2023, targeted a wide range of jack mackerel sizes (22 cm to 65 cm total length), but there was a low presence of juveniles (fish smaller than 31 cm of total length), where the highest proportions of juveniles in numbers were observed in November 2022 (8%) and April 2023 (8%). Research surveys in 2022 and 2023 also found the adult modal groups that were caught by commercial fleets during these years and, they also found much younger and smaller juveniles with total lengths as small as 3 cm total length. In late December 2022 IMARPE (Instituto del Mar del Perú) updated the available 2022 Jack mackerel assessment made for the Peruvian (far-north) stock with the JJM model using the configuration agreed during the 10th meeting of the Scientific Committee (SC10). This resulted in a range of options for setting the 2023 TAC that were included in its advice to the Government, initially recommending a TAC for 2023 based on the F_{2022} multiplier of no more than 1.5, which corresponded to a maximum estimated F = 0.137 and a maximum projected TAC = 144 000 t, accepting a risk of 0% risk that the current biomass will be lower than its reference level. Based on this advice, in February 2023, PRODUCE established a catch limit of 65 000 tons for the Jack mackerel (*Trachurus murphyi*) to be caught in Peruvian jurisdictional waters by the large-scale or industrial fleet during 2023 and a catch limit of 72 500 tons to be caught by the artisanal fishing vessels with purse seines and hold capacity equal or greater than 20 m^3 up to 32.6 m^3. Also, based on their regular low catches throughout the year and other socio-economic considerations, no catch limit has been established for the Jack mackerel fishery by artisanal fishing vessels that use passive fishing gear (curtain, hooks, among others), and purse seine vessels with a hold capacity of less than 20 m^3. Then on 10 March 10 2023, PRODUCE decided to extend only the Jack mackerel catch limit to be caught by the industrial fleet, from the first 65 000 tons up to 83 958 tons for the current year. An updated assessment with the same JJM model has been made by IMARPE on the basis of the most recent information and data available up to June 2023. The recent observations and assessments confirm the increasing trend in the biomass estimates observed from 2016 until last year. The model projection for this 2023 shows a slight decrease in its trend. Despite this, the Peruvian Jack mackerel stock is in an overall healthy situation considering the natural low abundance regime through which the stocks appears to have been going through during the last two decades.

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1. INTRODUCTION

This report updates information provided by the Peruvian delegation during earlier meetings of the SPRFMO Science Working Group and the SPRFMO Scientific Committee (IMARPE-PRODUCE 2012, 2012a, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021 and 2022).

2. THE MARINE ENVIRONMENT

Between November 2021 and May 2022, the environmental condition transitioned from neutral conditions to a predominance of cold conditions. After June 2022, the monthly mean temperature (SST) anomalies in the Niño 1+2 region showed an increase in their negative values from -1.16°C in July to -1.86°C in October, and then decreased to -0.24°C in January 2023. In February 2023, these values were within the neutral to warm ranges (+0.71°C) and reached a temperature anomaly of +2.63°C in June 2023. On the other hand, the LABCOS Index (Quispe and Vásquez, 2015), showed a decrease in negative anomalies reaching -0.13°C in December 2022. From January to June 2023 they gradually increased, registering positive anomalies of +0.12°C (January), +3.34°C (May), and +3.22°C (temporary) in June 2023 associated with the development of the Coastal El 2023 Niño event.

The most relevant feature between June 2022 and June 2023 was the high variability of the thermal conditions of the Peruvian marine environment, changing quickly from warm to cold conditions and viceversa, of varying extent and intensity. In February 2023, a rapid warming was recorded, giving way to a Coastal El Niño 2023 event, which continues to develop off the Peruvian coast. These changing environmental conditions are described by several indices based on observations of sea surface temperature anomalies in oceanic and coastal areas off Peru, such as (i) the Coastal El Niño Index (ICEN, **Figure 1**) in the Niño 1+2 region (area between 0-10°S and 80-90°W); (ii) the latitudinal distribution of local sea surface temperature anomalies (SSTA) along the entire Peruvian coastline based on IMARPE (Instituto del Mar del Perú) observations from its own network of coastal and marine laboratory stations (**Figure 2**); and the monthly mean sea surface temperature anomalies (SSTA) observed between January 2015 and June 2023 (**Figure 3**), for the El Niño 1+2 region (upper panel) and for the most coastal areas along the Peruvian coast (lower panel).

From July to December 2022, the SSTA from the IMARPE coastal laboratory network (**Figure 2**), indicated that oceanographic conditions were cold from Tumbes to Huacho and slightly cold from Callao to Ilo. However, from January to June 2023, the thermal anomalies (yellow color) showed an increase along the entire coastal strip indicating conditions characteristic of a coastal El Niño event.

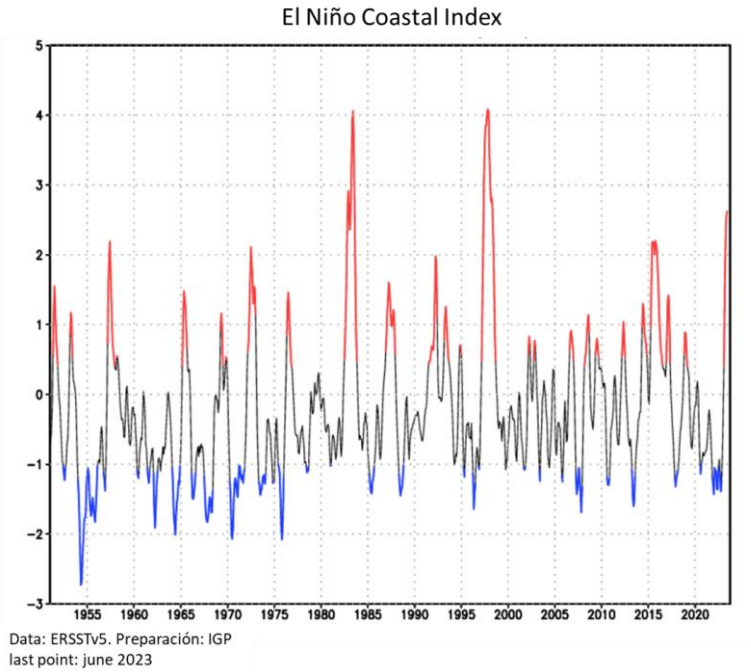

Figure 1. Coastal Index of El Niño (ICEN) in the El Niño 1+2 region, by month, from January 1950 to June 2023 Calculated as the 3-month moving average of the anomalies of the sea surface temperature in the Niño 1+2 region, referred to a 30-year (1981-2010) monthly mean pattern. Warm El Niño conditions are highlighted in red and cold La Niña conditions are highlighted in blue (data source: NOAA ERSST v5 – ICEN)

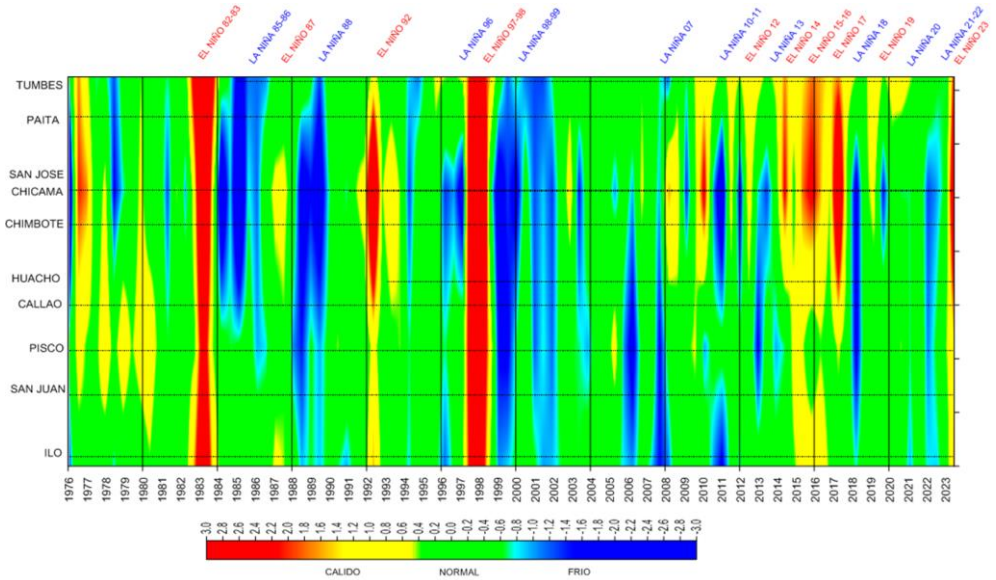

Figure 2. Sea Surface Temperature Anomalies (SSTA, in °C) from IMARPE's coastal laboratories and stations by latitude along the entire Peruvian coast, years 1976–2023 (until June 2022) (data source: IMARPE)

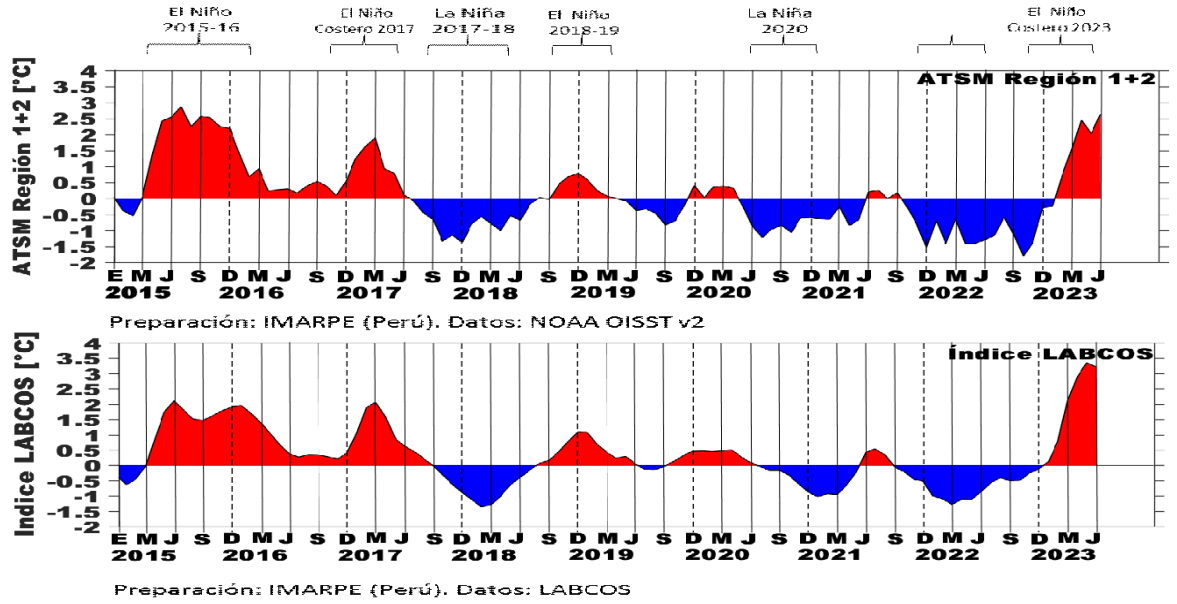

Figure 3. Mean monthly sea surface temperature anomalies (SSTAs, in °C) in the coastal El Niño 1+2 region (top panel) and along the Peruvian coastline as reflected by IMARPE's LABCOS index (bottom panel), from January 2015 to June 2023

Spatial changes in environmental conditions along the Peruvian coast in the summer of 2022 and between September and November 2022, showed a predominance of cold to neutral conditions, with the presence of negative anomalies (**Figure 4** and **5**). Then, between February and March 2023, there were warm conditions (**Figure 6**). Regarding the sea surface salinity (SSS) and its anomaly (SSSA), a decrease trend was also observed in summer 2023 (**Figures 7**, **8** and **9**). For details, a more extended description of environmental conditions during 2022 and 2023 are described below.

In summer of 2022, the SST varied between 13.9 and 27.9 °C. The highest temperatures (> 23 °C) were in the coastal zone north of Punta Sal, associated with positive anomalies of +2.5, while the lowest temperatures (< 16 °C) were recorded south of Pisco, associated with anomalies of up to -4 °C. In general, cold conditions prevailed, highlighting large areas, to the north of Talara, between Morrope and Salaverry, Huarmey and Huacho, Cerro Azul and Bahía Independencia, Punta Caballas and Atico, with anomalies greater than -3°C. Likewise, warm areas were found to the north of Punta Sal and south of Ocoña (17°S) with anomalies greater than +2°C and outside 60 nm between Supe and San Juan with anomalies of +1°C (**Figure 4**). These atypical conditions were due to during January 2022 a cold Kelvin wave have been propagated and pulses of strong winds were recorded, promoting a decrease in thermal anomalies and upwelling along the entire Peruvian coast. However, in February 2022, in the northern Peruvian coast, a change in atmospheric circulation was evidenced, such as episodes of wind weakening, which favored the

intrusion of warm waters from the north and anomalous warming to the north of Talara. In March 2022, the arrival of a warm Kelvin wave was recorded, generating an attenuation of the cold condition mainly in the northern zone.

During the spring of 2022, SST ranged from 12.6 to 19.1 °C and thermal anomalies ranged from -3.6 to +1.1 °C, indicating a predominance of cold conditions. However, within 10 nm off Punta Sal, a temperature of 21.5 °C with an anomaly of +2.3 °C was exceptionally recorded, related to local variability influenced by equatorial source waters. In general, the highest temperatures (> 17 °C) were recorded from Huacho to the north outside 50 nm, and from San Juan to the south outside 50 nm, approaching the coast up to 20 nm from Ocoña to the south. While the lowest temperatures (< 15 °C) were present near the coast from Pimentel to Atico, expanding up to 30 nm offshore, from Chimbote to Pisco. As for thermal anomalies, lower values (<-2 °C) were shown in the oceanic zone off Talara, extending to the north of Sechura Bay, as well as within 60 mn off the areas between Chimbote-Huacho and Pucusana-Cerro Azul. South of Cerro Azul, the negative anomalies were weakened, with cores with -1 °C anomalies and slight positive anomalies near Ocoña (**Figure 5**).

For the summer of 2023, SST varied between 17.3 and 28.6 °C, with the highest records (> 27°C) located in oceanic zones off Zorritos-Talara, while the lowest values (> 20°C) were in a coastal strip within 10 nm south of Pisco. In general, the thermal condition was warm, showing predominantly positive anomalies with some neutral and cold cores; with an average throughout the evaluated area of +2°C, highlighting cores of more than +4°C in front of Talara-Paita, Supe, Cerro Azul and Pisco. As well as large areas with anomalies greater than +3°C north of Paita, between Huarmey and Huacho and between Cerro Azul and Pisco (**Figure 6**).

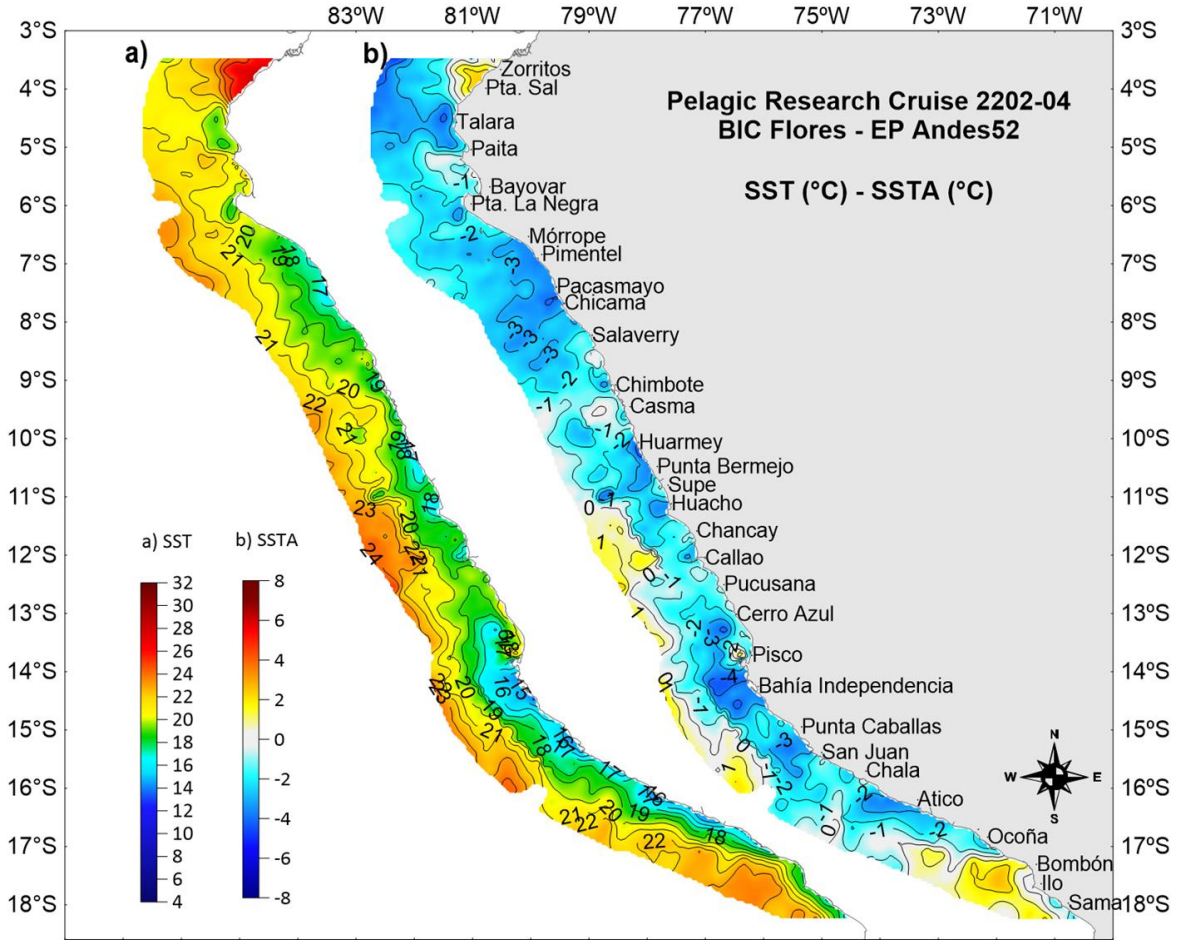

Figure 4. Distribution of the a) sea surface temperature (SST, in °C, left panel) and b) sea surface temperature anomalies (SSTA, in °C, right panel) during summer (February-March) 2022, as observed during IMARPE's Hydroacoustic Survey for the Assessment of Pelagic Resources, Cr. 2202-04, 17 February - 05 April 2022

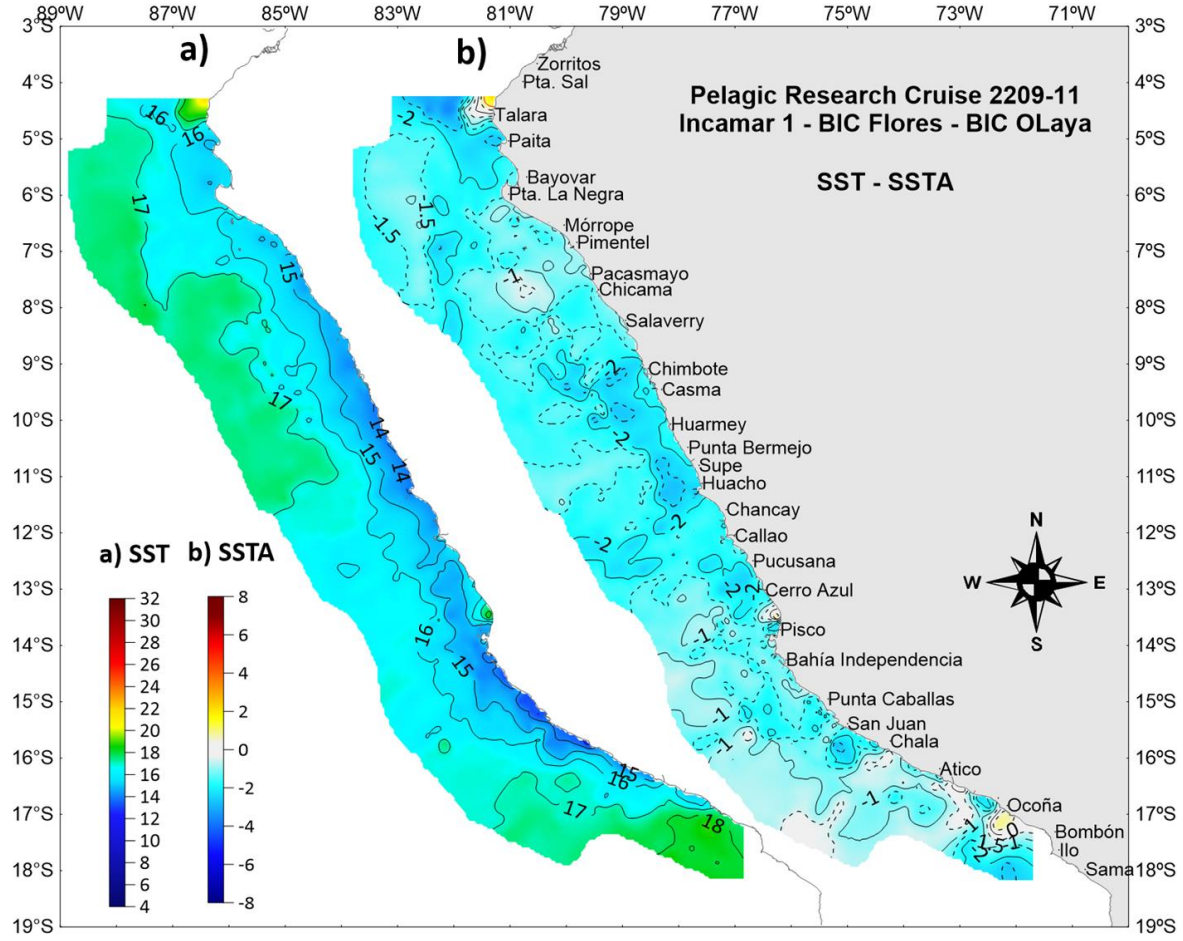

Figure 5. Distribution of the a) sea surface temperature (SST, in °C, left panel) and b) sea surface temperature anomalies (SSTA, in °C, right panel) during spring (September-November) 2022, as observed during IMARPE's Hydroacoustic Survey for the Assessment of Pelagic Resources, Cr. 2209-11, 12 September – 01 November 2022

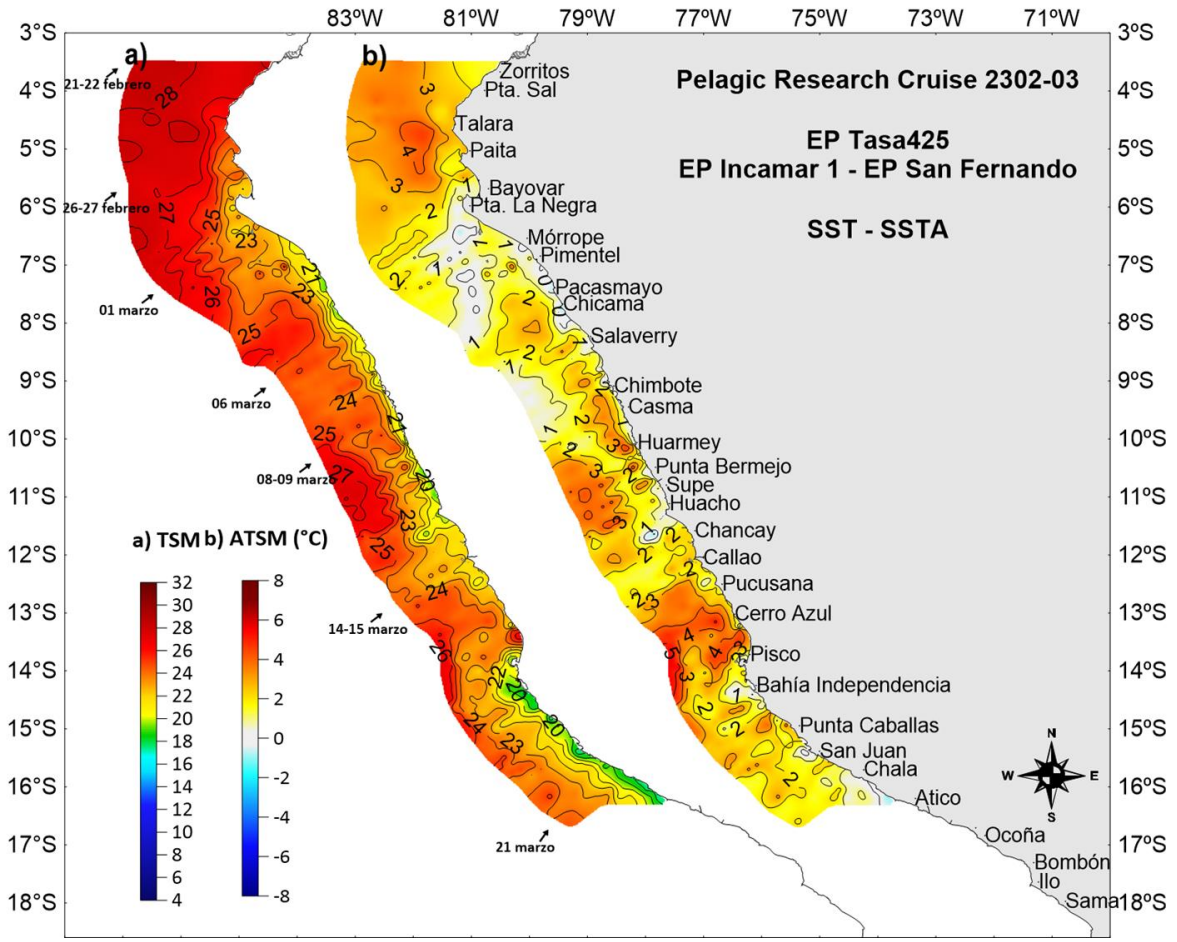

Figure 6. Distribution of the a) sea surface temperature (SST, in °C, left panel) and b) sea surface temperature anomalies (SSTA, in °C, right panel) during summer (February-March) 2023, as observed during IMARPE's Hydroacoustic Survey for the Assessment of Pelagic Resources, Cr. 2302-03, 21 February – 22 March 2023

The spatial distribution of sea surface salinity (SSS) during February-March 2022 had a normal trend (**Figure 7**), with the presence of Tropical Surface Waters (TSW) north of Talara, Equatorial Surface Waters (ESW) north of 6 °S (Punta La Negra), Subtropical Surface Waters (STSW) outside the 50-60 nautical miles between Punta La Negra and Pisco and outside the 15 miles south of Ocoña (17 °S), cold coastal waters, typical of upwelling were widely distributed within 60 nm south of Pimentel (7 °S). Also, the presence of freshwater from continental discharge and mixing waters were observed due to the interaction of ESW, STSW and Cold Coastal Waters (CCW) north of Pimentel and STSW and CCW south of this locality. On average the haline condition was neutral, with negative cores in the northern area due to the low salinity of the TSW and ESW and influenced by the Pacific slope river mouths and positive anomaly cores in areas of influence of the STSW.

During the spring of 2022, the SSS fluctuated between 34.8 and 35.2, with TSW off Mancora and ESW north of Talara that generated negative haline anomalies of up to -0.8 UPS. The highest salinities (> 35.1) associated with STSW were found in oceanic zones from Chicama to Pisco, approaching up to 70 and 50 nm from the coast, between Chimbote and Supe and up to 80 nm off Pisco. On the other hand, the CCW were found in the strip within 50 nm from Punta Falsa to Chala. There were also large areas with mixed waters, north of Paita due to the interaction of ESW, STSW and CCW, while south of Paita, the mixed waters were dominated mainly by the interaction of CCW and STSW. On average, the haline condition was neutral, negative anomalies south of Chimbote suggested that upwelling processes were active in this period (**Figure 8**).

For the summer 2023, the SSS ranged from 32.76 to 35.36, with anomalies from -1.43 to +0.28. The water masses associated with the TSW were located north of Talara. In contrast, the ESW moved unusually as far as Chicama (8°S) due to weakening winds, generating negative anomalies less than -0.2 and salinities greater than 35.1; the SSAs occurred off the central coast approaching up to 50 nm off Huarmey-Huacho and off Pisco, associated with positive anomalies of +0.1. The CCW were located within 50 nm south of Chicama; also, there were large low salinity cells in areas adjacent to river mouths, due to increased precipitation associated with the 2023 Coastal El Niño event, which generated a significant increase in inland water discharge volumes to the sea (**Figure 9**).

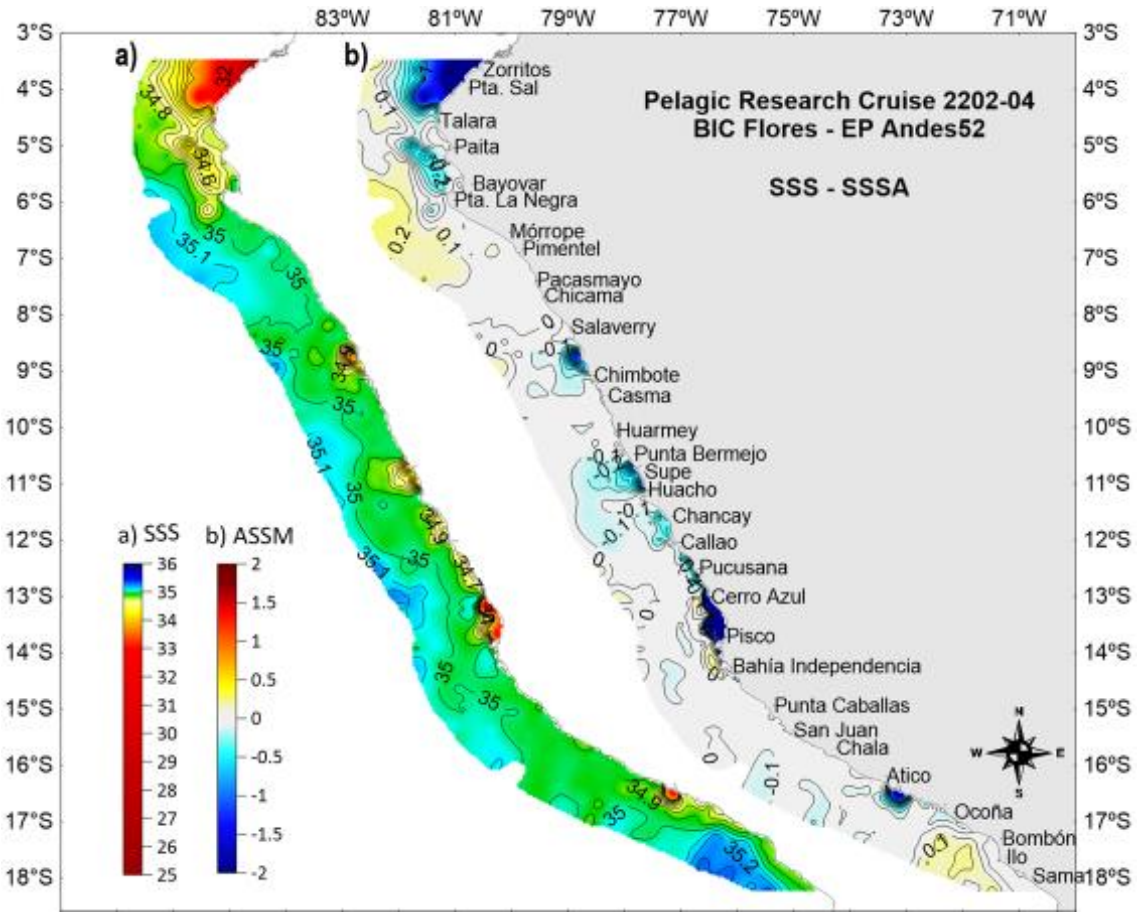

Figure 7. Distribution of the a) sea surface salinity (SSS, in psu, left panel) and the b) anomaly of the sea surface salinity (SSSA, in psu, right panel) during February-March 2022, as observed during IMARPE's Hydroacoustic Survey for the Assessment of Pelagic Resources, Cr. 2202-04, 17 February - 05 April 2022

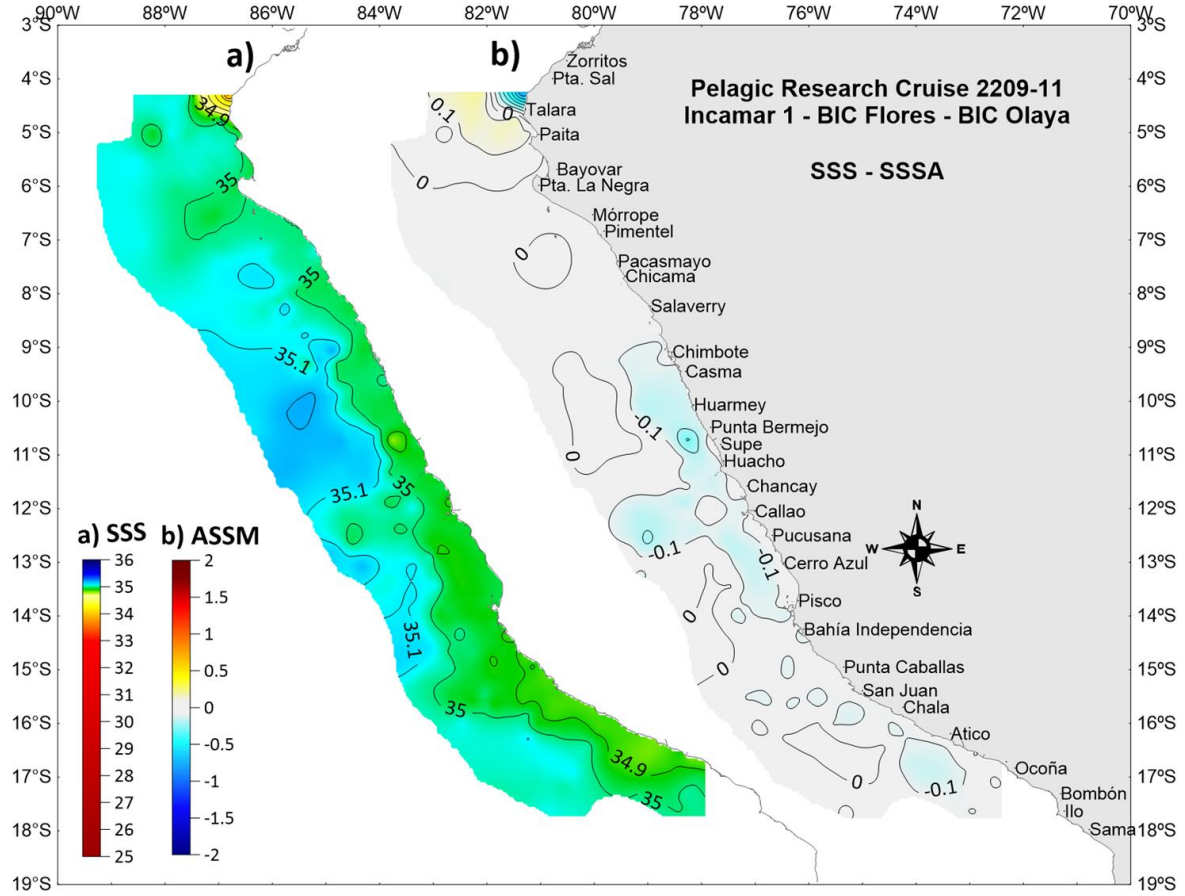

Figure 8. Distribution of the a) sea surface salinity (SSS, in psu, left panel) and the b) anomaly of the sea surface salinity (SSSA, in psu, right panel) during September-November 2022, as observed during IMARPE's Hydroacoustic Survey for the Assessment of Pelagic Resources, Cr. 2209-11, 12 September – 01 November 2022

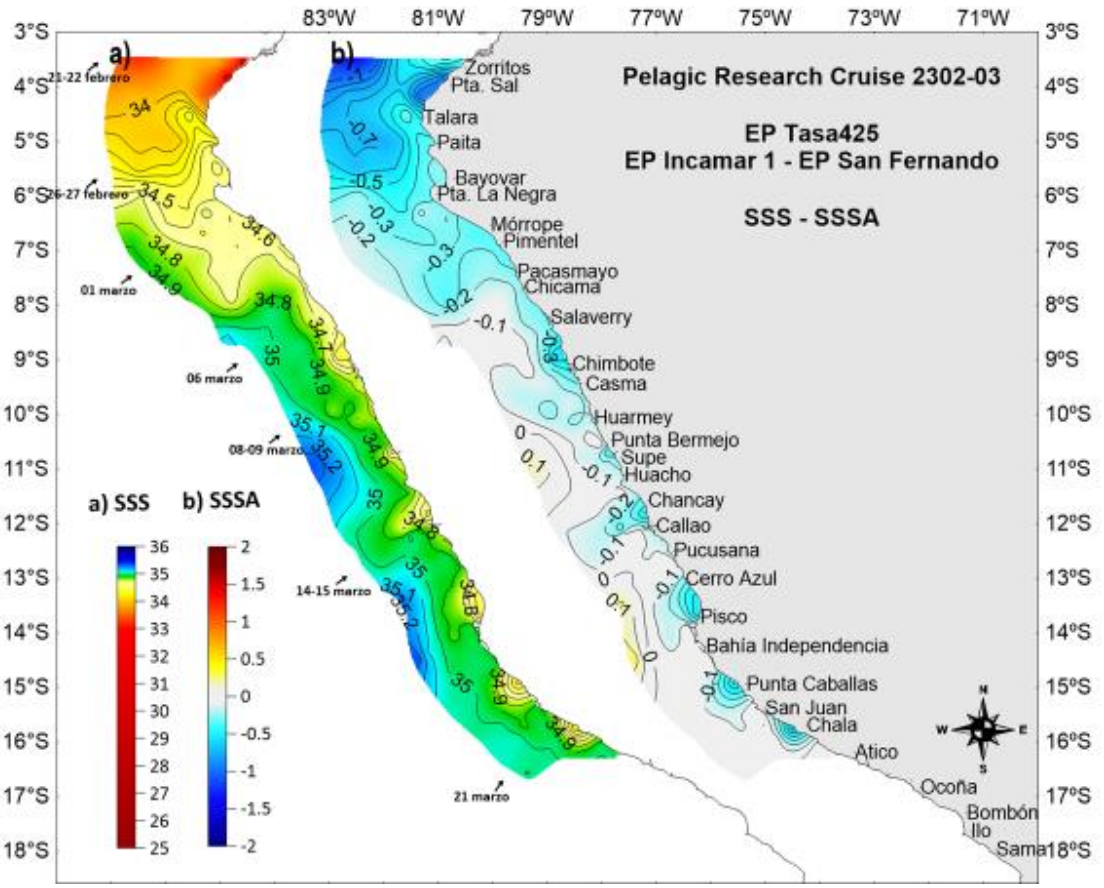

Figure 9. Distribution of the a) sea surface salinity (SSS, in psu, left panel) and the b) anomaly of the sea surface salinity (SSSA, in psu, right panel) during February-March 2023, as observed during IMARPE's Hydroacoustic Survey for the Assessment of Pelagic Resources, Cr. 2302-03, 21 February – 22 March 2023

3. CHARACTERIZATION OF THE STOCK

3.1 Spatial distribution

During 2019 it has been observed denser Jack mackerel concentrations within the reach of the industrial purse seine fleet at 20 to 80 nm from the coast, particularly between Chimbote (9°04'S) and Pisco (13°43'S). This was also repeated between Pisco and Morro Sama (18°00'S) during the first half of 2020, with an expansion as far north as Paita (5°00'S) closer to the coast during most of the second half of 2020. During late 2020 until May 2022 it has been observed the presence of denser Jack mackerel concentrations within 100 nm from the coast, particularly between Supe (10°47'S) and Bahia Independencia (14°14'S). Based on research survey information, during the summer 2023, low Jack mackerel concentrations were observed between Pacasmayo (7°24'S) and Chicama (7°50'S), at 27 mn off Callao

(12°03'S), and between Pisco (13°42'S) and Punta San Juan (15°22'S). However, based on the monitoring of its fishery and for this period (summer 2023), the highest concentration had been registered in the southern part of the Peruvian coast (further description in section 4.2).

3.2 Age and growth

The growth parameters used for Jack mackerel are those originally estimated by Dioses (1995) and confirmed by observations and growth estimates by Dioses (2013), Goicochea *et al*. (2013) and Diaz (2013): L_∞= 80.77 cm total length (TL), k = 0.1553 y^{-1} and t_0 = -0.3562.

3.3 Reproductive aspects

The monthly variability of the gonadosomatic index (GSI) of Jack mackerel in the Peruvian waters (**Figure 10**), showed higher values during 2012, indicating a favorable reproductive condition for the resource. After that, until 2019, the intensity in the reproductive process has been lower and/or out of phase. From 2020 to 2022, it was observed that the behavior of GSI values increased, even above the historical pattern and maintaining the trend. This is due to favorable conditions and food availability. But also, the Jack mackerel sizes used for the GSI estimations during 2023 were larger than in past years, this could also explain these results. During the first part of 2023, the resource has presented a reproductive behavior in accordance with its historical pattern, continuing in its period of reproductive inactivity for the month of June 2023.

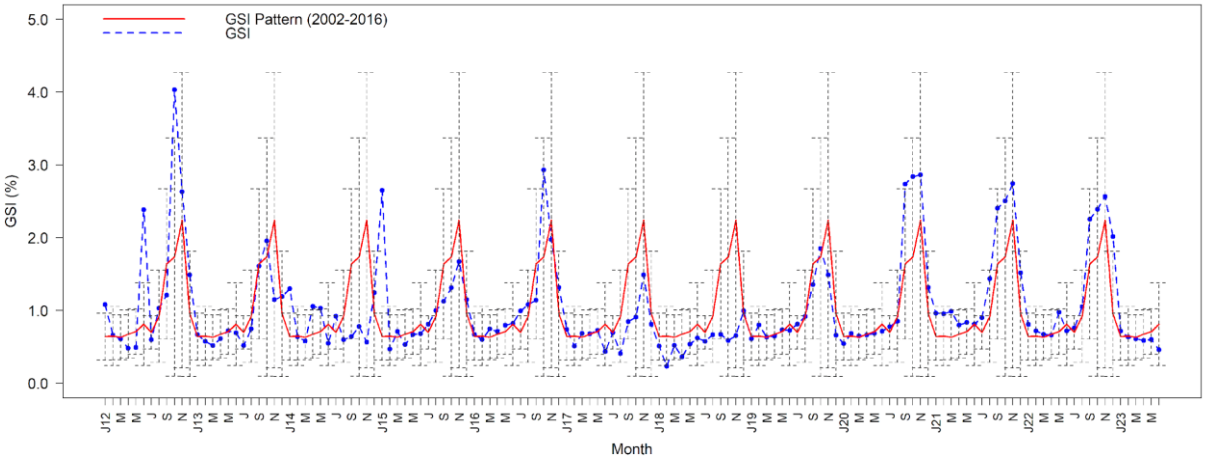

Figure 10. Monthly variability of Gonadosomatic Index (GSI) of Jack mackerel above 26 cm TL caught in Peruvian jurisdictional waters. The red line represents the monthly mean for the period 2002 – 2016, the vertical gray lines represent their standard deviation. The blue dots and dashed lines are the current monthly values observed from January 2012 to June 2023

3.4 Trophic relationships

The updated information on preys in its food content (**Figure 11**) still confirms that Jack mackerel is an opportunistic forager, with changes in their diet most likely indicating changes in their ecosystem (Konchina 1981; Muck and Sanchez 1987; Alegre *et al*. 2015). It is also confirmed that there is a great diversity of preys in the diet of Jack mackerel off Peru as it forages on a large variety of species (95 preys in more than 60 taxa groups have been identified), although there has been a clear predominance of euphausiids.

The dominance of euphausiids in the diet of Jack mackerel is more evident during the decades of the 1980s and 1990s, corresponding to a slightly warmer multidecadal period, while a more diversified diet is observed during the slightly colder period of 2001 to 2014. During these slightly colder years, euphausiids continued to be an important component of the Jack mackerel diet, although there was an increased presence of other species, especially zoeas and red squat lobster (*Pleuroncodes monodon*), with this last prey becoming the dominant component of the Jack mackerel diet during the warmer years of 2015 to 2019, since it has been particularly abundant, probably benefitting from the influence of the strong 2015-2016 El Niño, the moderate 2017 coastal El Niño, and the weak 2018-2019 El Niño.

The increase of red squat lobster in the diet of Jack mackerel since 2001, and particularly since 2015 is consistent with the noticeable increase in the abundance of red squat lobster observed off Peru since the late 1990s (Gutiérrez et al. 2008), while their clearer dominance during 2015-2018 (with percentages of 75-90% per year) might also be associated with the proximity to the coast of the subtropical subsurface waters between 10°S and 15°30'S and of the cold coastal waters from 16°S south, as well as with the more coastal distribution of most of the catches (and samples) taken in 2015-2018. This prey predominance changed in more recent years, with the increase in the proportions of euphausiids (39%) and engraulids (25%) with a lower proportion (31%) of red squat lobster in 2019; followed by still low proportion (29%) of red squat lobster and a much higher proportion (47%) of mesopelagic fish (mostly Vinciguerria lucetia) in 2020; the slight increase of red squat lobster (38%) and engraulids (22%), followed by other teleosts (22%) and euphausiids (18%) in 2021; the noticeable increase of euphausiids (45%), followed by red squat lobster (25%) and engraulids (12%) in 2022; and, the dramatic increase of red squat lobster (72%), followed by euphausiids (27%) in the first semester of 2023.

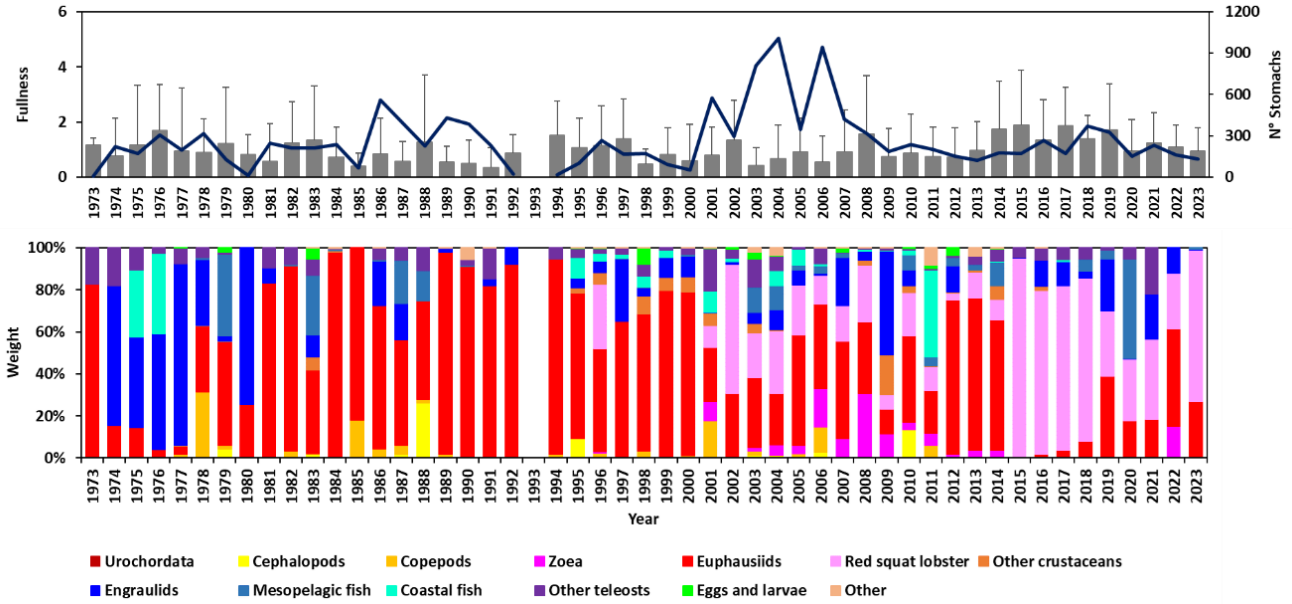

Figure 11. Index of fullness (in %, vertical bars, top panel), sample size (solid lines, top panel) and proportion of preys (vertical bars, lower panel) in stomach content of Jack mackerel *Trachurus murphyi* off Peru from 1973 to 2023. Updated from Alegre et al. (2013, 2015)

4. DESCRIPTION OF THE FISHERY

There are two main groups of vessels that fish for Jack mackerel in Peruvian national waters: the first is the industrial purse seine fleet, with 104 industrial purse seiners with hold capacities above 36.2 m3; and a second group constituted of artisanal and small-scale fleets, with a maximum holding capacity of 32.6 m3. The small-scale fleet includes around 552 small purse seiners, lightly mechanized with a hold capacity between of 20 and 32.6 m3; and the artisanal fleet can include up to 18000 small boats using a wide variety of manual fishing gear, of which about 704 vessels hold capacities under 20 m3 are the most frequently fishing Jack mackerel, mostly with small purse seines.

Industrial purse seiners participate in two types of pelagic fisheries. One for Peruvian anchoveta (*Engraulis ringens*) used mostly for fishmeal. The other one for Jack mackerel, also targeting chub mackerel (*Scomber japonicus*), bonito (*Sarda chiliensis*) and other mid-sized pelagics such as sardine (*Sardinops sagax*) when available. These fisheries, used exclusively for direct human consumption, take place during different fishing seasons, adopt different searching (and fishing) strategies, use different types of purse seines (with mesh-size of 13 mm for anchovy and 38 mm for mid-size pelagics), as well as different maneuvering and storage holding on board. The fleet cannot fish for both (i.e., anchoveta and mid-size pelagics) during the same trip, and it has been noted that whenever the fishing season is open for the two groups (anchoveta and mid-size pelagics), the industrial

purse seine fleet clearly prefers to fish anchoveta. The small-scale and artisanal fleets are more flexible and opportunistic, and target indistinctly a large variety of species depending on their availability and market demand.

4.1. Catch and CPUE trends

Jack mackerel landings in Peruvian waters between 2011 and 2017 were in continuous decline, and between 2015 and 2017 annual catches were among the lowest records (**Figure 12**). Low catches in those years were associated with the displacement and dispersion of Jack mackerel concentrations due to the impacts of the weak 2014 El Niño, the strong 2015-2016 El Niño, the moderate 2017 coastal El Niño, and the weak-to-moderate 2017-2018 La Niña.

Catches during the first part of 2018 were also low but increased slightly during the second half of 2018 and had a cleared increase reaching much higher catches during 2019, which were maintained during 2020, 2021, 2022 and so far, the first half of 2023, getting close to, but still almost 20% under the historical average for 1970-2022. This increase in catches was associated with neutral to cold environmental conditions, which may have favored the increased abundance and the availability of Jack mackerel in more concentrated and larger schools, more attractive to the industrial purse seine fleet.

The industrial purse seine fleet did not target much and did not report significant catches of Jack mackerel between 2014 and early 2018. This was mainly due to the scarcity of attractive enough concentrations of Jack mackerel, but also due to the high demand, good price, increased abundance and higher availability of other species that can and are usually caught by this same fleet, such as Peruvian anchoveta (*E. ringens*), chub mackerel (*S. japonicus*) and bonito (*S. chiliensis*). This resulted in that most Jack mackerel catches that were reported during those years were those taken by smaller vessels of the artisanal and the small-scale purse seine fleets.

Towards the end of 2018 and during 2019 the availability and the total and monthly catches of Jack mackerel increased significantly with respect to the previous three years and remained high during the period 2020-2022 and the first part of 2023 (**Figure 13**). These higher catches were mainly made by the industrial purse seine fleet during the relatively short fishing seasons during which this fleet was allowed to fish and target Jack mackerel. When having the choice, part of this fleet may prefer other species, such as anchoveta, chub mackerel or bonito. In contrast, monthly catches of Jack mackerel by artisanal and small-scale fleets are usually much lower and tend to spread more evenly throughout the year, albeit with some fluctuations, mostly related to local market demand, seagoing weather conditions and availability of suitable Jack mackerel school concentrations in coastal areas.

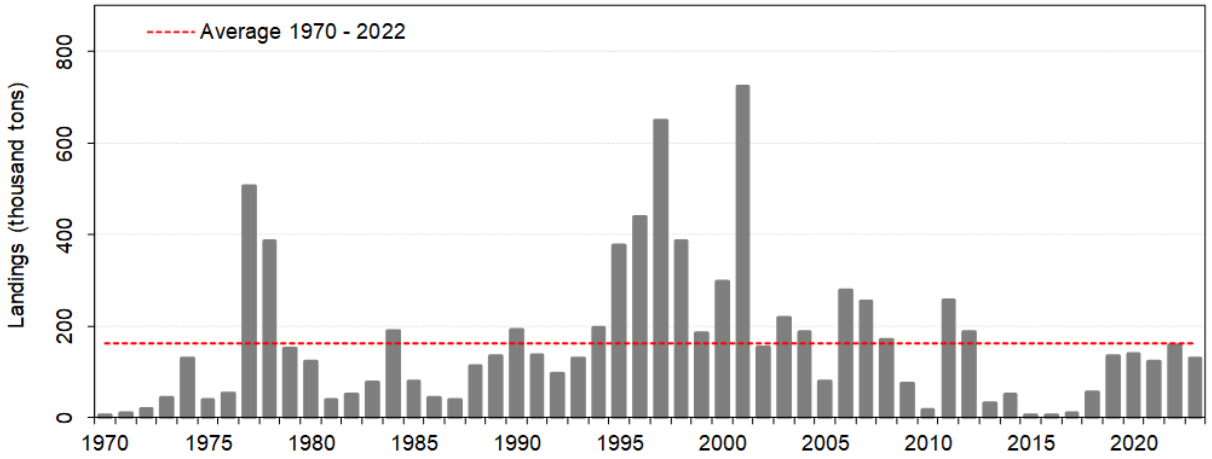

Figure 12. Total annual landings of Jack mackerel (*Trachurus murphyi*) caught in Peruvian waters, years 1970-2022, plus January-June 2023

Within the first three months of 2019, the total Jack mackerel catches nearly doubled those of the whole year in 2018 and six-fold of those taken by year between 2015 and 2017. Despite all this, fishing for anchoveta and other pelagic fisheries has been competing for the attention of the industrial purse seine fleet, as partly evidenced by the drop in monthly catches in March and April 2019 in coincidence with the opening of the anchoveta fishing season, which happened to remain closed during January and February 2019 and the first part of March 2019. A similar situation occurred during the early months of 2020, 2021, 2022 and 2023.

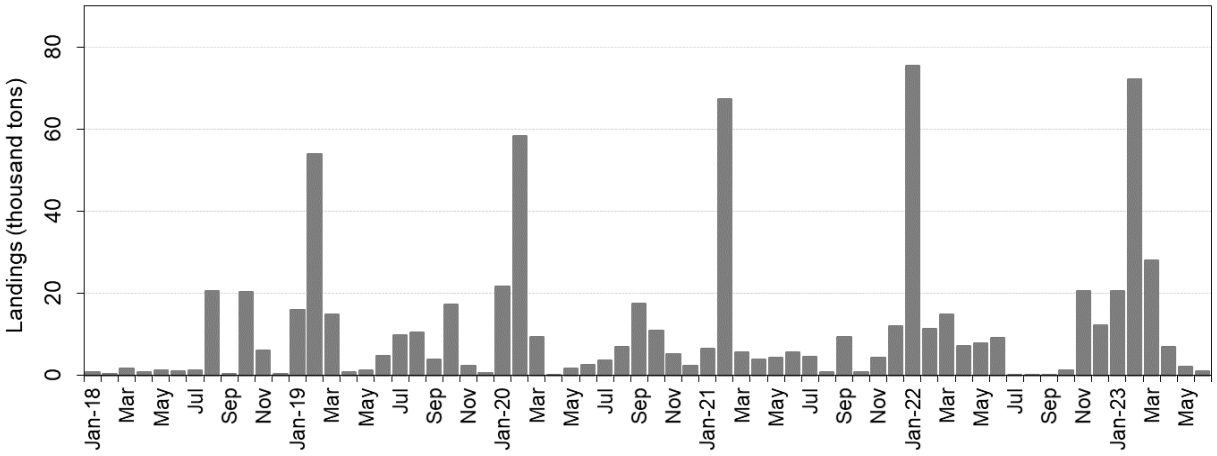

Figure 13. Total monthly landings of Jack mackerel (*Trachurus murphyi*) caught in Peruvian waters, between January 2018 and June 2023

The previous increase in monthly Jack mackerel catches during 2018 and 2019 and the continued high catches during 2020 and more recently, during the first part of 2023 can also be explained by the increasing trend in the CPUE (Capture Per Unit

of Effort) abundance indexes from both the industrial fleet and the group of artisanal and small-scale fleets (**Figure 14**). As can be noted, the monthly CPUE (in tons per trip) of both fleet groups increased during the second half of 2018 and continued to increase, with some fluctuations, during the whole of 2019 and early 2020. Remaining at relatively high levels with a generally increasing trend in 2021 till March 2023. Between April and June 2023, the CPUE values showed a negative trend which appear to be associated with the displacement and dispersion of Jack mackerel concentrations due to the impact of coastal El Niño 2023.

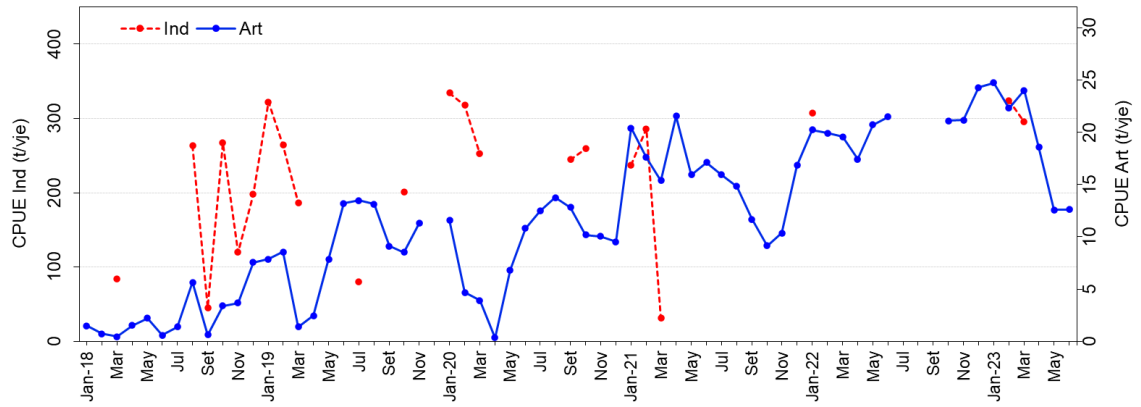

Figure 14. Monthly catch per unit of effort (CPUE, in tons per trip) of Jack mackerel (*Trachurus murphyi*) by the industrial purse seine fleet (red dots and broken lines) and by the artisanal and small-scale purse seine fleets (blue dots and lines) fishing in Peruvian waters between January 2018 and June 2023

The months with no CPUE data for the industrial purse seine fleet was due to the closure of the fishery as part of the conservation and management measures applied by the Peruvian Government. As opposed to the industrial purse seine Jack mackerel fishery that may be subject to several seasonal closures throughout the year, the artisanal and small-scale fleets are usually allowed to fish for Jack mackerel all year round.

The increase in the abundance of Jack mackerel in the period 2018-2023 illustrated by CPUE values of both fleet groups is corroborated by observations made during the regular hydroacoustic pelagic resource assessment surveys conducted by IMARPE during the same period (2018-2023). These surveys may not be as effective in recording Jack mackerel concentrations that are dispersed or forming dense schools close to the surface. Usually they only cover areas within 60 to 100 nm distance from the coast, and potentially could miss important off-shore Jack mackerel concentrations. For example, as reported in IMARPE-PRODUCE (2020), a recent pelagic stock assessment survey conducted by IMARPE from 15 February to 29 March 2020 only covered the first 90 nm from the coast, while most of the catches made during February-March 2020 by the industrial fleet came from fishing areas between 90 and 170 nm distance from the coast. But, even so, the

observations made during this and other surveys have also shown a significant increase in the acoustic abundance indices of Jack mackerel in late 2018 and 2019 and throughout 2020-2021 and early 2022. In fact, the acoustic abundance indices observed since September 2018 have been similar to or well above the maximums observed between 2010 and 2014 and are consistently higher than those estimated during 2015-2017. In addition, the acoustic abundance index observed during the acoustic survey from September to November 2019 was the highest since 2007.

4.2. Fishing areas

During 2022 the Jack mackerel fishing areas were located within 110 nm distance from the coast, mainly between Supe (10°47'S) and Morro Sama (18°00'S), with small nuclei off Paita (05°02'S) and Pimentel (06°50'S). The fishing areas of the artisanal and small-scale fleet were widely distributed and the industrial fishing season and its fishing areas mostly concentrated during January 2022 between Callao (12°00'S) and Bahía Independencia (14°15'S) within 80 nm from the coast (**Figure 15**). It should be noted that the absence of information on the fishing areas between July and September was due to the end of the fishing activities for all types of fleet (R.M. 216-2022-PRODUCE).

During the first part of 2023, the Jack mackerel fishing areas were located in the center-south zone of the Peruvian coast within 120 nautical miles (nm) distance, between Supe (10°47'S) and Morro Sama (18°00'S). In the summer (January-March), the main fishing areas were located between Supe (10°47'S) and San Juan de Marcona (15°23'S), gradually moving further south in April. In June, the main fishing areas were located between Atico and Morro Sama, within 90 nm, associated with the approach to the coast of the Surface Subtropical Waters.

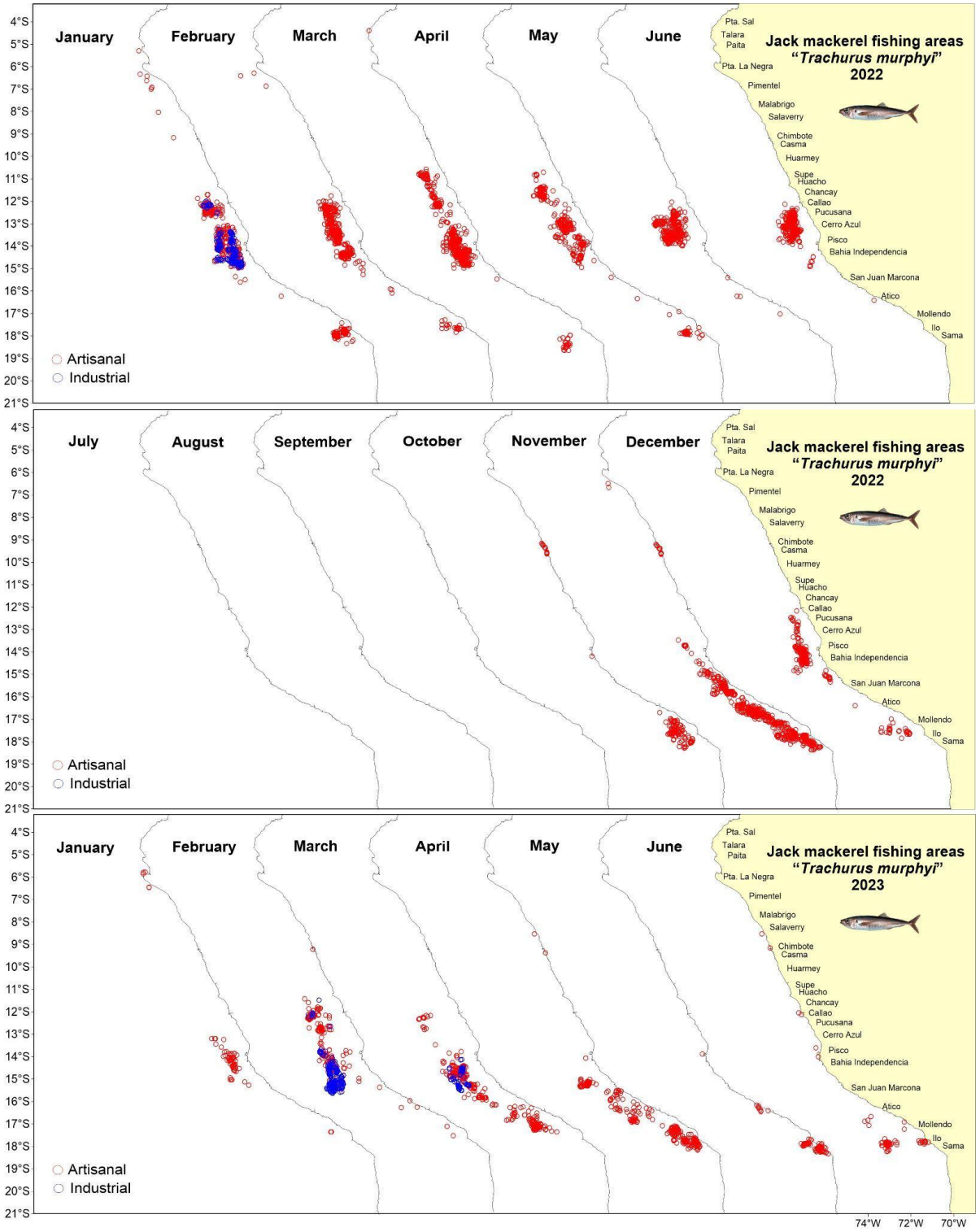

Figure 15. Distribution of the Jack mackerel (*Trachurus murphyi*) fishing areas of the industrial purse seine fleet (blue circles) and by the artisanal and small-scale fleets (red circles) fishing in Peruvian jurisdictional waters, by month, between January 2022 and June 2023

4.3. Size structure

Monthly size frequency distributions of the Jack mackerel observed in Peruvian fisheries by all fleets between January 2022 and June 2023 (**Figure 16**) showed that the fishery targets a wide range of Jack mackerel sizes, with unimodal or multimodal groups, and sizes ranging from 22 cm to 65 cm in total length (TL).

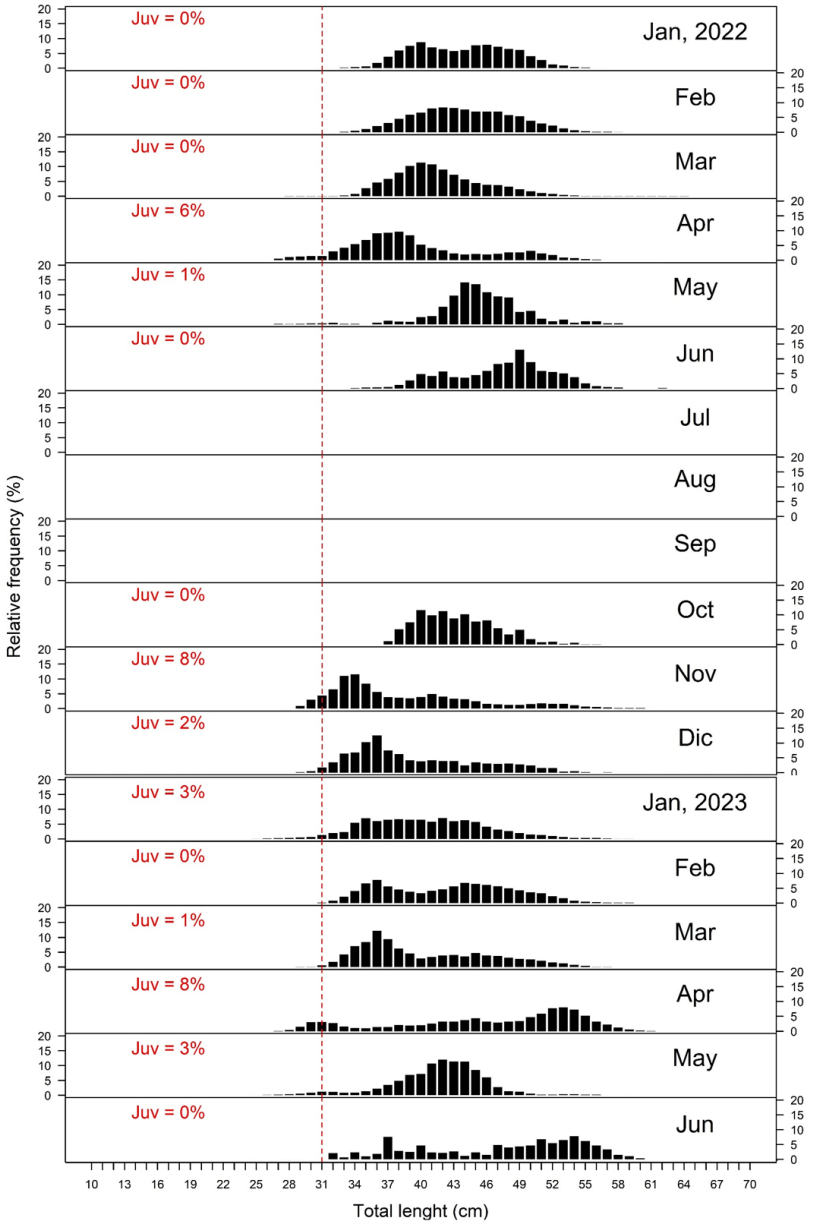

Figure 16. Size frequency distribution of Jack mackerel (*Trachurus murphyi*) caught in Peruvian jurisdictional waters by the Peruvian artisanal, small-scale and industrial fleets, numbers by size in percentage by month, between January 2022 and June 2023

There was a low presence of juveniles (fish smaller than 31.0 cm TL) in commercial catches between January 2022 - June 2023 (**Figure 16**). Most catches during 2022 and 2023 (Figure 16) were of adult Jack mackerel and the highest proportions of juveniles in number per month were observed in November 2022 (8%) and April 2023 (8%).

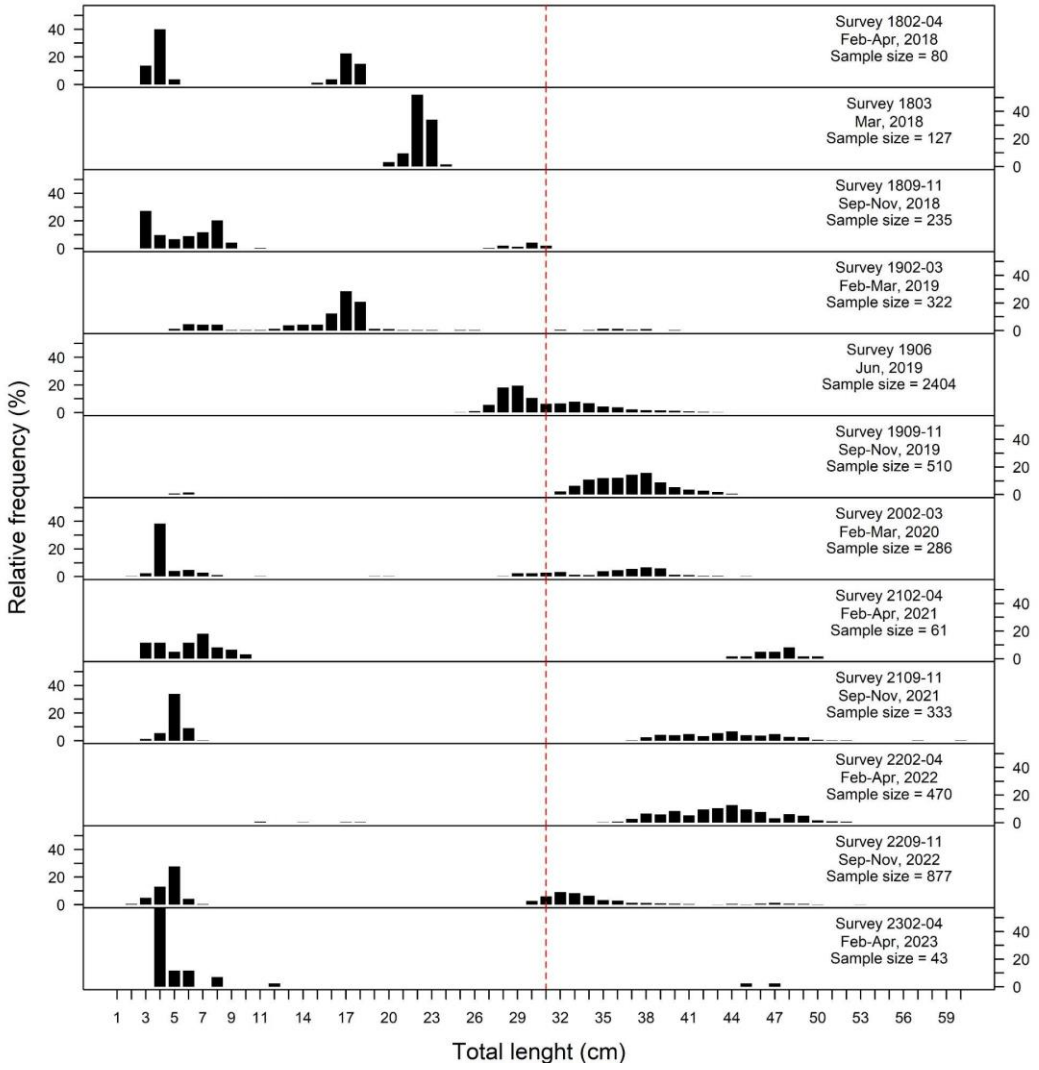

Figure 17. Size-frequency distribution of Jack mackerel (*Trachurus murphyi*) caught in Peruvian jurisdictional waters during research surveys conducted by IMARPE between February 2018 and April 2023

Diverse size groups were present in commercial catches throughout 2022 and the first part of 2023. Besides, there was no large difference between the observed monthly size-frequency distributions of Jack mackerel caught by the artisanal and small-scale fleets and those caught by the industrial fleet, although their main fishing

areas were slightly different. The main fishing areas of the industrial purse seine fleet were more or less within the same latitudes as the artisanal and small-scale fleets, although farther offshore (as shown in **Figure 15**).

Research surveys conducted by IMARPE from 2018 to 2023 also found the adult modal groups that were caught by commercial fleets during the same years and, since the research vessels use different fishing gears with smaller meshes, they also found much younger and smaller juveniles with total lengths as small as 3 cm TL (**Figure 17**). Such small fish do not appear at all in the commercial fishery that uses more selective nets with a minimum mesh size of 38 mm and their presence during research surveys provides a valuable evidence of the presence (although not in great abundance) of cohorts of early juveniles and pre-recruits, not yet available for commercial fishing but that will be soon recruited for the exploited population.

The above also reinforces the observation made by Csirke & Ñiquen (2017) on the consistent occurrence of all life-history stages of Jack mackerel in Peruvian waters and that the Peruvian Jack mackerel stock reproduces and completes its full life-cycle entirely in Peruvian waters, where it constitutes a unique biological and fishery unit, with most if not all the characteristics of a self-sustained stock unit.

5. STOCK ASSESSMENT

This section provides a brief summary of the late 2022 assessment of the Peruvian stock of Jack mackerel (far-north stock) which was used by the Peruvian Government to set the Jack mackerel total allowable catch (TAC) in Peruvian national jurisdictional waters for 2023. This is followed by a 2023 review and update of the Joint Jack Mackerel (JJM) model made by IMARPE using the most recent data and information with presumed catches projected to the end of 2023.

5.1. 2022 assessment and 2023 TAC

In December 2022, the assessment was made in order to advise the Vice-Ministry of Fisheries of the Ministry of Production (Ministerio de la Producción, PRODUCE) on the most current situation of the stock and the possible TAC for 2023 (IMARPE 2022) and was based on the latest version of the JJM model developed during the 10th meeting of the SPRFMO Scientific Committee held in a hybrid mode (from 26 to 30 september 2022 in Seoul) and hosted by the Republic of Korea (SPRFMO 2022), but with all data and information updated to the end of December 2022.

The stock size estimated on January 1st 2023 was projected to the end of the year under several exploitation scenarios, each one related to a TAC and fishing mortality (F). Based on these exploitation scenarios, a range of options was chosen considering those for which there was a high enough probability that the spawning

biomass estimated at January 1st 2024 be greater than that estimated for January 1st 2023; that the spawning biomass for 2023 will continue to be greater than that needed for the Maximum Sustainable Yield (MSY) and that the ratio between the current F and F_{MSY} required for the MSY remains below 1.

In addition to the results of the updated JJM model, in providing its late December 2022 advice to the Government on the prospects of the Peruvian Jack mackerel fishery for 2023, IMARPE also considered the most recent information it had access to on the prevailing environmental conditions that could affect its catch, distribution, abundance, size-frequency distribution (among other aspects) in Peruvian waters. This assessment also took into consideration the environmental conditions during 2023, mainly driven by the effects of the Coastal El Niño 2023 and changes in atmospheric circulation.

Therefore, even if the observed environmental conditions were described as cold conditions from July to December 2022, from the beginning of 2023 the conditions changed. The sea surface temperature anomaly increased from January to June 2023 along the entire Peruvian coast, signaling conditions very characteristic of a coastal El Niño. With prospects that warmer conditions will continue for a few months, there was a certain degree of uncertainty on how the environmental conditions during 2023 would be like. This caused IMARPE's advice to be guided by a certain sense of cautiousness when deciding on a precautionary range of values of F and corresponding TACs to be included in its late December 2022 advice to the Government, with values under the estimated F_{MSY}.

This produced a range of acceptable options and IMARPE's recommendation was that a TAC for 2023 be established considering a multiplier of F_{2022} not exceeding 1.5, that corresponded to a cautionary F = 0.137 and a projected TAC = 144,000 t, accepting a risk of 82.0% that the estimated biomass by January 1st 2024 be lower than that estimated for January 1st 2023, and a 0% risk that the current biomass will be lower than its reference level. This TAC recommendation scenario was even more conservative than the one used by the scientific committee of increasing the previous year's catch by 15%.

Even if the observed CPUE and the JJM biomass estimates showed clear positive trends from 2016 to 2020, since 2021, this values have remained relatively stable, although above that required for MSY, the IMARPE advice noted and took into account some concerns regarding the low incidence of juveniles observed during the 2020 and 2021 commercial catches and the low estimates of recent recruitment obtained with the JJM model. In addition, there is a certain level of uncertainty regarding the expected warmer environmental conditions during the rest of 2023 and the effect of the El Niño on the distribution and local abundance of the Jack mackerel school's concentrations.

In 2022, sea conditions were predominantly cool and from December 2022 a transition occurred to neutral conditions. A very rapid warming process occurred in February and March 2023. In the Niño 1+2 region during the second half of March 2023, strong warming is widespread. Given that the sea surface temperature (SST) in the Niño 1+2 region shows above normal values, coastal El Niño conditions are expected to continue developing, at least until July of the current year. This means that SST values in the Niño 1+2 region, which includes the northern and central areas of the Peruvian sea, will continue to be above normal (ENFEN 2023).

In its December 2022 advice, IMARPE noted that, consequently, its recommended F and TAC were set below those corresponding to the MSY, indicating that the above values could be readjusted in the course of the year if the results of follow-up research surveys and the regular monitoring of the environmental conditions and of the state of the stock and the fishery showed that there was a greater availability of Jack mackerel and generally more favorable conditions than those observed or estimated by late December 2022 assessment.

Based on this advice, on 01 February 2023 PRODUCE established a catch limit of 65 000 tons for the Jack mackerel (*Trachurus murphyi*) to be caught in Peruvian jurisdictional waters by the large-scale or industrial fleet during 2023 and a catch limit of 72 500 tons to be caught by the artisanal fishing vessels with purse seines and hold capacity equal or greater than 20 m^3 up to 32.6 m^3 (ref.: R.M. Nº 000042-2023-PRODUCE). Based on their regular low catches throughout the year and other socio-economic and legal considerations, no catch limit has been established for the Jack mackerel fishery by artisanal fishing vessels that use passive fishing gear (curtain, hooks, among others), and purse seine vessels with a hold capacity of less than 20 m^3.

Then on 10 March 10 2023, PRODUCE decided to extend only the Jack mackerel catch limit to be caught by the industrial fleet, from the first 65 000 tons up to 83 958 tons for the current year (ref.: R.M. Nº 000103-2023-PRODUCE). As advised by IMARPE, PRODUCE's resolution also indicated that the above TAC could be modified depending on the biological and/or environmental factors, including evidence about the state of the stock that may be provided by IMARPE.

5.2. 2023 Assessment

The main purpose of this latest 2023 assessment is to review and update the JJM model estimates with the most recent information up to June 2023, but with estimated total catch projected to December 2023. For this, the following topics were covered: i) the information updating for the 2023 assessment and ii) the sensitivity analysis.

5.2.1. Updated information for the 2023 assessment

Information about catch, catch at length, and weight at age were updated to June 2023, but with estimated total catch projected to December 2023. The echo-abundance, selectivity and the remaining biological data (sexual maturity, age and growth and M) were maintained to be unchanged with respect to the 2014 model since there was no new estimate or data to be added.

Besides, as an illustrative process we show the effect of changing metrics of size frequency data from total length (TL) to fork length (FL) since the growth parameters used in the SPRFMO JJM model configurations are in FL, while the assessments conducted by Peru use sizes in LT, which is how the information is recorded. The Peruvian delegation presented in the 10th SC SPRFMO meeting a report entitled "Review of the Growth Parameters and Length Metrics Used for the Assessment of the Peruvian Stock of Jack Mackerel (Far-North Stock) with the JJM Model Under the Two Stocks Hypothesis" (IMARPE-PRODUCE, 2022a). This document demonstrated that the use of FL or TL as standard metric for data and parameters do not produce significant changes in the assessment outputs. But also highlight the importance of data quality review in order to improve the assessment of Jack mackerel.

The IMARPE´s Fisheries Monitoring System routinely collects catch and length composition data. From this, the yearly length-frequency distributions were calculated up to June 2023. The revised CPUE abundance index based on the industrial and the artisanal and small-scale catch and effort data under a Generalized Additive Model used in 2019 was updated, but now for the period 2002-2023 (**Figure 18**).

It is noted that the updated 2023 CPUE (updated to June 2023) is lower than the 2022 CPUE, but still higher than the 2021 CPUE. This decrease is consistent with the trend in monthly CPUE, particularly from the group of artisanal and small-scale fleets since 2023, as shown in **Figure 14**.

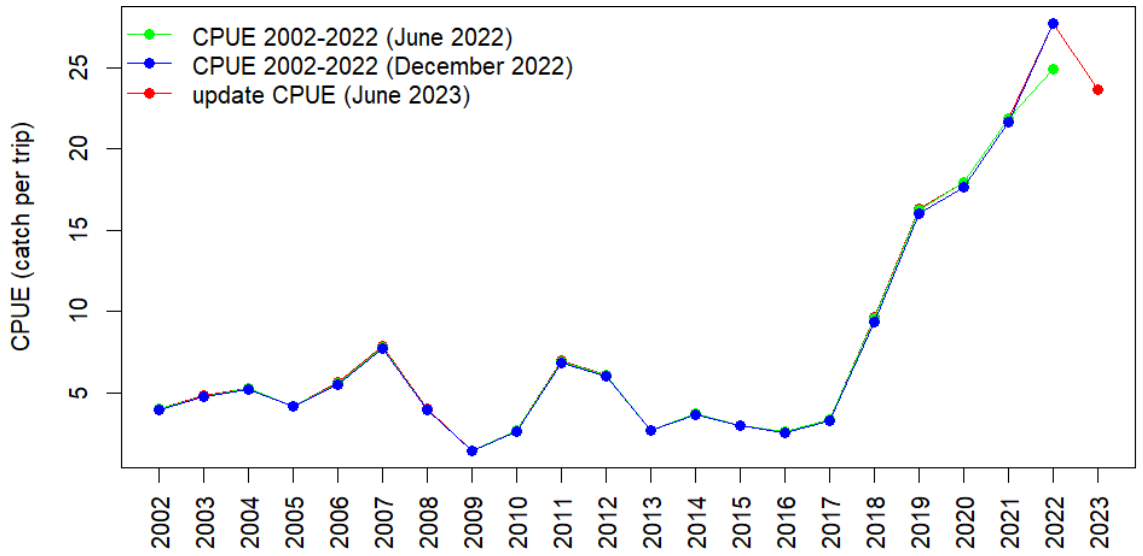

Figure 18. Updated CPUE time series of Jack mackerel (*Trachurus murphyi*) caught in Peruvian jurisdictional waters by the industrial, artisanal, and small-scale fleets between 2002 and 2023

As mentioned in previous reports, the *echo-abundance* index used in the assessment was estimated as the mean value of all the Nautical Area Backscattering Coefficients (S_A) recorded during the acoustic surveys conducted by IMARPE since 1985. The use of the S_A coefficient is preferred to the acoustic biomass estimates in order to reduce potential sources of bias that might be introduced by using length frequency data collected during the acoustic surveys to estimate fish density in numbers (abundance) and weight (biomass).

The current record of echo-abundance of Jack mackerel only provides estimates up to 2014, because the environmental conditions typical of the strong El Niño in 2015-2016, the moderate coastal El Niño in late 2016, early 2017, late 2018, and early 2019 caused the anchoveta to be distributed very close to the coast, and, therefore, the acoustic surveys that are primarily designed to survey the anchoveta stock cover areas closer to the coast (less than 60 nm distance from the coastline) where there is a reduced probability of finding the best concentrations of Jack mackerel.

Then, the pelagic stock assessment acoustic survey conducted in early 2018 had a wider offshore coverage (from 5 to 100 nm distance from the coastline) but it is noted that the coastal cooling and stronger upwelling associated with the weak-to-moderate La Niña in late 2017 to early 2018 have caused the dispersal farther offshore, beyond the surveyed areas, of most of the good concentrations of Jack mackerel. Similar environmental conditions have been observed during La Niña events from late 2020 to mid-2022, characterized by a greater dispersion of Jack mackerel off Peru. The more recent pelagic surveys have also covered undetermined fractions of the total distribution of Jack mackerel in Peruvian waters.

In addition, by the end of 2022 there was a rapid transition from La Niña to coastal El Niño conditions (of strong magnitude) by the beginning of 2023, which has forced scientific surveys to be carried out very close to the coast by 2023. Therefore, there is no updating of the echo-abundance index in the current 2023 JJM assessment.

The biological data, including sexual maturity at age was estimated from a length-based ogive using the information from Perea *et al.* (2013) and Dioses (2013a). The weight at age matrix was estimated from the mid length at age, age and growth parameters and the length-weight relationship parameters estimated by year.

A summary of the fishery dependent, fishery independent and biological data used is given in **Table 1**. Besides, during this 2023 assessment, the effect of the progressive addition of updated data was measured (models type 1).

Table 1. Data used in the 2022 assessment of the Peruvian (far-north) Jack mackerel stock

Type	**Data**	**Details**
From the fishery	Catch	1970 – 2023
	Catch-at-length	1980 – 2023
	CPUE	2002 – 2023
	Selectivity	Dome shaped
Fishery independent	Echo-abundance	1985 – 2014
	Selectivity	Logistic
Biological	Growth parameters	$k=0.16\ y^{-1}$
		Linf=80.77 cm (TL, corresponding to Linf=73.56 cm in FL for the assessment)
		L0=15.31 cm (TL, corresponding to L0=13.56 cm in FL for the assessment)
	Natural mortality	M=0.33/year
	Maturity at age	First maturity = ~2 years
	Weight at age	From updated W-L parameters

5.2.2. Sensitivity analysis

As usual, the model sensitivity to different hypotheses, such as that regarding the steepness of the relationship between recruitment and spawning biomass were also tested (models type 2, Table 2).

5.2.3. 2023 Joint Jack Mackerel (JJM) model outputs

A set of model configurations were implemented for the 2023 assessment with the JJM model (see **Table 2**). The aim was to present the updated assessment of the Jack mackerel in the far north, and in turn, to show the corresponding standardization of metrics for both the length frequency data and the growth parameters (models type 0) and evaluate the impact of i) the progressive information updating for the 2023 assessment (models type 1); and ii) the sensitivity model to different hypothesis such as the stock productivity (models type 2).

Regarding the standardization of metrics (models type 0), the results again corroborate that the use of FL or TL do not change significatively the results (**Figure 19a**). However, it is important to use the corresponding metrics for the data and parameters. On the other hand, the progressive addition of updated information, either catches, length compositions, mean weight at age, and CPUE (models type 1), did not result in a substantial change in the level and overall trend of the total biomass, being almost the same, especially at the end of the series (**Figure 19b**). The level and trend in biomass resulting from different assumptions about steepness were very similar (**Figure 19c**).

Table 2. Model configurations implemented in the 2022 JJM assessment of the Peruvian (far-north) Jack mackerel stock

Model	Description
Standardization of units of measurement	
0.0	- As 2022 configuration and data - Indices: echo-abundance (cv = 0.2) and CPUE (cv = 0.2, 2002-2017; cv = 0.3, 2018-2022)
0.1	As in model 0.0 but with standardized metrics for fishery length composition data and growth parameters to fork length (FL)
Data update	
1.0	As 0.1.

1.1	As in model 1.0 but with revised catches through 2022 and projected 2023 catch estimates
1.2	As in model 1.1 but with updated length composition data to 2023
1.3	As in model 1.2 but with updated mean weight at age (2013-2023)
1.4	As in model 1.3 but with updated CPUE (2002-2023)
Model configuration	
2.0	As in model 1.4 (steepness = 0.65)
2.1	As in model 2.0 but with steepness = 0.8

According to the final model configuration (model 2.1), two periods or regimes, with marked contrast of productivity were observed until late 2010s. The first period of higher biomass during the 1980s and 1990s, and the second one with lower biomass between 2000 and at least 2018. Since 2019, a rapid increase in biomass, to levels similar to those estimated for the high productivity regime, has been observed. These two contrasting regimes described by the JJM model are consistent with the observed decadal regime changes in the marine environment and in the distribution, abundance population structure and other biological characteristics of many marine species, including Jack mackerel, in the Peruvian marine ecosystem described by several authors (*e.g.*: Jordan 1983, Chavez *et al.* 2003, 2008, Csirke 2013, Csirke *et al.* 2013, 2018, Arguelles *et al.* 2019). On the other hand, the higher biomass estimated for Jack mackerel in the recent 3-4 years could be just a temporary biomass burst but also, as it was noted during the SC9, a result of bias in CPUE indices due to a possible increased efficiency of the fleet and observed changes in the Jack mackerel spatial distribution. However, it could also be an indication that a regime shift (to higher abundance) is in the making, whose expected magnitude and duration are, in any case, great uncertainties worth looking into in future analyses. In addition, the current biomass estimation of the JJM for this year shows a continuous decrease in its trends. This needs to be further studied for the upcoming years.

The mean value of fishing mortality estimated for years between 1970 and 2023 was very similar for the nine configurations, as well as their distributions (**Figures 19b**, **19d** and **19f**).

The history and current situation of the unfished biomass, total biomass and annual fishing mortality of the Peruvian (far-north) stock as estimated with the JJM model are presented in the top three panels in **Figure 20** and those of the spawning stock biomass and resulting recruitment are presented in the lower panel in the same figure.

As noted early, the stock would have passed through two stages of productivity, or regimes, with high levels of total biomass during the 1990s and low levels since 2000 to at least 2018. These two main stages are represented by two stock-recruitment regimes (**Figure 20**, lower panel). With one high productivity regime from 1970 to 1996 and a lower productivity regime from 2001 to 2021.

Although, as noted earlier, the consistent increasing trend in the last 3-4 years is worth further consideration from this “regime” perspective. The period 1997-2000 was not considered in the fitting of the two stock-recruitment curves due to the high variability observed for those years, which apparently was mainly induced by the very strong 1997-1998 El Niño and probable instability caused by the regime change itself.

It is noted that the outputs obtained with the final configuration of the JJM model used, as well the eventual forward projections under various scenarios of F, indicate that the total biomass as well as the spawning stock biomass are well above the levels required for the MSY under the presumed current low abundance regime, and would still be well above the MSY levels if a higher abundance regime is assumed. Nevertheless, even if the stock appears to be in good health and the biomass estimates are high despite the recent decrease, there is a need to be precautionary and follow-up on, and pay attention to the low future recruitments predicted by the JJM model based on the stock-recruitment relationship mean curve for the low abundance regime (**Figure 20**) and to the low incidence of juveniles observed in the commercial catches during the second half of 2019, the whole of 2020, 2021, 2022, the first part of 2023 and the probable occurrence of a Global El Niño for the following months. As well as to the low recent recruitments estimated by the JJM model, and the uncertainties regarding future environmental conditions regarding the current warmer conditions as we described above. On this, it is also noted that the estimates and projections of biomass and other variables obtained with the JJM also show the great variability of past recruitments and reaffirm the great uncertainty about the intensity of future recruitments, reflecting quite well what has been observed and is partially described in sections above with respect to environmental variability and its effects on the behavior, distribution, abundance, recruitment, etc., of Jack mackerel in Peruvian waters.

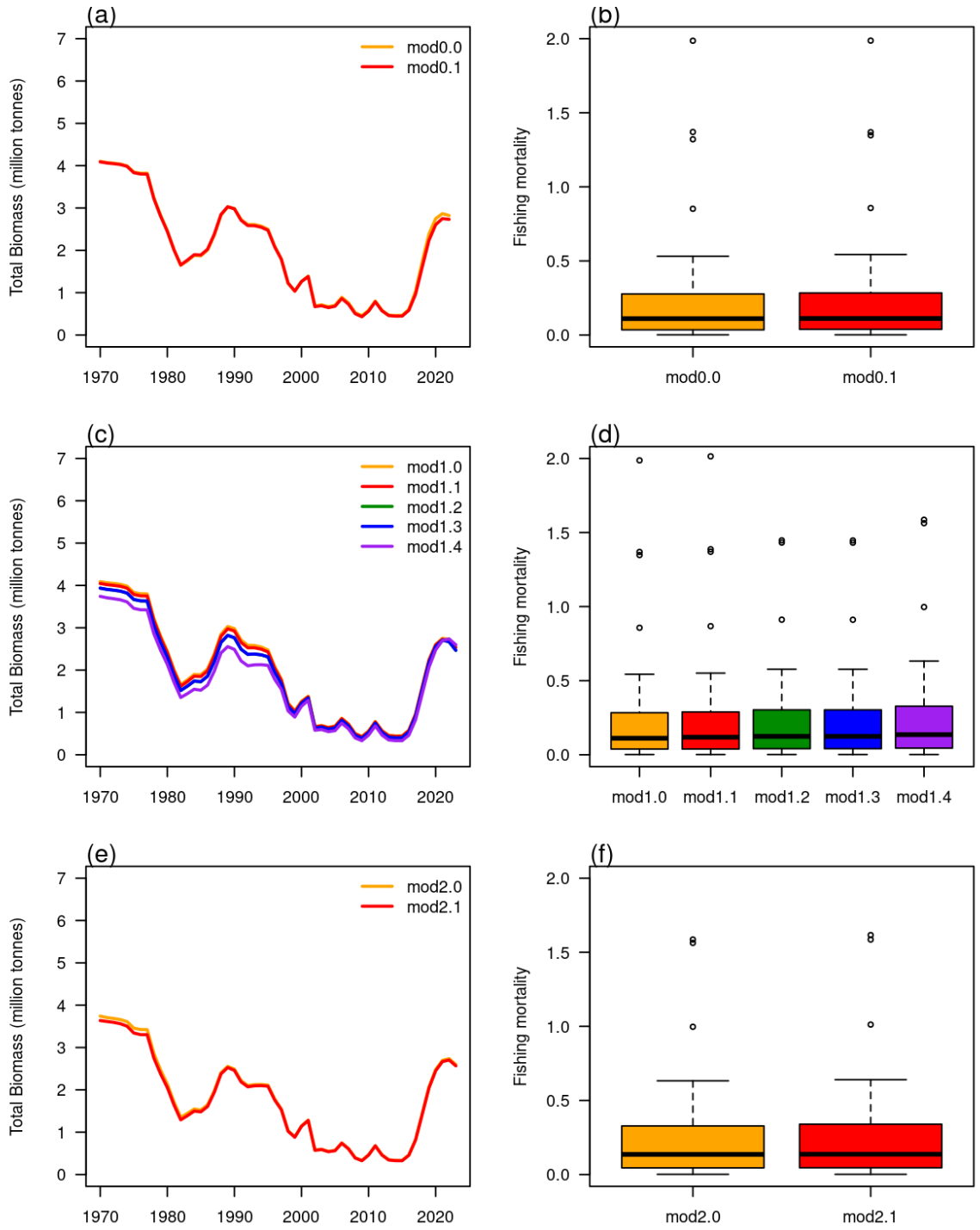

Figure 19. Results of the final JJM model configuration showing the estimated total biomasses of Jack mackerel (Figures a), c) and e)) and boxplots of fishing mortality (Figures b), d) and f)) for the three model groups respectively

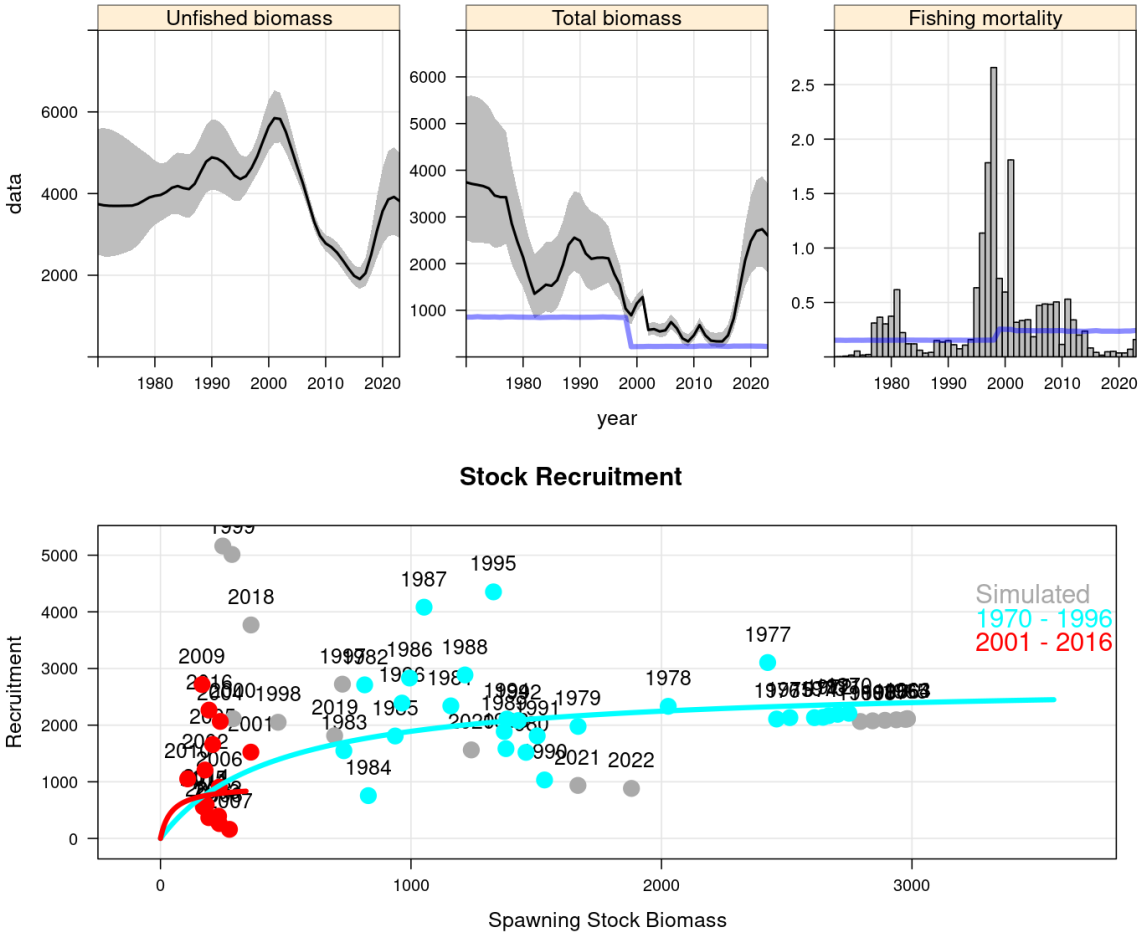

Figure 20. Outputs of the final configuration of the JJM model showing the history and current situation of the Peruvian (far-north) stock of Jack mackerel (*Trachurus murphyi*). Unfished biomass, total biomass (in thousand t) and yearly fishing mortality are presented at the top panels. The stock-recruitment relationship showing two regimes is presented in the lower panel. The horizontal blue lines in the two top-right panels represent the estimated reference levels of mean total biomass (BMSY) and annual fishing mortality (FMSY) corresponding to the Maximum Sustainable Yield (MSY)

6. REFERENCES

Alegre, A., P. Espinoza & M. Espino. 2013. Trophic ecology of Jack mackerel *Trachurus murphyi* in Peru, 1977 - 2011. *Revista peruana de biología*. Special issue (published in Spanish with titles, abstracts and captions in English), 20(1): 075 - 082.

Alegre, A., A. Bertrand, M. Espino, P. Espinoza, T. Dioses, M. Ñiquen, I. Navarro, M. Simier & F. Ménard. 2015. Diet diversity of jack and chub mackerels and ecosystem changes in the northern Humboldt Current system: A long-term study. *Progress in Oceanography* 137: 299–313.

Arguelles, J., J. Csirke, D. Grados, R. Tafur & J. Mendoza. 2019. Changes in the predominance of phenotypic groups of jumbo flying squid *Dosidicus gigas* and other indicators of a possible regime change in Peruvian waters. Working paper presented to the 7th meeting of the Scientific Committee of the SPRFMO, La Havana, Cuba, 5-12 October 2019. SPRFMO Doc. SC7-SQ03: 19p

Csirke, J. 2013. The Jack mackerel in Peru. *Revista peruana de biología*. Special issue (published in Spanish with titles, abstracts and captions in English) 20(1): 5-8.

Csirke, J., R. Guevara-Carrasco & M. Espino (eds). 2013. Ecology, fishery and conservation of Jack mackerel (*Trachurus murphyi*) in Peru. *Revista peruana de biología*. Special issue (published in Spanish with titles, abstracts and captions in English), 20 (1): 001-114.

Csirke, J. & M. Ñiquen. 2017. Evidences of the consistent occurrence of all life-history stages of Jack mackerel (*Trachurus murphyi*) in the northern Humboldt Current System, off Peru and Ecuador. Working paper presented to the 5th meeting of the Scientific Committee of the SPRFMO, Shanghai, China, 23-28 September 2017. SPRFMO Doc. SC6-JM03: 16p

Csirke J, Argüelles J, Alegre A, Ayón P, Bouchon M, Castillo G, Castillo R, Cisneros R, Guevara-Carrasco R, Lau L, Mariátegui L, Salazar C, Tafur R, Torrejón J, Yamashiro C. 2018. Biology, population structure and fishery of jumbo flying squid (*Dosidicus gigas*) in Peru. Bol. Inst. Mar Peru. 33(2): 302-364

Chavez, F., J. Ryan, S.E. Lluch-Cota, M. Ñiquen. 2003. From anchovies to sardines and back: multidecadal change in the Pacific Ocean. Science 299 (5604): 217-221

Chavez, F., A. Bertrand, R. Guevara-Carrasco, P. Soler & J. Csirke. 2008. The northern Humboldt Current System: brief history, present status and a view towards the future. Prog. Oceanogr. 79: 95-105

Diaz, E. 2013. Estimation of growth parameters of Jack mackerel Trachurus murphyi caught in Peru, from length frequency analysis. *Revista peruana de biología*. Special issue (published in Spanish with titles, abstracts and captions in English), 20(1), 061-066.

Dioses, T. 1995. Análisis de la distribución y abundancia de los recursos jurel y caballa frente a la costa peruana. Informe Progresivo del Instituto del Mar del Perú (IMARPE), Callao, Perú, No 3: 55 pp

Dioses, T. 2013. Age and growth of Jack mackerel *Trachurus murphyi* in Peru. *Revista peruana de biología*. Special issue (published in Spanish with titles, abstracts and captions in English), 20 (1): 045-052.

Dioses, T. 2013a. Abundance and distribution patterns of Jack mackerel *Trachurus murphyi* in Peru. *Revista peruana de biología*. Special issue (published in Spanish with titles, abstracts and captions in English), 20 (1): 067-074.

ENFEN. Comunicado Oficial ENFEN N°03-2023. Estado del sistema de alerta: Alerta de El Niño costero. 16 de marzo de 2023.

Goicochea, C., Mostacero, J., Moquillaza, P., Dioses, T., Topiño, Y., & Guevara-Carrasco, R. 2013. Validation of the formation rate growth rings in otoliths of Jack mackerel *Tracurus murpphyi* Nichols 1920. *Revista peruana de biología*. Special issue (published in Spanish with titles, abstracts and captions in English),, 20(1), 053-060.

Gutiérrez, M., A. Ramírez, S. Bertrand, O. Morón & A. Bertrand. 2008. Ecological niches and areas of overlap of the squat lobster 'munida' (*Pleuroncodes monodon*) and anchoveta (*Engraulis ringens*) off Peru. Progress in Oceanography 79, 256-263.

IMARPE-PRODUCE. 2012. National report on the situation of the Peruvian stock of Jack mackerel (northern stock) and the Peruvian fishery in national jurisdictional waters. Peru 2nd National Report 2012. 11th Meeting of the Science Working Group of the SPRFMO, Lima, Peru, 15-19 October 2012. Doc. SPRFMO SWG-11-08a: 65p.

IMARPE-PRODUCE. 2012a. Characteristics of the Peruvian stock (northern stock) of Jack mackerel (*Trachurus murphyi*) in the Southeast Pacific and notes on the scientific basis for its differentiation. 11th Meeting of the Science Working Group

of the SPRFMO, Lima, Peru, 15-19 October 2012. Doc. SPRFMO SWG-11-JM-03: 27p

IMARPE-PRODUCE. 2013. National report on the situation of the Peruvian stock of Jack mackerel (far-north stock) and the Peruvian fishery in national jurisdictional waters. Peru National Report No 2. 1st Meeting of the SPRFMO Scientific Committee, La Jolla, Ca., U.S.A., 21-27 October 2013. Doc. SPRFMO SC-01-13: 31p

IMARPE-PRODUCE. 2014. National report on the situation of the Peruvian stock of Jack mackerel (far-north stock) and the Peruvian fishery in national jurisdictional waters. Peru National Report No 2. 2nd Meeting of the SPRFMO Scientific Committee, Honolulu, Hawaii, U.S.A., 01-07 October 2014. Doc. SPRFMO SC-02-17: 40p

IMARPE-PRODUCE. 2015. National report on the situation of the Peruvian stock of Jack mackerel (far-north stock) and the Peruvian fishery in national jurisdictional waters. Peru National Report No 2. 3rd Meeting of the SPRFMO Scientific Committee, Port Vila, Vanuatu, U.S.A., 28 September - 03 October 2015. Doc. SPRFMO SC-03-19: 21p

IMARPE-PRODUCE. 2016. National report on the situation of the Peruvian stock of Jack mackerel (far-north stock) and the Peruvian fishery in national jurisdictional waters. Peru National Report No 2. 4th Meeting of the SPRFMO Scientific Committee, The Hague, Kingdom of the Netherlands, 10-15 October 2016. Doc. SPRFMO SC-04-09: 23p

IMARPE-PRODUCE. 2017. National report on the situation of the Peruvian stock of Jack mackerel (far-north stock) and the Peruvian fishery in national jurisdictional waters. Peru National Report No 2. 5th Meeting of the SPRFMO Scientific Committee, Shanghai, China, 23-28 September 2017. Doc. SPRFMO SC5-Doc19: 21p

IMARPE-PRODUCE. 2018. National report on the situation of the Peruvian stock of Jack mackerel (far-north stock) and the Peruvian fishery in national jurisdictional waters. Peru National Report No 2. 6th Meeting of the SPRFMO Scientific Committee, Puerto Varas, Chile, 9-14 September 2018. Doc. SPRFMO SC6-Doc20: 31p

IMARPE-PRODUCE. 2019. National report on the situation of the Peruvian stock of Jack mackerel (far-north stock) and the Peruvian fishery in national jurisdictional waters, period January 2018 - June 2019. Peru National Report No 2. 7th Meeting of the SPRFMO Scientific Committee, La Havana, Cuba, 7-12 October 2019. Doc. SPRFMO SC7-Doc34: 27p

IMARPE-PRODUCE. 2020. National report on the situation of the Peruvian stock of Jack mackerel (far-north stock) and the Peruvian fishery in national jurisdictional waters, period January 2019 - June 2020. Peru National Report No 2. 8th Meeting of the SPRFMO Scientific Committee, New Zealand (hosted remotely), 3-8 October 2020. Doc. SPRFMO SC8-Doc24: 32p

IMARPE-PRODUCE. 2021. National report on the situation of the Peruvian stock of Jack mackerel (far-north stock) and the Peruvian fishery in national jurisdictional waters, period January 2020 – June 2021. Peru National Report No 2. 9th Meeting of the Scientific Committee of the SPRFMO, Held remotely, 27 September - 2 October 2021. Doc. SPRFMO SC9-Doc23: 34p

IMARPE-PRODUCE. 2022. Informe sobre el desarrollo de la pesquería de jurel *Trachurus murphyi* durante el 2022, situación actual y perspectivas de explotación para el 2023. Informe interno IMARPE, Oficio N° 001327-2022-IMARPE/PCD, 27 diciembre 2022: 24p

IMARPE-PRODUCE. 2022a. Review of the Growth Parameters and Length Metrics Used for the Assessment of the Peruvian Stock of Jack Mackerel (Far-North Stock) with the JJM Model Under the Two Stocks Hypothesis. Report. 10th Meeting of the SPRFMO Scientific Committee, Seoul, Korea, 26-30 September 2012. Doc. SPRFMO SC6-Doc20: 31p

Jordan, R. 1983. Variabilidad de los recursos pelágicos en el Pacífico Sudeste: 106-120. Inf. Pesca FAO, 291: 113-130.

Konchina, Y. 1981. The Peruvian Jack mackerel, *Trachurus symmetricus murphyi*, a facultative predator in the coastal upwelling ecosystem. Journal of Ichthyology 21, 46–59.

Muck, P. & G. Sánchez. 1987. The importance of mackerel and horse mackerel predation for the Peruvian anchoveta stock (a population and feeding model). In: Pauly, D. Tsukayama

Perea, A., J. Mori, B. Buitron & J. Sánchez. 2013. Reproductive aspects of Jack mackerel *Trachurus murphyi*. *Revista peruana de biología*. Special issue (published in Spanish with titles, abstracts and captions in English),, 20 (1): 020-034.

Quispe, J. & L. Vásquez. 2015. Indice “LABCOS” para la caracterización de eventos El Niño y La Niña frente a la costa del Perú, 1976-2015. Boletín Trimestral Oceanográfico, IMARPE, Callao, Perú. Vol. 1 (1-4): 12-16.

SPRFMO, 2022. 10th Scientific Committee meeting report. Held in a hybrid mode, 27 to 20 September 2022. SPRFMO SC10 report:86 p.