Conceptual model for common sardine (*Strangomera bentincki*) in the south central zone of Chile (32° - 47°S).

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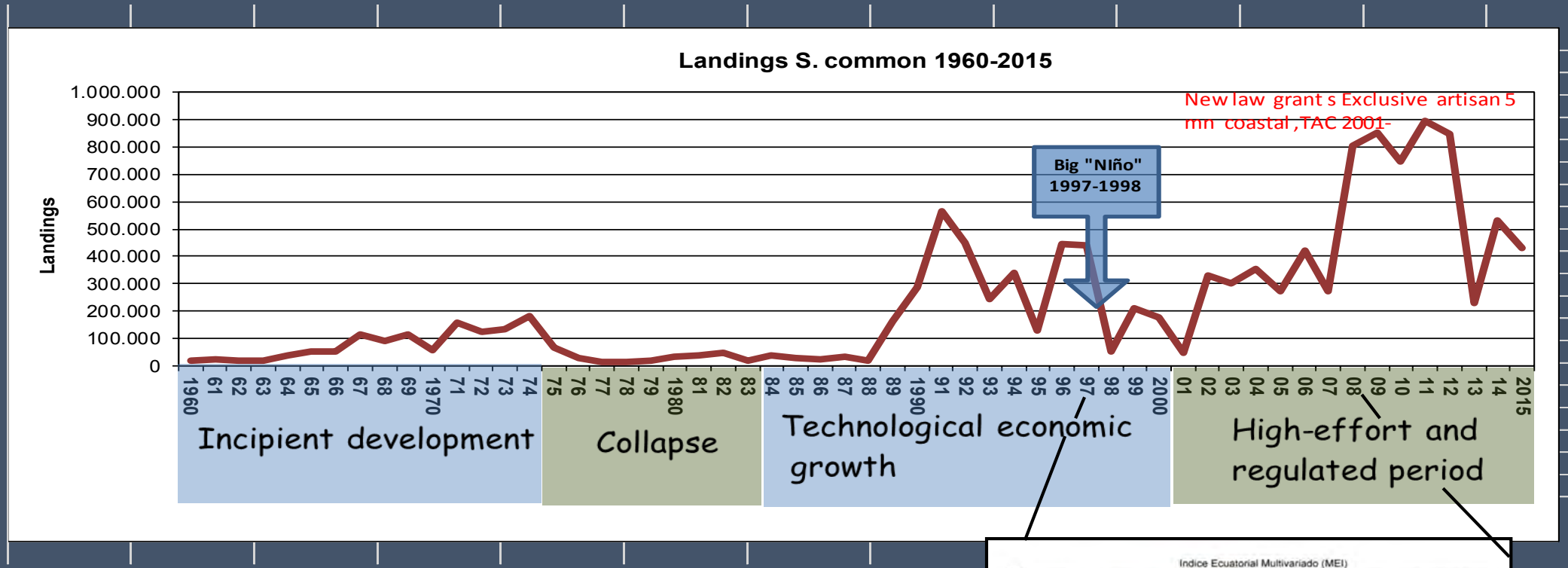
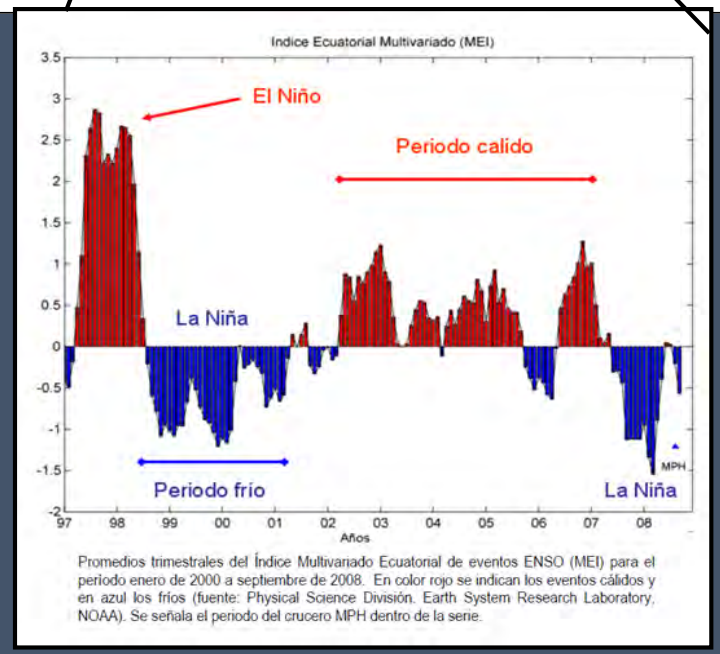


- Historical landings show high variability and increasing trend of catches over time
- Markedly influenced by environmental factors at all stages of its life cycle.



Promedios trimestrales del Índice Multivariado Ecuatorial de eventos ENSO (MEI) para el periodo enero de 2000 a septiembre de 2008. En color rojo se indican los eventos cálidos y en azul los fríos (fuente: Physical Science División. Earth System Research Laboratory, NOAA). Se señala el periodo del crucero MPH dentro de la serie.

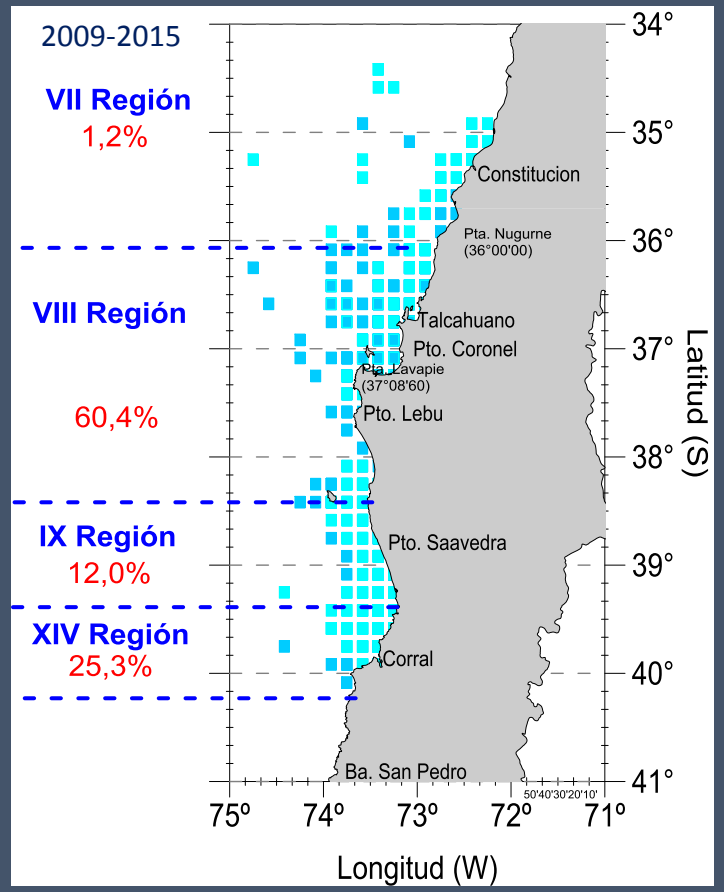
BACKGROUND

- Introduction
- Objective
- Methods
- Results
- Conclusions

Fleet

INTRODUCTION

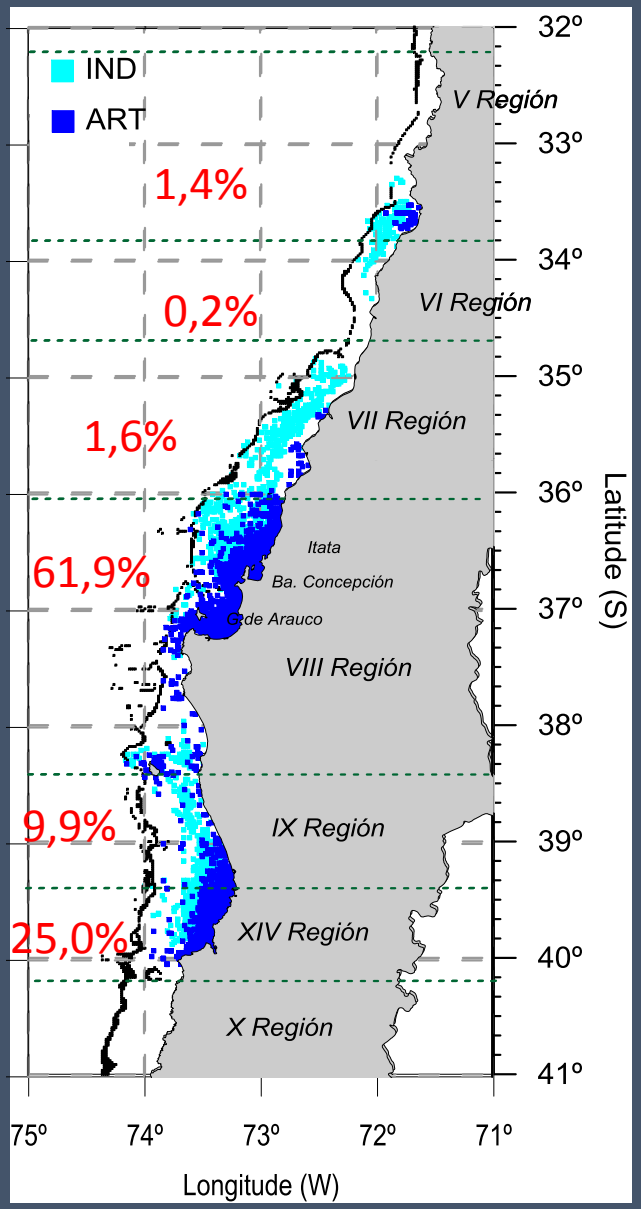
SARDINA COMÚN (*Strangomera bentincki Norman 1936*)
Clupeiformes-Clupeidae



In Chile, one of the largest national pelagic fishing activity is concentrated in the south-central zone (34°-41°S), being mainly artisanal sustained for about fifteen years on the common sardine stock.

- These small species is characteristic of upwelling systems
- Opportunistic strategists
- Contribution to the trophic chain
- Small size (less than 20 cm LT) with fast growth
- High rate of natural mortality
- Markedly influenced by environmental factors at all stages of its life cycle.
- Show a coastal spatial distribution (less 30 nm), for spawning expression (eggs and larvae), and juveniles and adults.
- They are a genetic unit (stock) with unequal demographic distribution by zones (Galleguillos *et al*, 1997; Aranis et al, 2015)
- Origin multi-species fishery together anchovy and jack mackerel.

Spatial distribution of sets catch
s. common, 2005-2015



Industrial and artisanal catches are focused clearly on the continental shelf and mostly in the VIII region (62%) and secondarily the IX and XIV regions (35%).

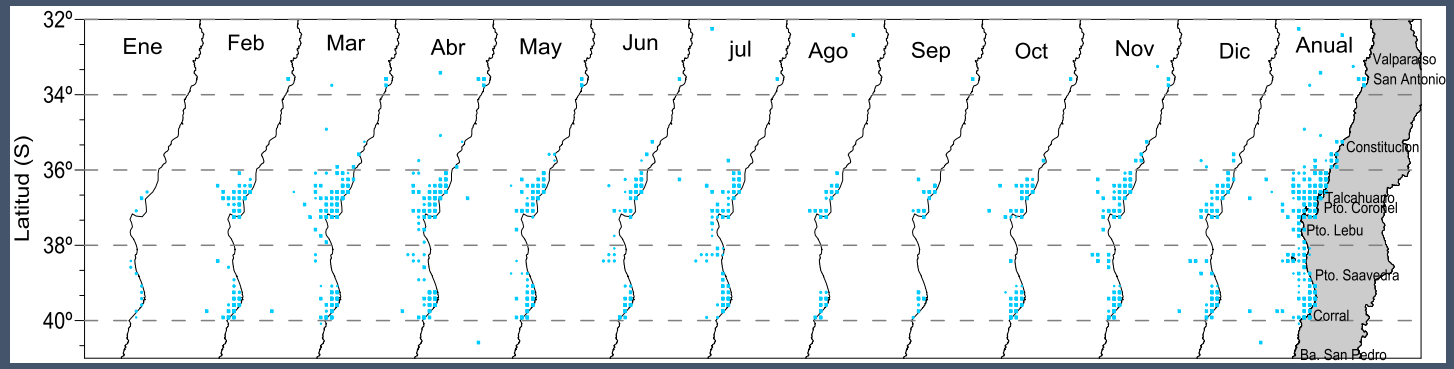
Differences to the north and south of Punta lavapié from an environmental-oceanographic and biological point of view

North of Punta Lavapié, the coastline tends toward the northeast, the platform widens more than 70 km, cut by the Biobío canyon and the Itata Canyon, and the Gulf of Arauco and the Bays of Concepción and Coliumo.

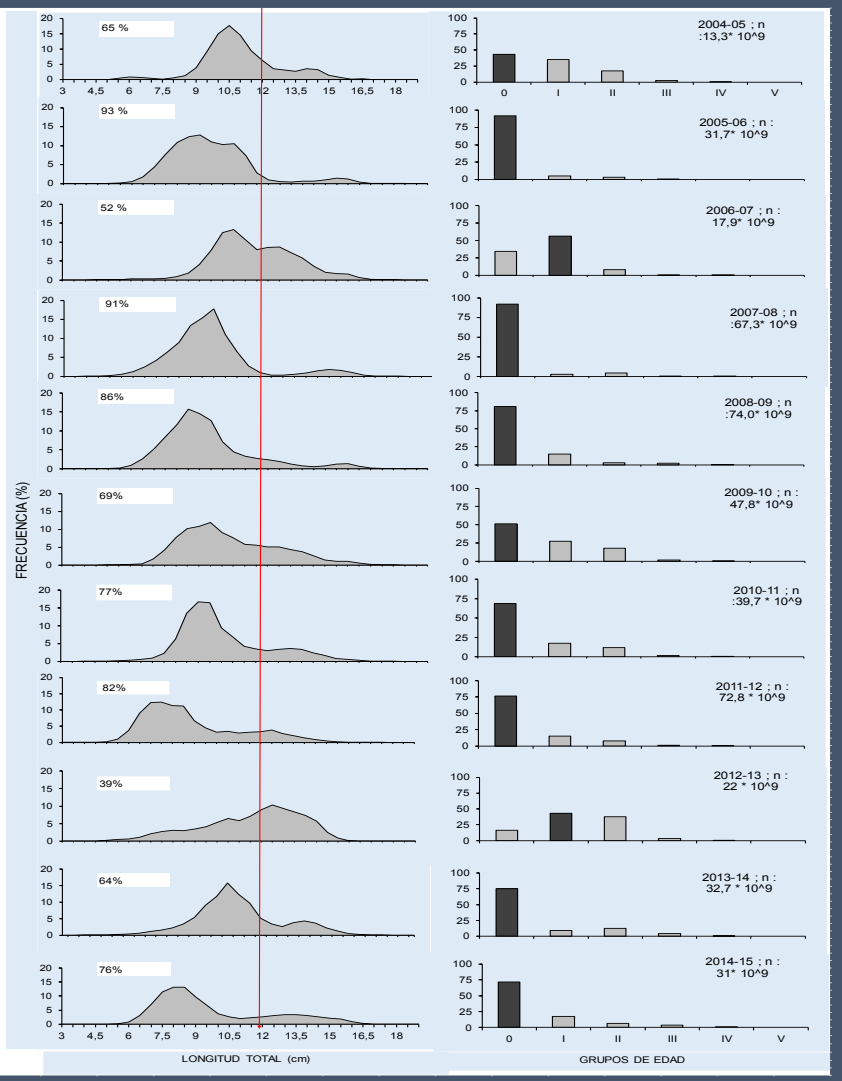
The Punta Lavapié itself, a source of upwelling, represents the zone of smaller width of platform from which the coastal jet leaving the zone of the platform of Conception and Gulf of Arauco as adjacent to the Flow, potentially forming an upwelling shadow zone wich define conditions of low spawning and catch.

To the south of Punta Lavapié, the spatial and temporal variability of the currents, the wind and the fresh water supply coming from important rivers together with the continental shelf structure and the form of the coast define the environmental conditions of the zone Spawning and fishing.

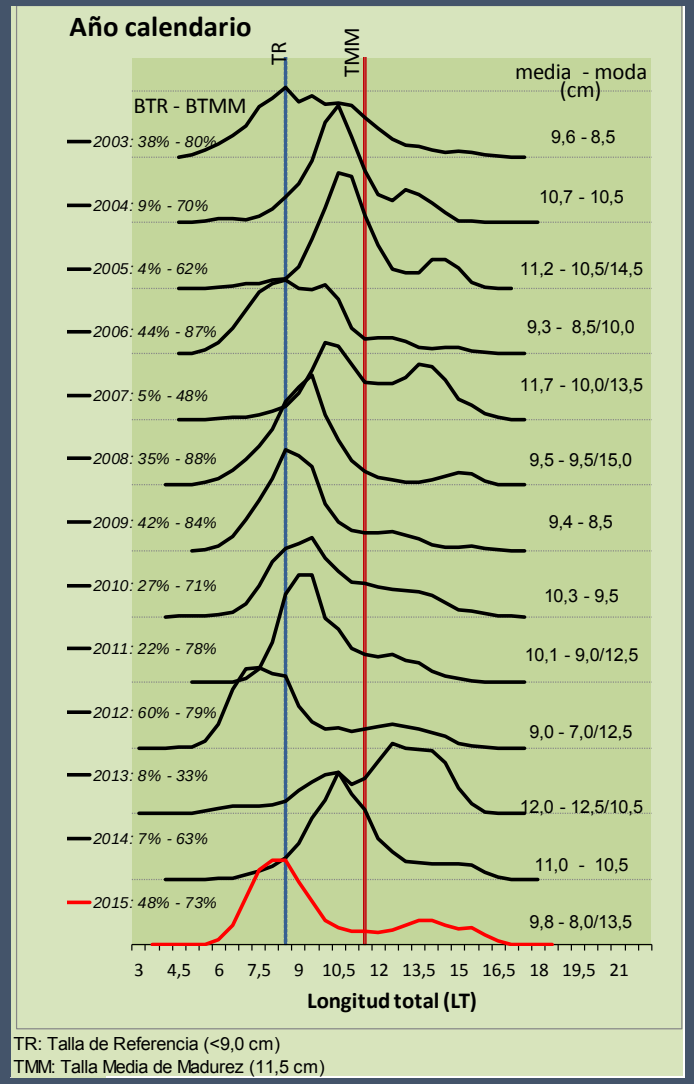
Historic Seasonality 2009-2015



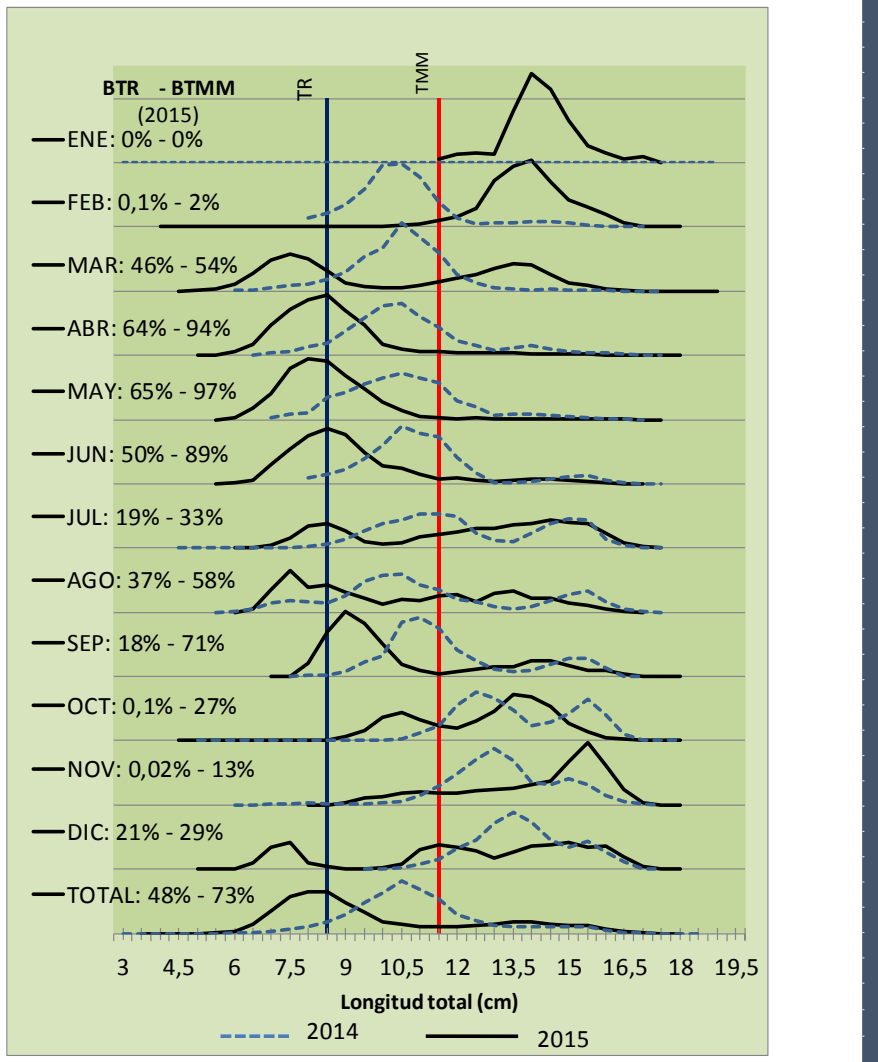
Structure of length/age (%) of common sardine in San Antonio-Valdivia, 2004-2015.



Size distribution, 2003-2015 and monthly 2014-2015 from V to XIV Regions.

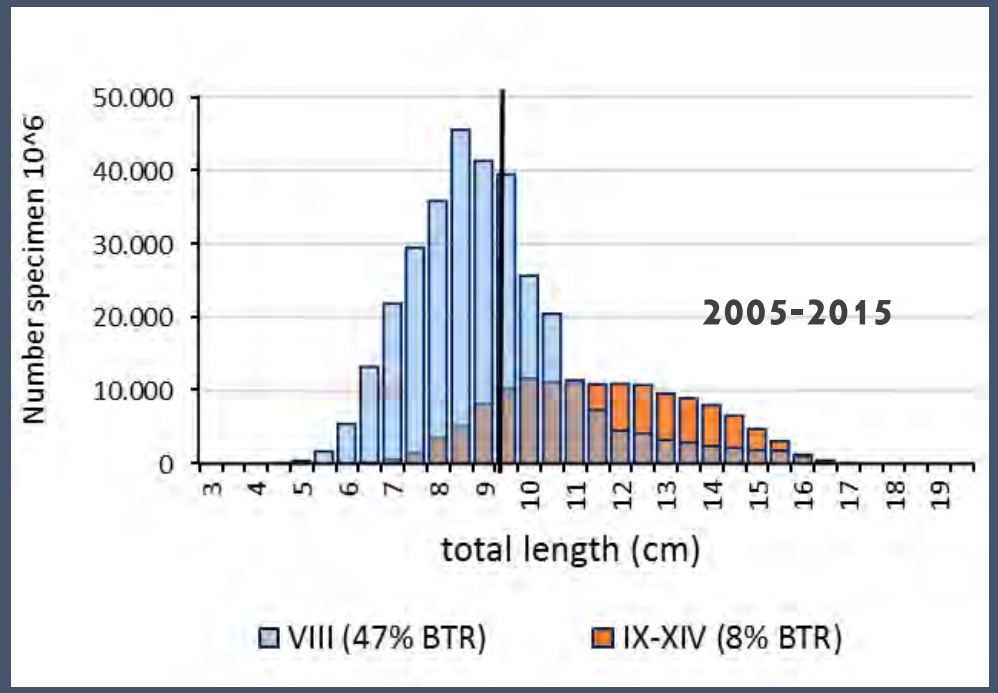


TR: Talla de Referencia (<9,0 cm)
TMM: Talla Media de Madurez (11,5 cm)

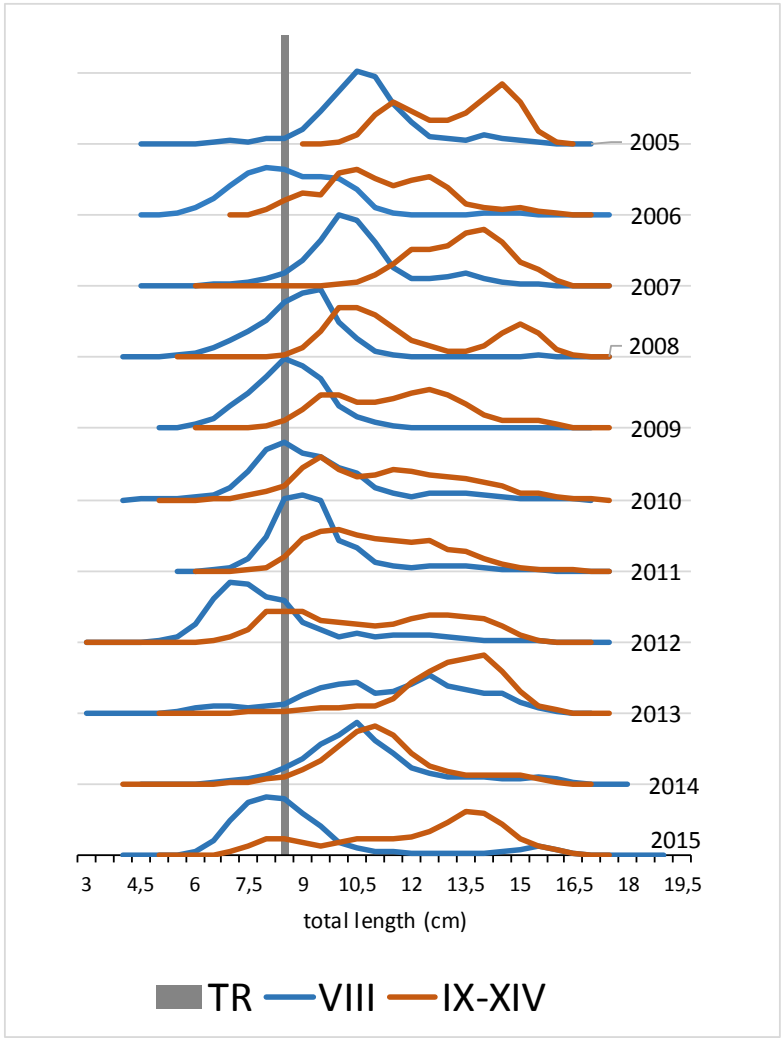


The historical catches are dominated in juveniles less than one year old under the average size of maturity (11.5 cm LT)
There is a strong seasonality of recruitment from the end of the year until april (extending more exceptionally)

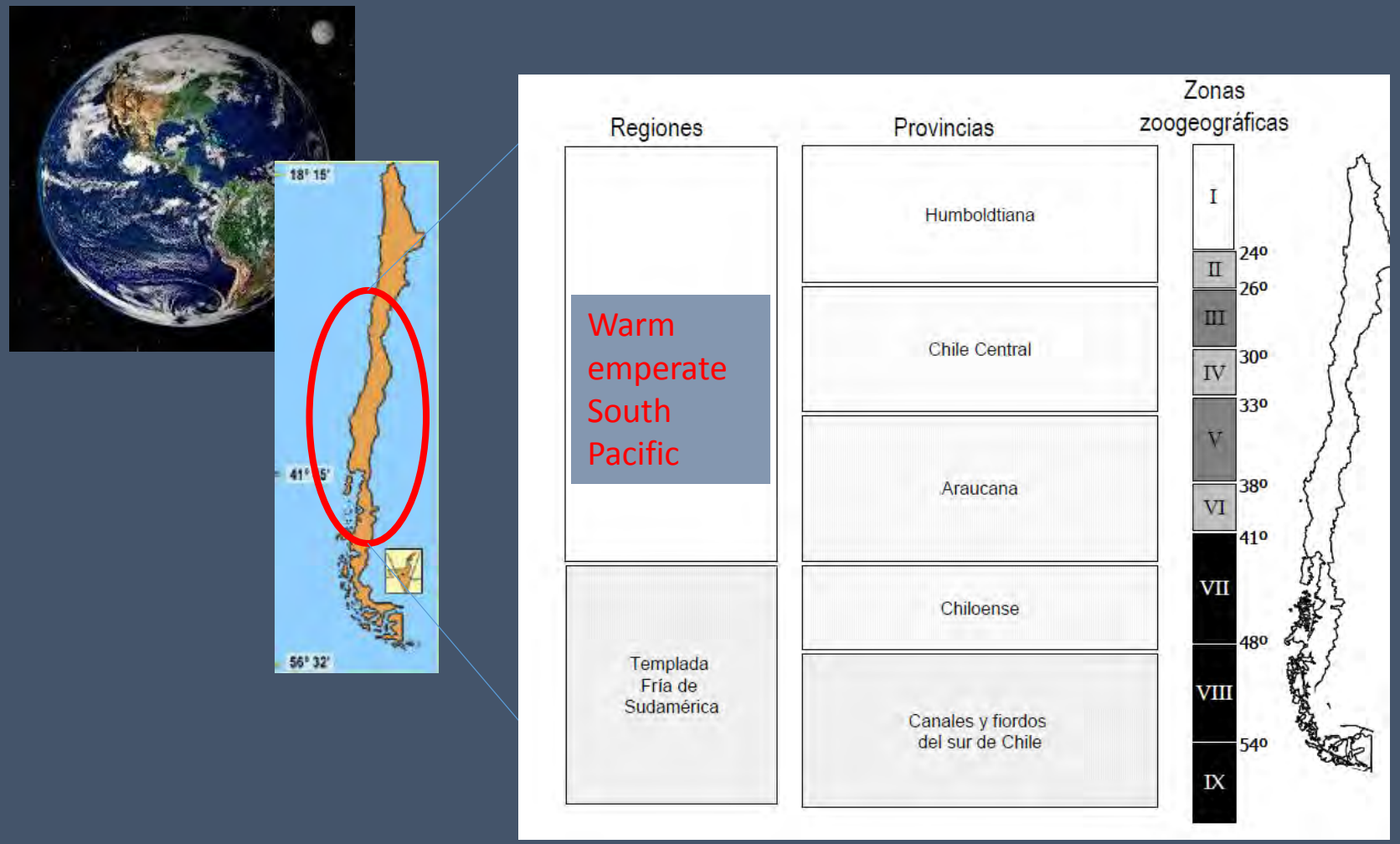
Structure of sizes according to macrozone VIII and IX-XIV



There are evident demographic differences between the north and south zones of 37° 10'S



Year	Región	%<9,0
2005	VIII	5,3
	IX-XIV	0,0
2006	VIII	54,3
	IX-XIV	6,0
2007	VIII	8,3
	IX-XIV	0,0
2008	VIII	42,2
	IX-XIV	0,7
2009	VIII	55,1
	IX-XIV	2,9
2010	VIII	44,4
	IX-XIV	7,6
2011	VIII	33,9
	IX-XIV	5,2
2012	VIII	76,1
	IX-XIV	23,0
2013	VIII	11,8
	IX-XIV	1,5
2014	VIII	9,8
	IX-XIV	4,6
2015	VIII	61,9
	IX-XIV	13,2



Humboldt Ecosystem

Between these regions and their boundary or transition areas, important exchange processes take place, such as marine currents and upwelling, sinking, divergence and advection, causing a high dynamism in the ocean, as a geographic environment, and on the physical directly influences

This image describes the process of constructing the classification of Chilean marine ecosystems. It was carried out during the year 2015-16

It is possible to consider these water bodies as relatively homogeneous units in physical, chemical and biological characteristics.
Intermediate ecosystem units, among which we will call ecosystems and what we call ecoregions.
Department of Planning and Biodiversity Policies of the Division of Natural Resources and Biodiversity of the Ministry of the Environment.

METHOD

- **The information of the fishery comes from the daily activity of the pelagic industrial and small scale fleet, obtain on board or in the landings monitored by IFOP in the main ports of the center-south zone of Chile. (IFOP, SSP)**
- **Historical patterns of major fishery, biological and environmental indicators.**
- **Monthly satellite surface temperature information.**

- Information (SST), satellite chlorophyll (Cloa) and geostrophic currents were incorporated. The TSM and CLOA MODIS are derived from the Ocean Color Web satellite data distribution program (oceancolor.gsfc.nasa.gov). On the other hand, the data of geostrophic currents came from the satellite altimetry data distribution program AVISO (www.aviso.altimetry.fr).
- **TSM images**, which come in ascending and descending format, were averaged and all global satellite data were cut to the area of interest.
- **Satellite SST data** (2002-2014) acquired from the Ocean Color Web allowed us to calculate the monthly climatology of the south-central zone of Chile, from which the SST anomaly was calculated.
- From the satellite SST, the surface gradient (GTSM) was calculated to represent the fronts of thermal origin present in the fishing zone.
- Numerically: Where C is the property (temperature) and ΔX is the zonal distance in Km that separates Ci + 1 from Ci. The intensity of these measurements showed a band in which the breaks associated with frontal zones near the coast move (Fedorov & Kuz'mina 1977, Fedorov 1985, Letelier et al., 2009).
- The daily data of the components of the geostrophic velocities allowed to calculate the magnitude of the current (Mag) Mag = (U2 + V2) 1/2. Daily sea level anomaly data, geostrophic currents and current magnitude were averaged monthly over the same period.
- TSM, ATSM, GTSM, Cloa and Mag

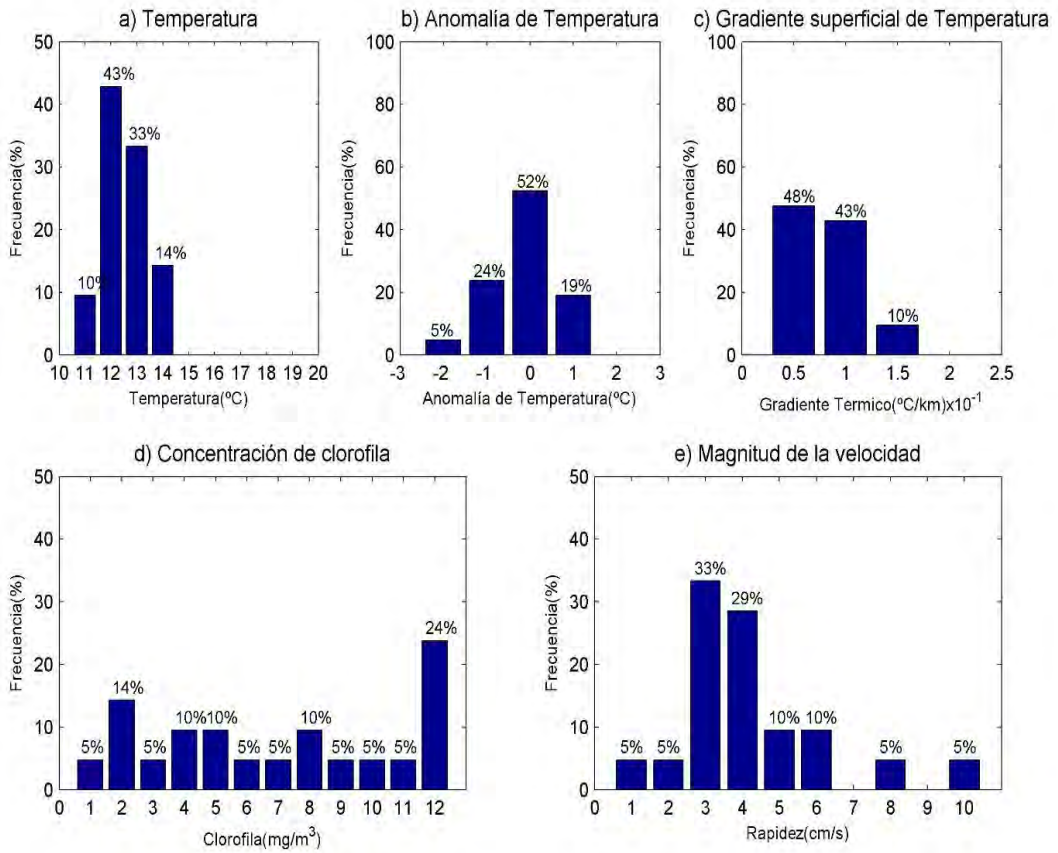
Phases life cycle				
	Eggs	Larvae	Youngs	Adults
Extension stage	3-4 days (1)	30-50 days	120-150 days	> 150 days
Nutrition/Diet	Protein/Vitello	Nauplii copepod, eggs, copepodites, dinoflagelaates, mollusk larvaes	Copepods, cirripedian larvae	Copepod, euphausiid, diatoms, invertebrates and fishes eggs.
Seasonality	Winter, Spring, Early Summer	Sprint, Fall, Winter	Spring, Summer	Fall, Summer, Winter
Geographic distribution	35°30'-39°40'S; 34°30'-37°10'S; 38°-39°S	36°30'S-39°00'S	34°30'-37°10'S 34°30'-38°11'S	35°30'S-39°00'S
Deeph of water column	0-40 m	0-45 m		0-50 m / 5-10m
Temperature (°C)	10.75-13.80	10.75-13.81	9.0-150	9.0-18.0
Salinity (psu)	32.0-34.5	30.0-34.0	33.0-33.6	30.0-34.7
Oxygen (ml/L)	5.5-6.7	6.0-8.0	3.5-6.5	3.5-8.0
Chlorophile a (mg/m3)	4.0-10.0	1.0-11.0		0.5-14.0
Winds (m/s)	3.0	3.0-11.0		3.0-11.0

Historical collection of bibliographic information about tehe cycle of life

Sets information;

Own and bibliographical information to characterize resource and environment

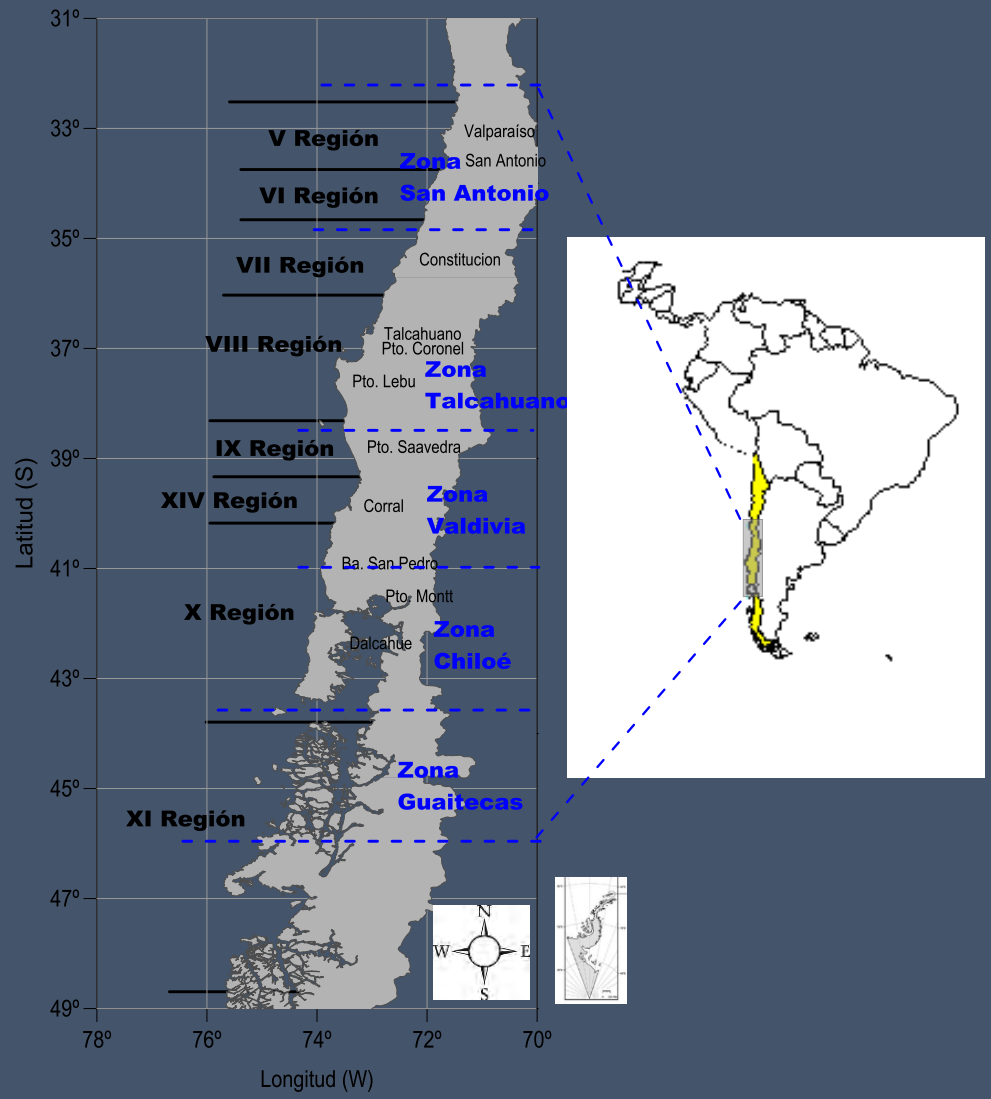
(A) SST, (b) ATSM, (c) Thermal gradient, (d) Chlorophyll concentration and (e) magnitude of geostrophic velocity between January of 2013 and December of 2014. The data correspond to 7.596 sets of fishing of the industrial fleet.



OBJECTIVE

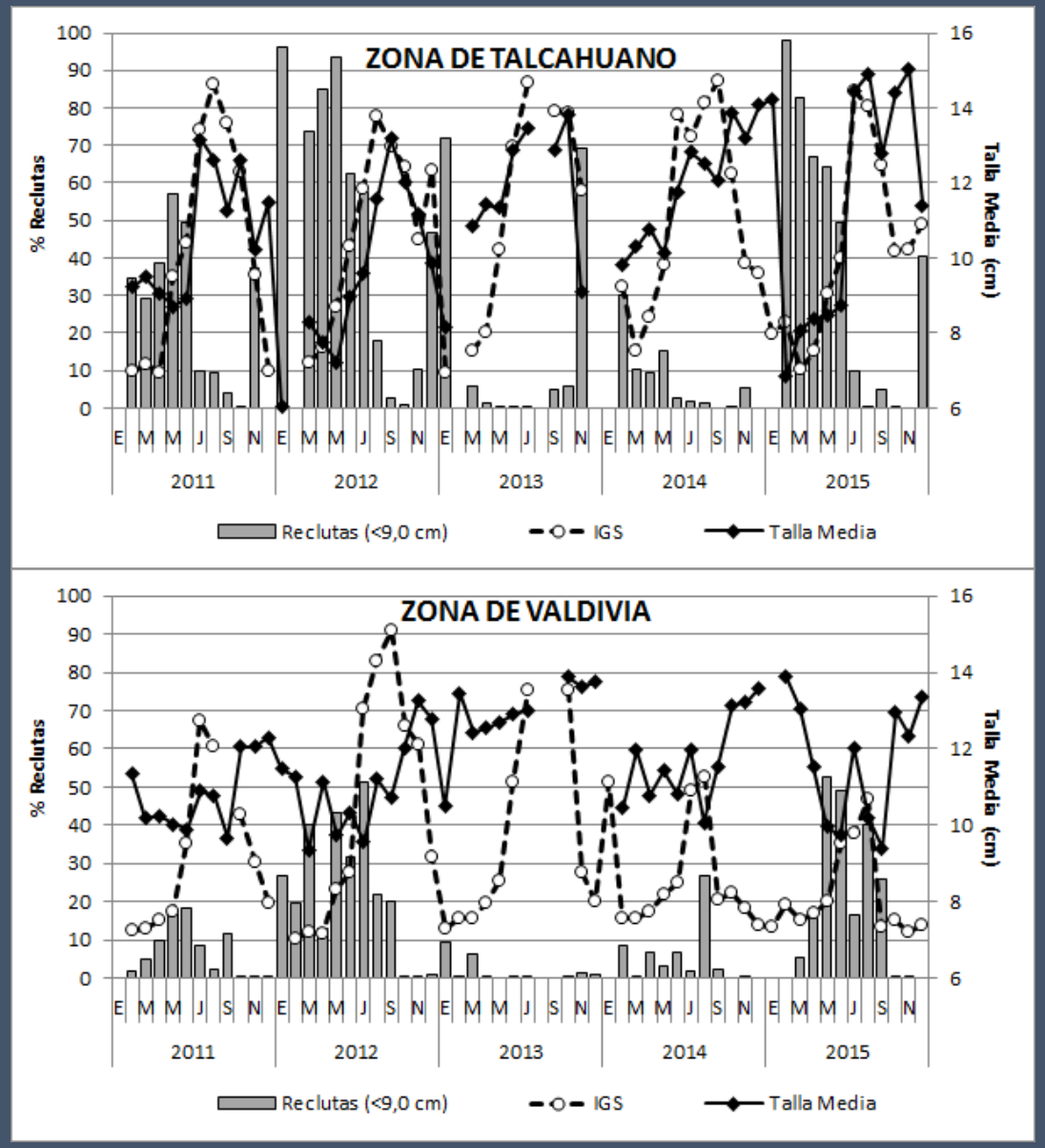
In two nearby areas of distributed the same population they manifest in different patterns of their main indicators of life processes.

Due to the high spatio-temporal variability in common sardines, related mainly to fishery exploitation and environmental changes, it is necessary to know the environment-resource relationship for the development of sustainable fisheries management over time.



RESULTS

Fraction ratios of recruits and common sardine spawners 2011-2015.

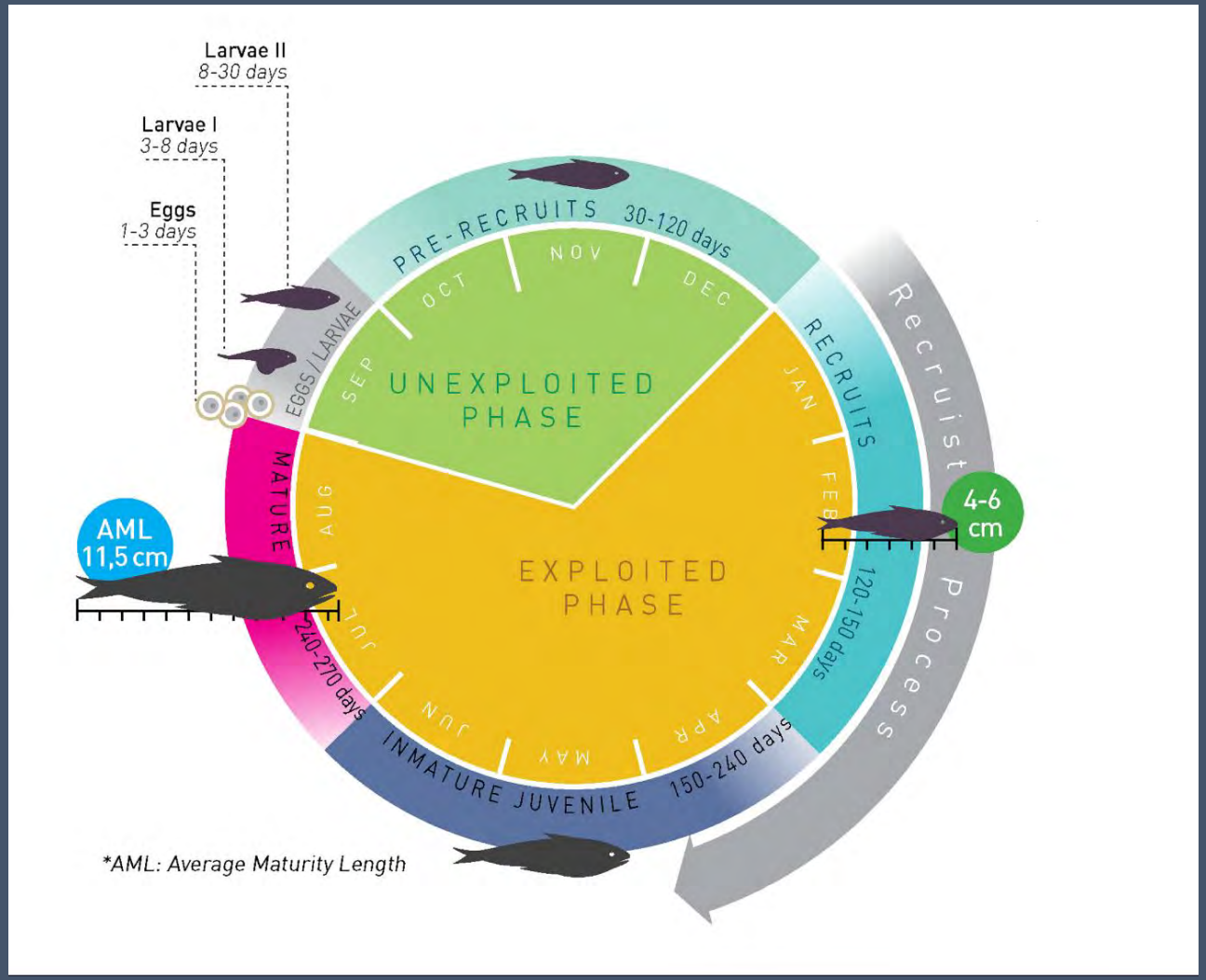


Evidence of decoupling of biological processes not explained by endogenous factors.

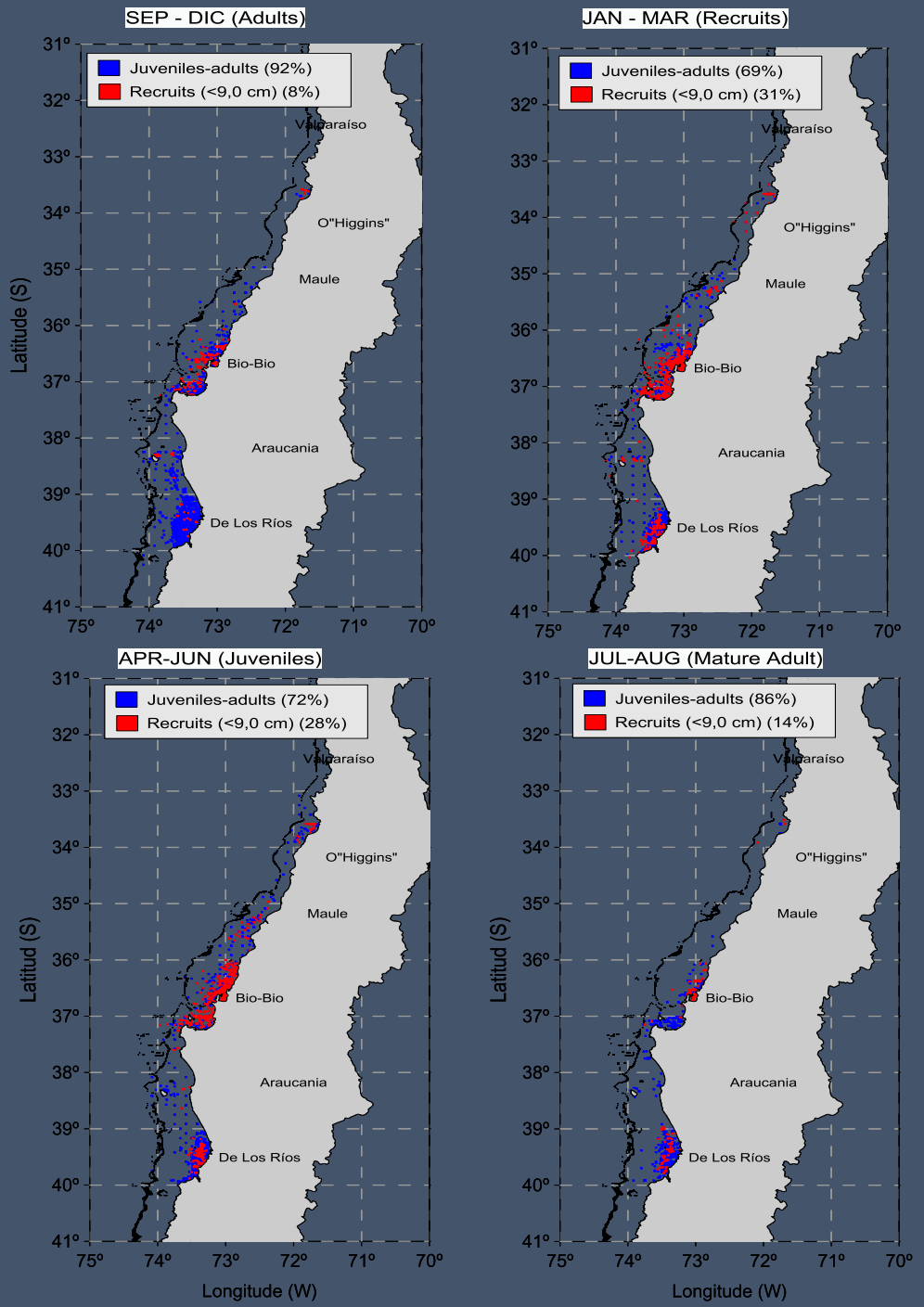
High or low reproductive processes are not consistent with recruitment, and are the subjects that are being addressed from an environmental resource point of view

Inter-regional unequal manifestations by magnitude and temporality.

Recruitment Proccess



- Seasonality: From summer to autumn the recruitment that sustains the great pelagic fishery of the south of Chile takes place
- Reference Sizes 8.5 cm TL.
- Process expressed in two main areas with unequal expression



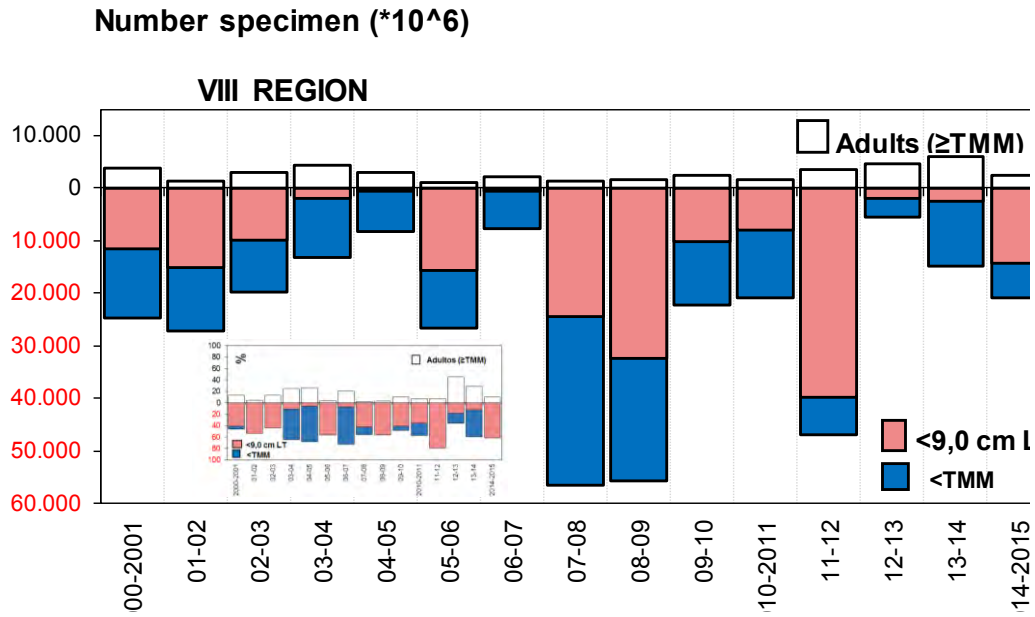
Distribution of sardines: Adults and recruits, according to period and process.

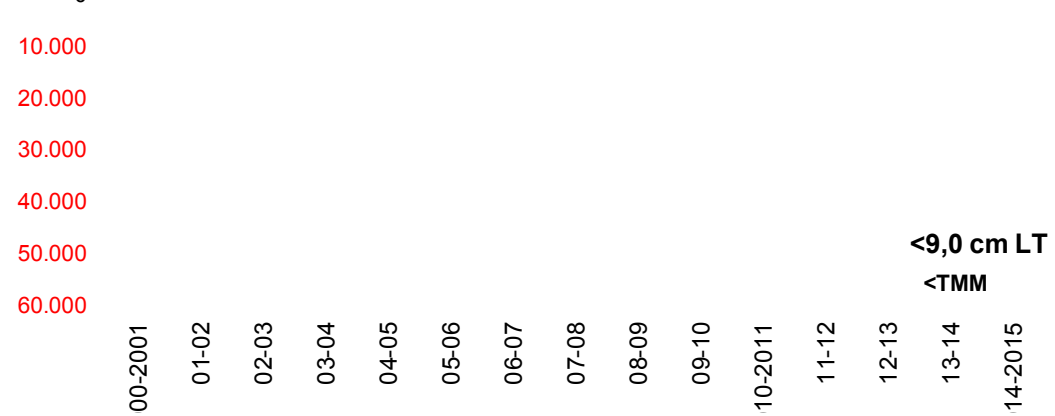
Youth-adult domain: September-December

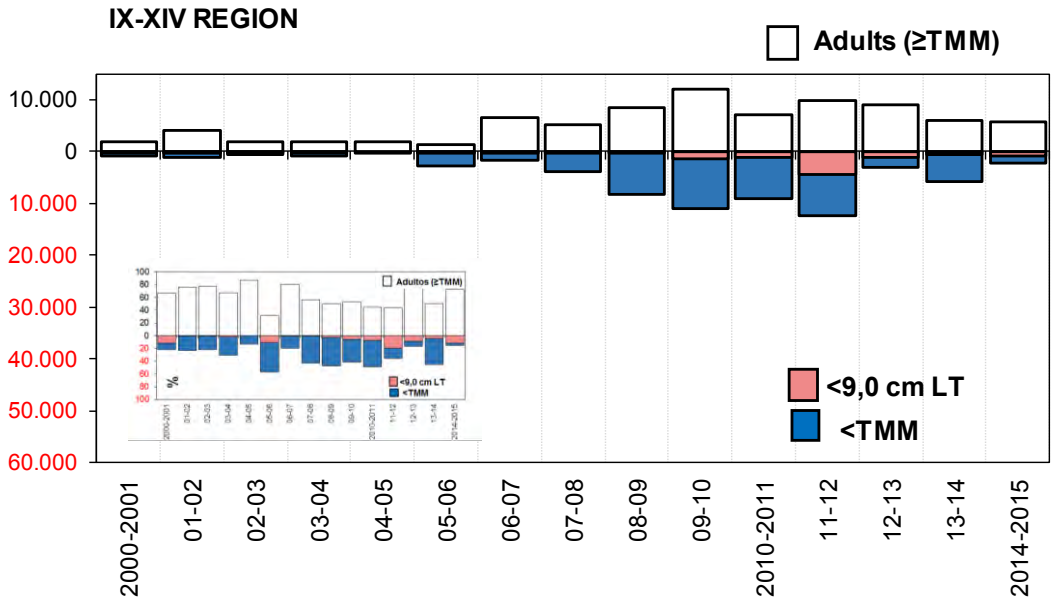
Recruit domain: January-June

The points on the map correspond to fishing bids or trips. For each of them, the percentage of individuals <9.0 cm (≤ 8.5 cm) was calculated. The periods of each graph is based on the infographics of the conceptual model. The blue: if the% is between 0 and 31, the size structure of the set or trip was dominated by adults The red: if the% is between 32 and 100, the size structure of the set or trip was dominated by recruits.

Annual recruitment of c

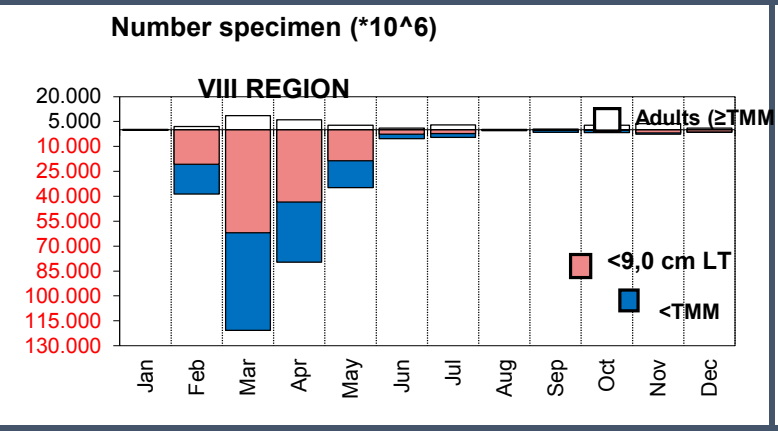


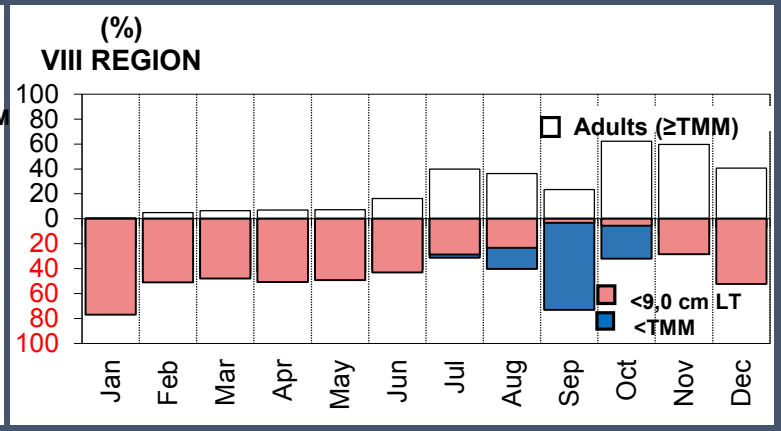


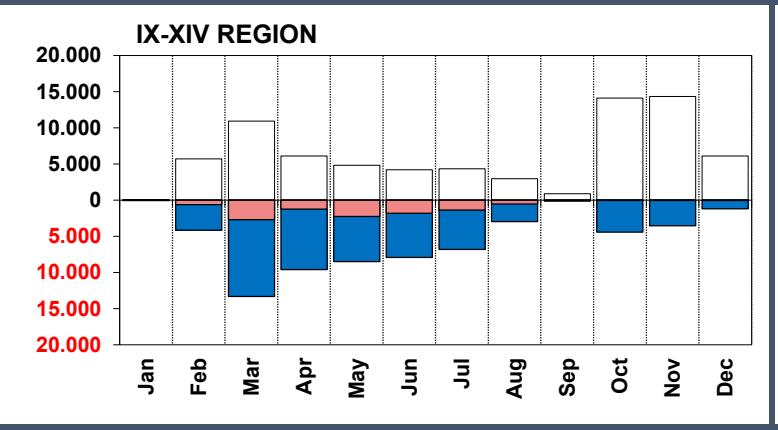


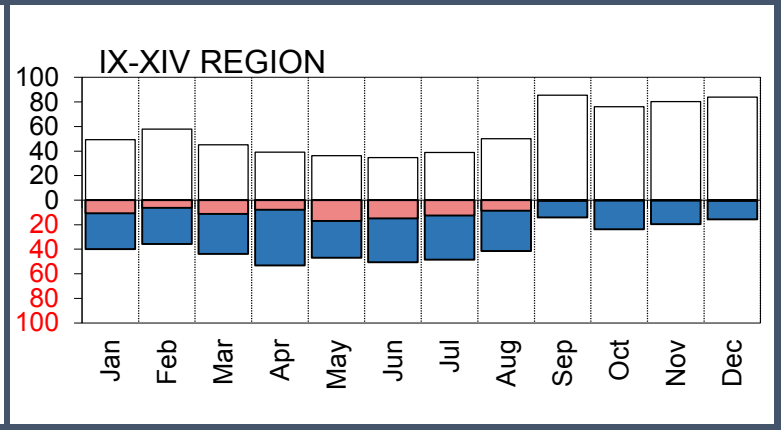
of juveniles especially in Region
in IX-XIV Regions

Seasonal recruitment of sardine, 2001-2015



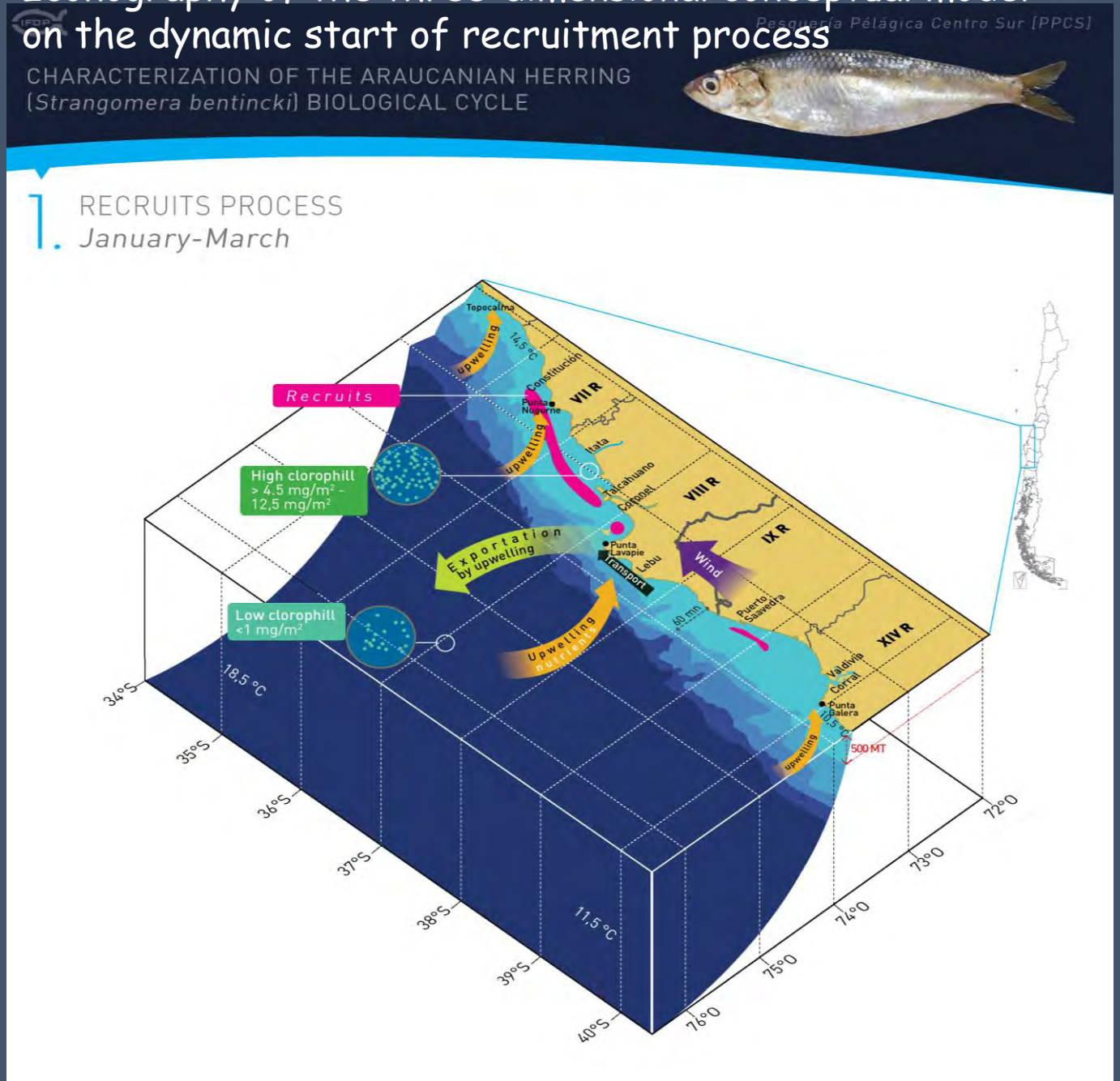






Incorporation of juveniles, growth and removal by catches and greater contribution of adults during the reproductive.

Iconography of the three-dimensional conceptual model on the dynamic start of recruitment process

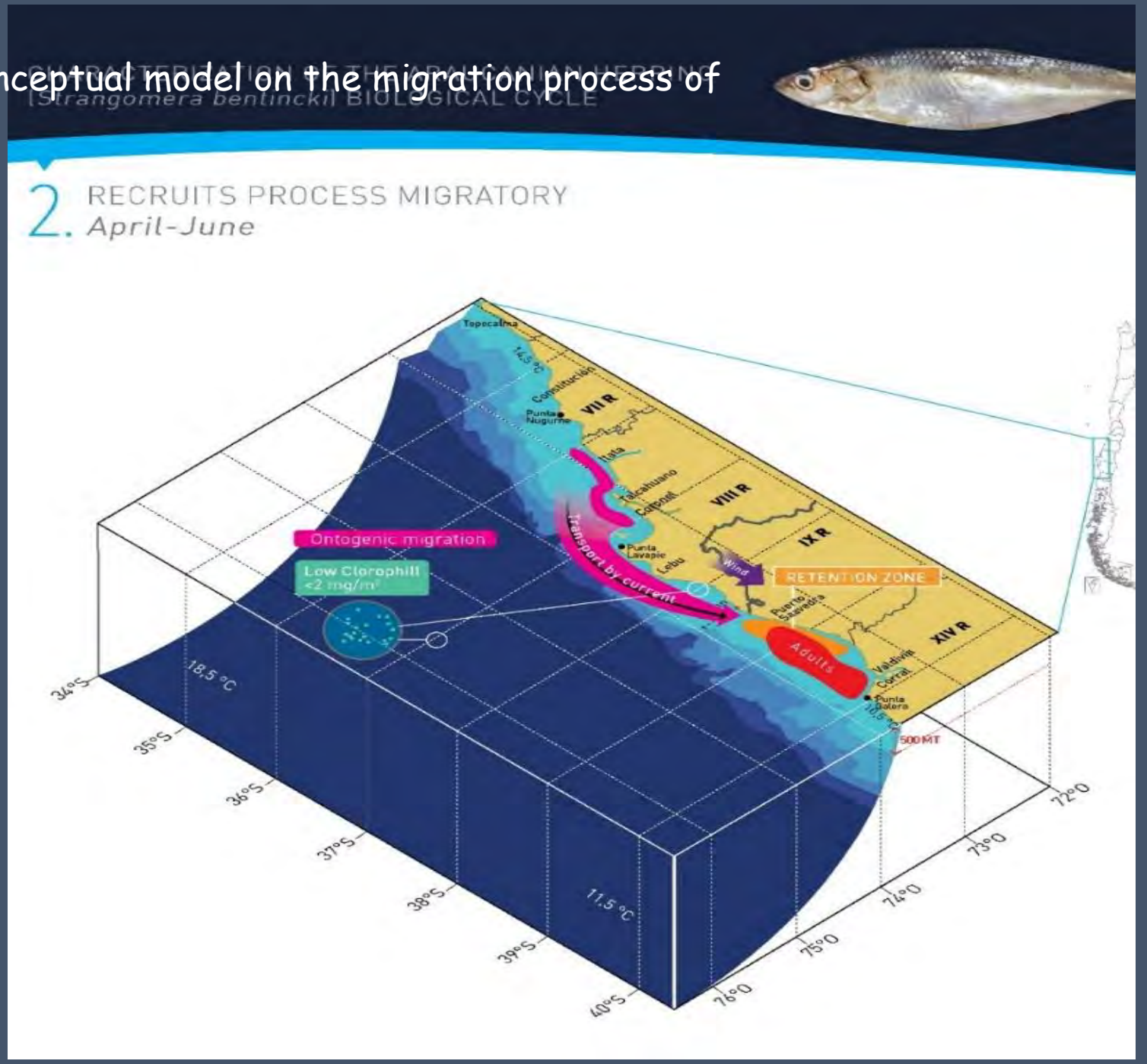


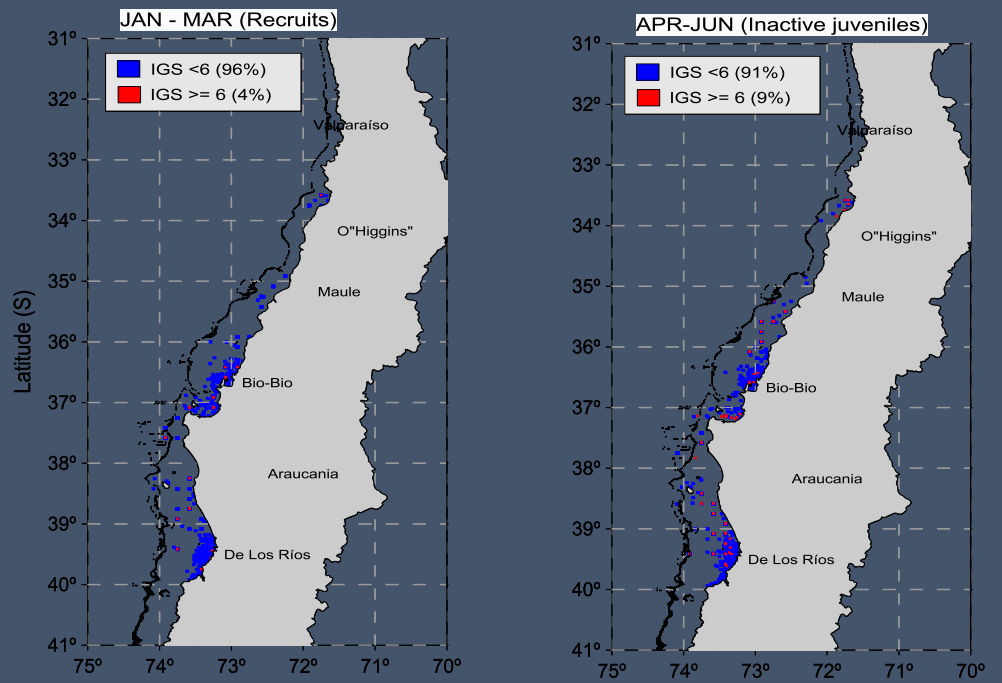
- the form of the coast and the continental shelf allow the wind towards the Ecuador to induce diverse seasonal outbreaks of coastal upwelling (Punta Curaumilla, Punta Topocalma, Punta Nugurne, Punta Lavapié and Punta Galera).

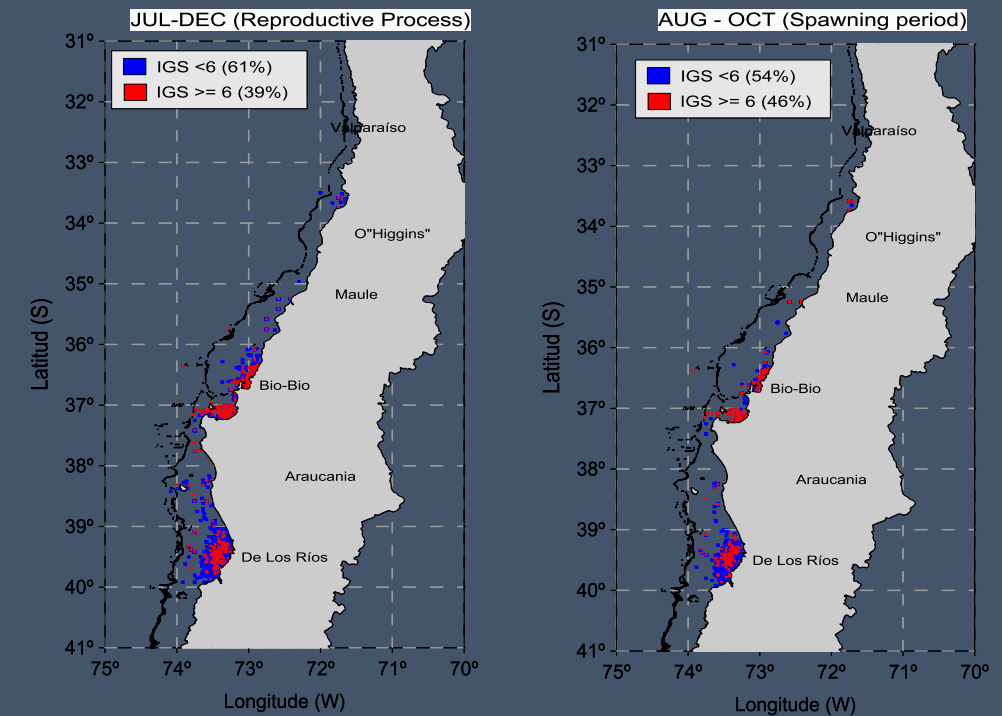
- A three-dimensional view of the ocean, as we move away from the coast and increase the depth of the sea, overlap water masses, with different oxygen content, temperature, and salinity, with species whose life cycle sometimes occurs at different depths And others that always live in a depth.

Iconography of the three-dimensional conceptual model on the migration process of recruitment

- A three-dimensional view of the ocean, show the displacement of juveniles from the north of 37 ° S to the south, forming a majority demographic structure of adults in the IX and XIV Regions.





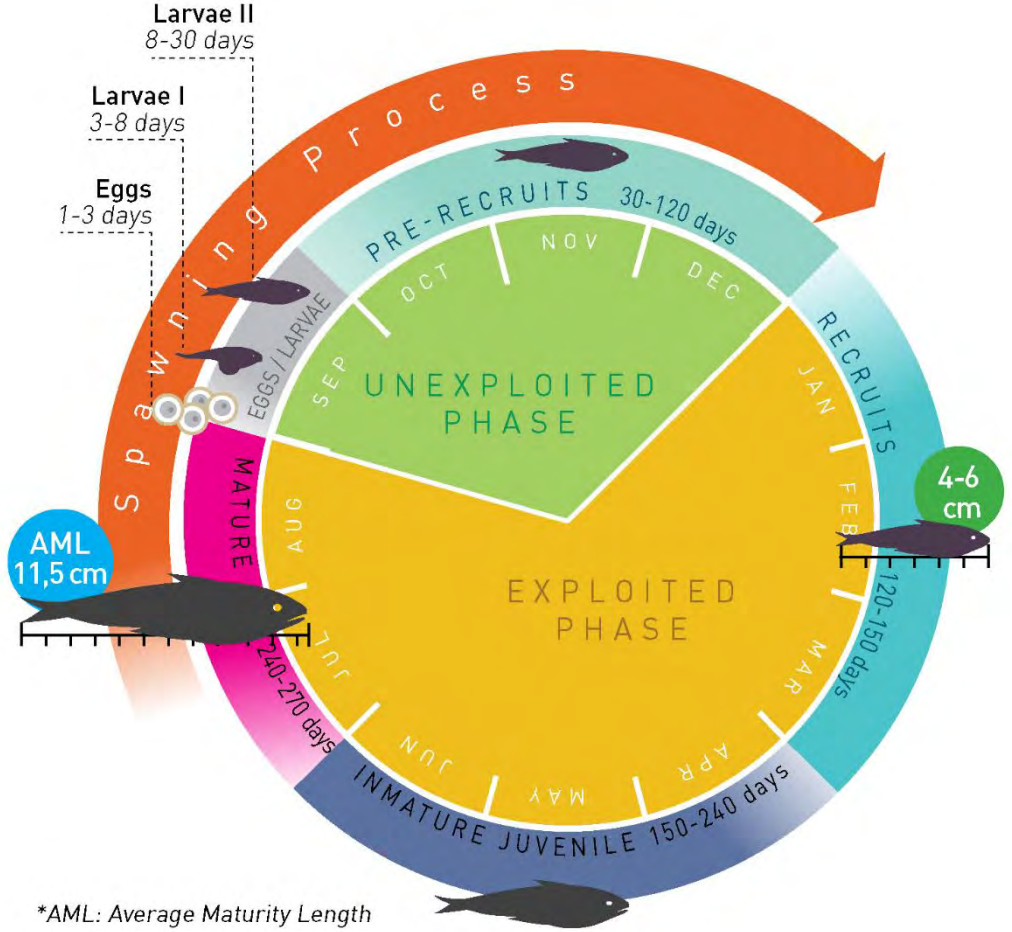


Dynamic distribution of sardin: actives and inactives, according to period and process. (1997-2015)

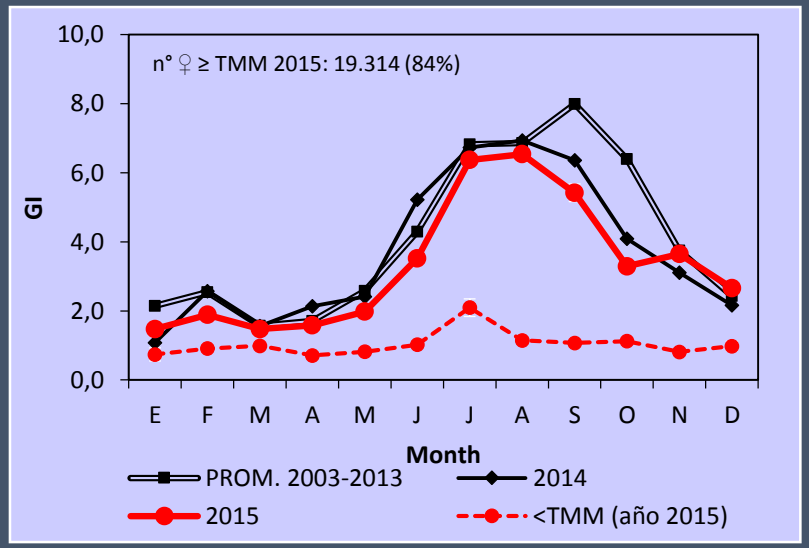
Between January and June: Reproductive rest

Between July and October Reproduction and partial spawning

Clearly done process in protected zones, retention and very coastal areas

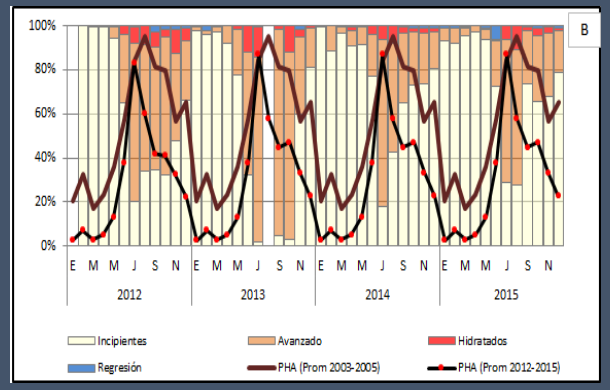


- **Reproductive conceptual model confirming spring spawning of specimens over 11.5 cm TL**
- As for the purely pelagic environment, we find groups of more coastal species, which usually reach small size and usually form schools, but for reasons of their life cycles are separate agglomerations of the rest (nerito-pelagic). Probably, for reproductive reasons they form schools more dense at certain times of the year.



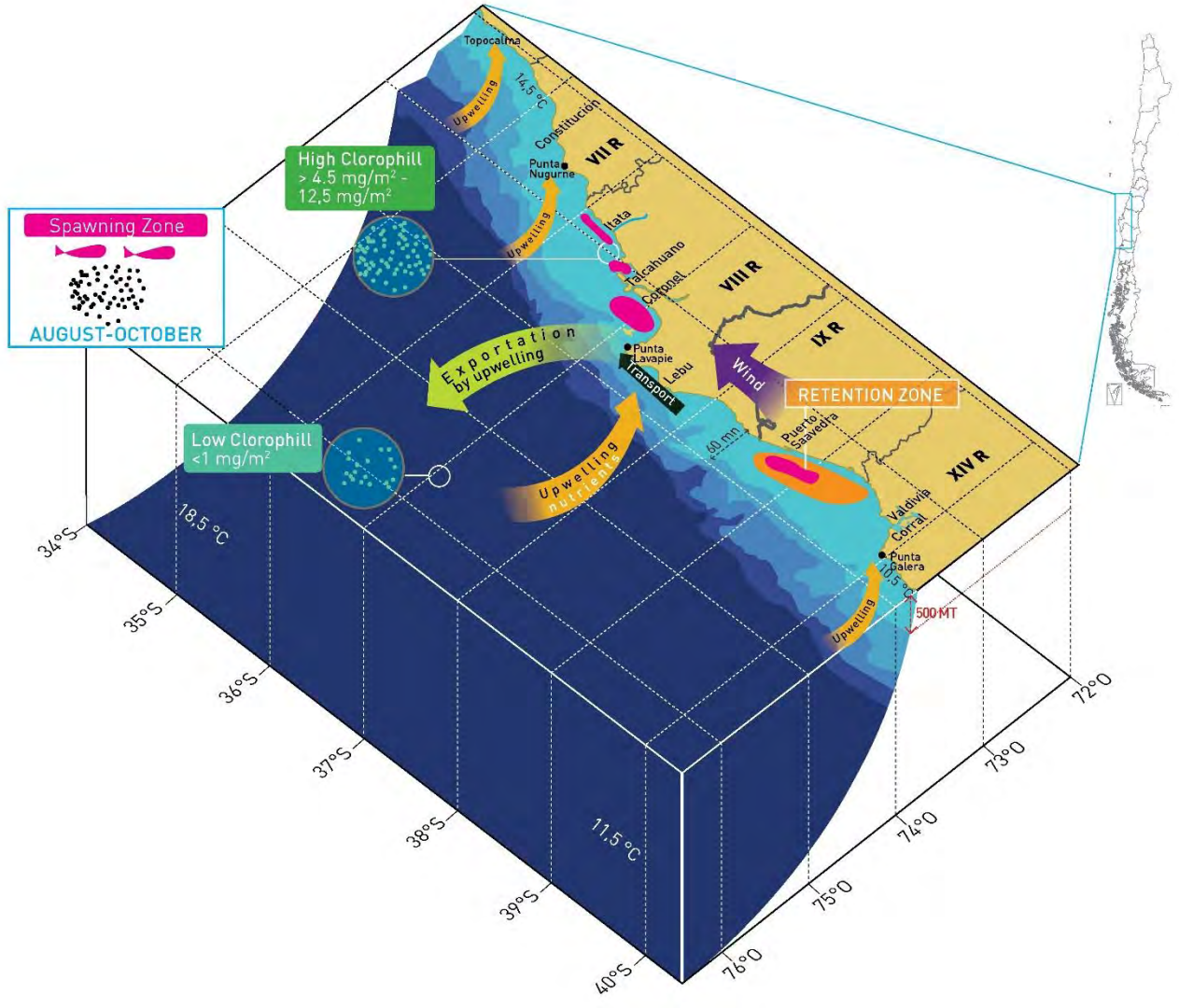
Reproductive Process

Process triggered in coastal protected or retention areas that present different environmental conditions which give rise to cohorts that face conditions that define their success to sotck and its fisheries.



CHARACTERIZATION OF THE ARAUCANIAN HERRING
(*Strangomera bentincki*) BIOLOGICAL CYCLE

3. REPRODUCTIVE PROCESS
July-December



CONCLUSIONS

- The spawning areas of the sardine are of high reproductive activity in the golf courses, bays and protected areas in Region VIII, but in IX-XIV there is an important less protected coastal retention area and the environmental conditions associated with the sardine. Contribution of the southern rivers and the environment less associated with upwelling, lower wind dynamics an important salt gradient generated by the river contribution which contributes to coastal retention.

- There are strong arguments for a disagreement between spawning and recruitment associated with environmental conditions and migration processes that define population segregation reflected in an unequal reproductive/recruitment in each macro-region.

- In-situ oceanographic studies associated with biological data need to be intensified to understand spatial connectivity and recruitment, including changes in resource availability, migration, synchronization, transport losses, or other factors. All contribute to a biophysical review of the life history processes of small pelagics.

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THE END
THANK YOU