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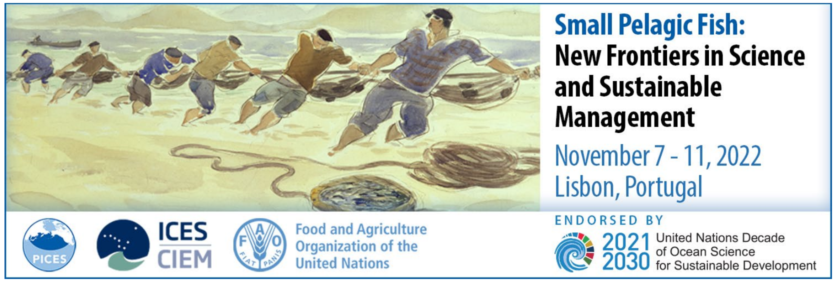

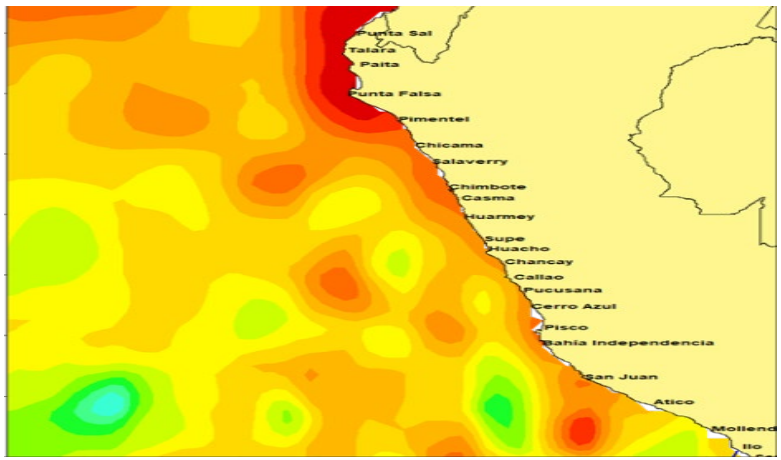

Relationship between oceanic vorticity and catches of Chilean jack mackerel (*Trachurus murphyi*) by the industrial purse-seine fishing fleet in Peruvian waters 2011 - 2021

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Introduction

- To contribute to model the Chilean Jack Mackerel (CJM) habitat, we related the vorticity in the ocean obtained from satellite data (cyclonic and anticyclonic eddies) to the availability of fish (CJM mainly) through the acoustic detection of structures such as internal waves.

- This was intended to demonstrate if the eddies are coupled to sub-mesoscale structures of the ocean that can be detected using sound.

- Surveying for fishing grounds makes it possible to direct fleets to the best available areas, in order to improve the efficiency and performance of fishing operations.

    - However, the cost of explorations is high. It is necessary to generate predictive tools (models) that allow to increase the efficiency of fish stock assessment and fishing operations.

    - The findings to be described are only representative for the adult fraction of the CJM population.

Data

- Information on fishing sets of Jack mackerel catches (2011-2021), > 7,000

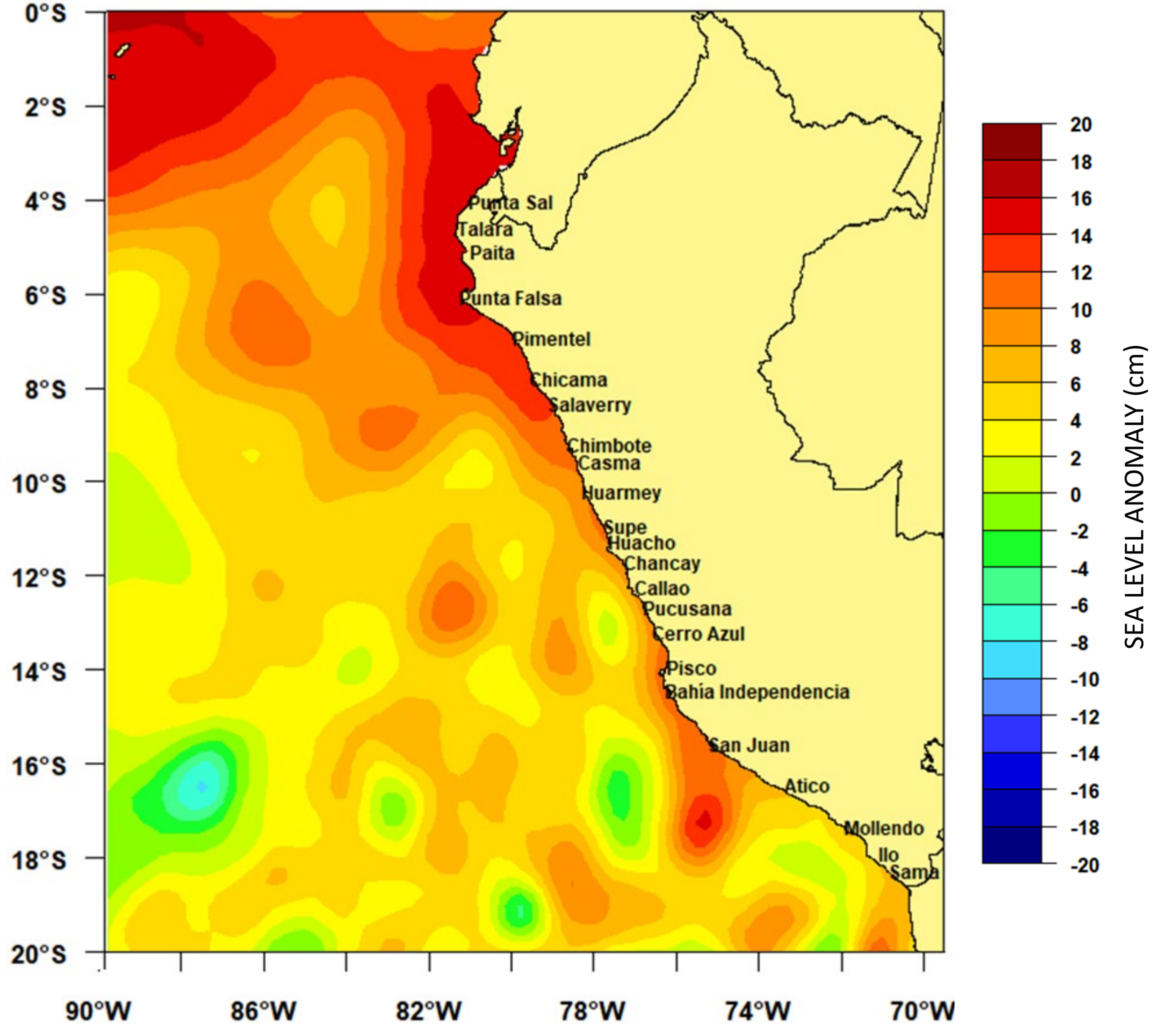
- IMARPE's raw files 38 and 120 kHz from 12 surveys 2011-2021. Over 72,000 ESDU were surveyed.

- Acoustic detections of fish schools of several species.

- Satellite data on sea level anomaly (SLA) from Copernicus (https://marine.copernicus.eu/). SLA data was generated weekly according to availability of catch data.

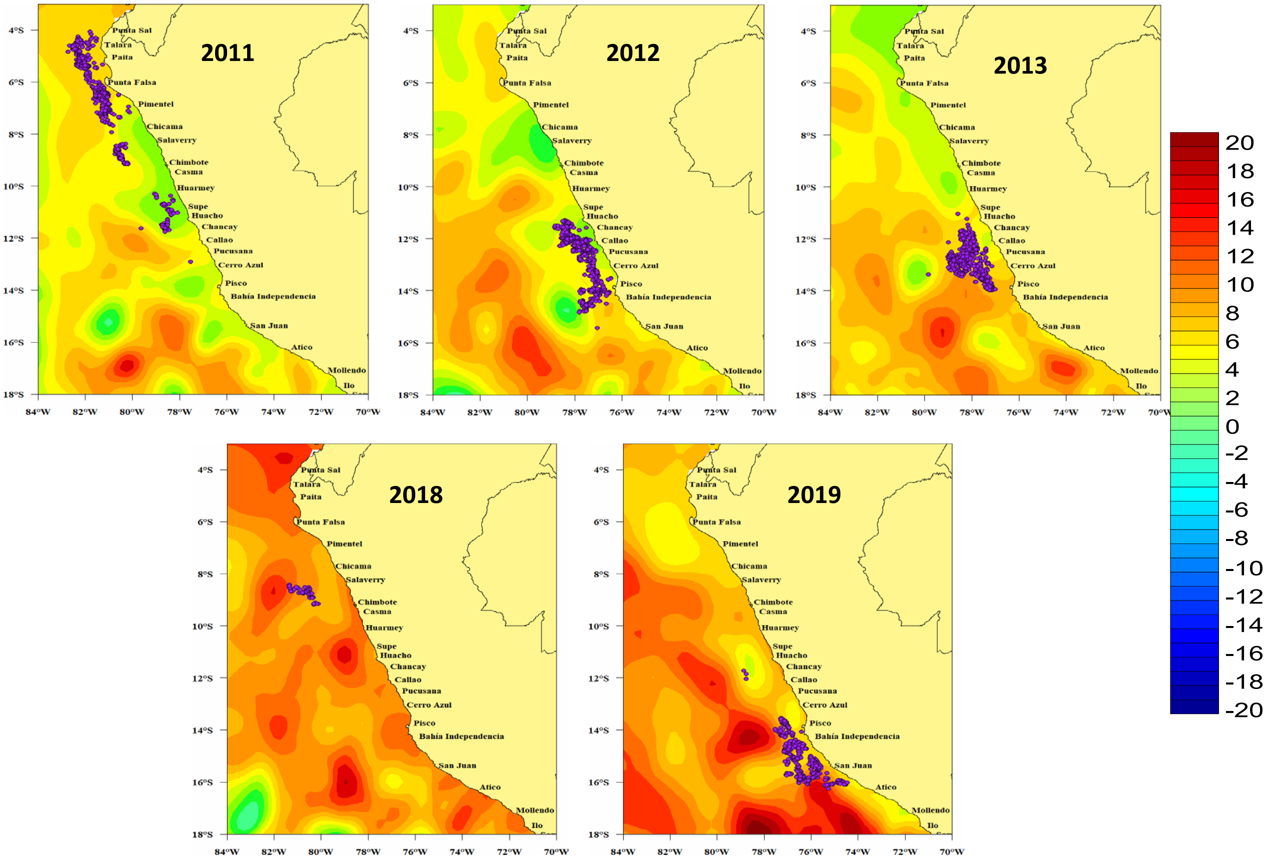
Methods

- Identification of cyclonic and anticyclonic eddies from SLA satellite imagery.
- GAM models to identify the SLA range of values for jack mackerel by years/seasons.
- Analysis of the acoustic abundance of macrozooplankton using the Ballon et al. (2011) dB-difference algorithms.
- Use of "Linea 98" algorithm to detect the ULOMZ.
- Wavelet analysis to detect internal structures along the upper limit of the oxygen minimum zone using the Grados et al. 2016 algorithms.
- Proximity analysis of detected schools by species during surveys in relation with location of detected sub-meso structures.



Results (1)

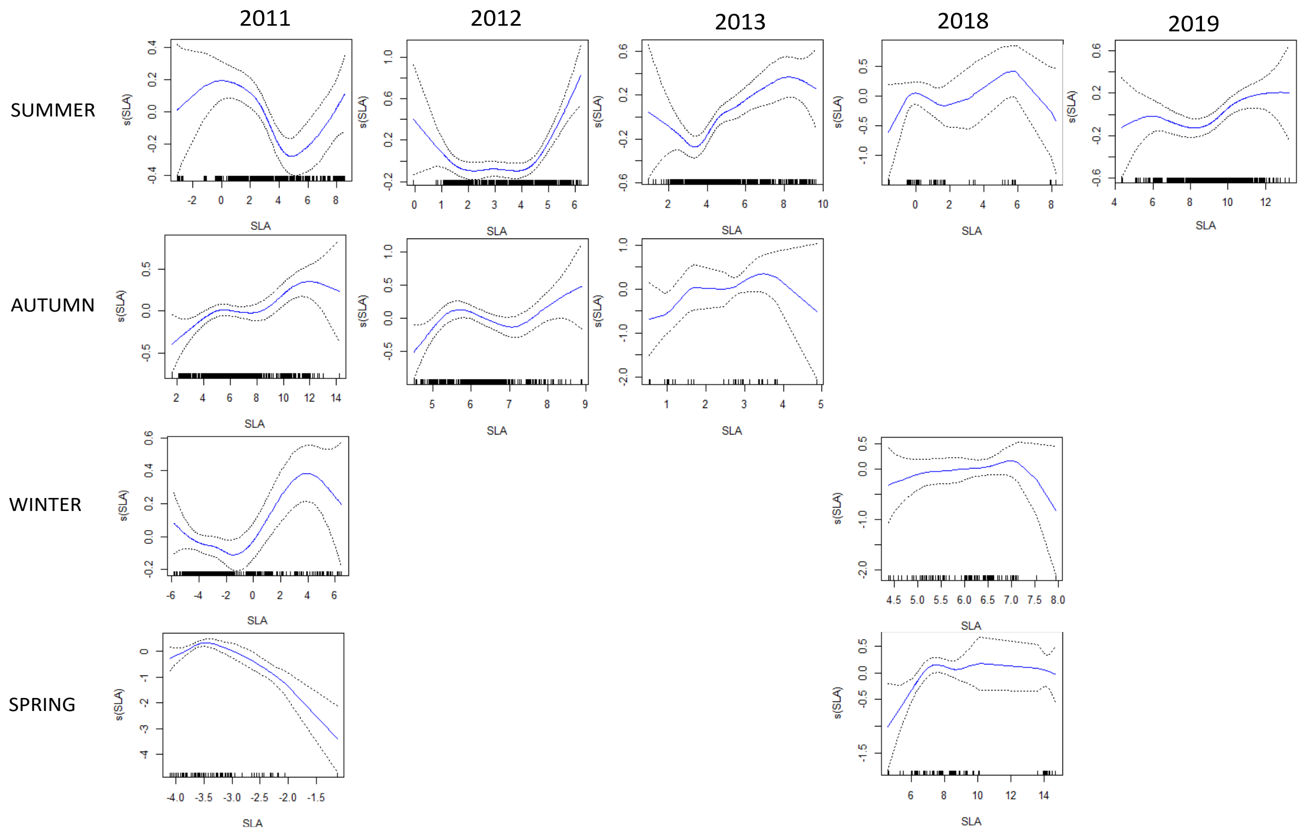
- Location of jack mackerel catches in 2011, 2012, 2013, 2018 and 2019 according to SLA values.



Jack mackerel catches by the industrial purse-seine fleet, during summers, by years between 2011 to 2013 and 2018 to 2019 (represented by purple circles), on SLA images constructed as averages for February months in the indicated years. The quasi-circular red color areas correspond to convergence processes (anticyclonic eddies in the southern hemisphere), and yellow and green colors correspond to divergence processes (cyclonic eddies).

Results (2)

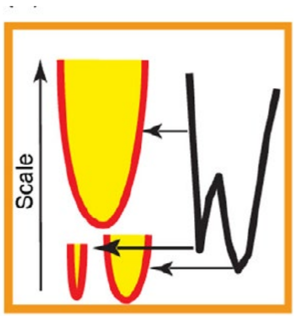
- Generalized additive models (GAM) of SLA values (cm) regarding CJM catches.



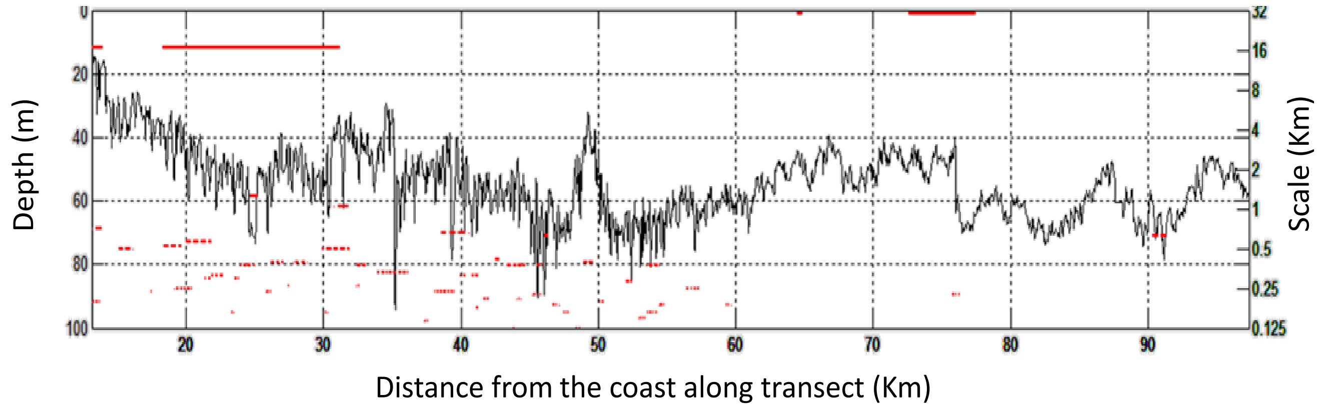
GAM models based on the logarithmic value of catches (blue lines) according to the sea level anomaly (SLA, in cm) by seasons between 2011 to 2013 and 2018 to 2019. The dotted gray lines represent the 95% confidence limits.

Results (3)

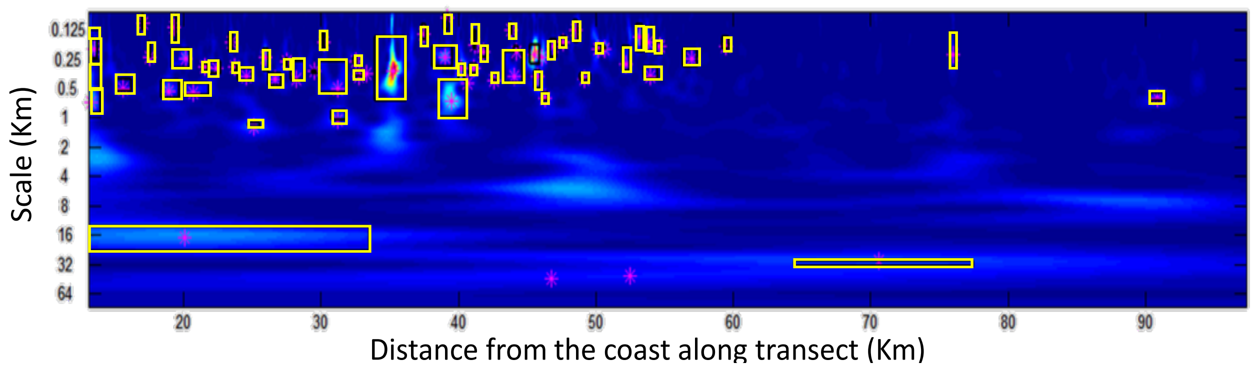
- Classification of sub-mesoscale structures from acoustic surveys (six types of structures)



Grados et al. 2016



Wavelet spectrum



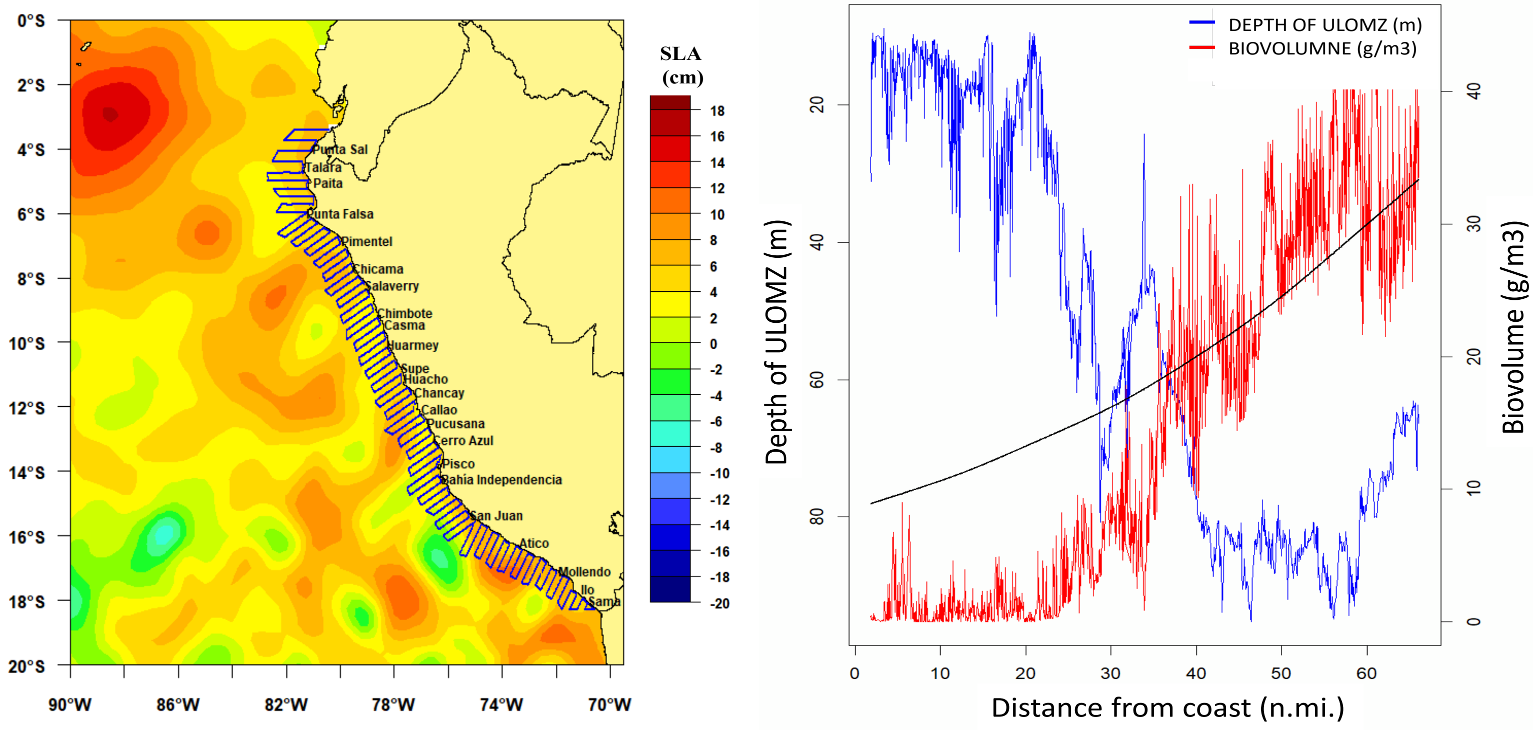
1 and 2: internal waves
3, 4 and 5: sub-mesoscales
6: mesoscale

Cluster type	1	2	3	4	5	6
Width (km)	0.91 ± 0.35	0.75 ± 0.26	0.83 ± 0.56	2.15 ± 1.19	0.79 ± 0.35	1.00 ± 0.99
Height (m)	2.27 ± 1.08	1.82 ± 0.48	2.63 ± 0.67	2.58 ± 1.05	1.83 ± 0.50	1.99 ± 0.63
Depth (m)	47.36 ± 30.98	40.30 ± 26.41	48.86 ± 28.07	53.13 ± 35.15	47.90 ± 26.45	53.01 ± 18.22
DS (m2)	7.74 ± 1.77	5.09 ± 1.36	16.48 ± 3.68	10.61 ± 1.91	4.69 ± 1.02	6.33 ± 1.34
DC (km)	60.53 ± 48.32	55.16 ± 44.52	86.46 ± 26.49	69.73 ± 49.78	94.99 ± 33.55	60.04 ± 38.63
DShelf	37.83 ± 52.76	21.96 ± 50.93	41.75 ± 48.98	41.35 ± 55.98	38.36 ± 55.58	3.05 ± 34.20
Lat (°S)	11.52 ± 3.82	10.54 ± 3.73	10.59 ± 3.92	11.12 ± 3.83	10.51 ± 3.71	10.66 ± 3.71
Lon (°W)	77.66 ± 2.74	78.24 ± 2.68	78.61 ± 2.71	78.06 ± 2.62	78.76 ± 2.63	78.35 ± 1.98
% cluster	20%	35%	21%	5%	10%	9%

Sample of results on the detection of physical structures in the ocean along a 90 km long transect (top panel), where the yellow rectangles (mid-panel) highlight the 6 types of clusters (bottom panel) that have been detected. Notice the fluctuations of the upper limit of the oxygen minimum zone (ULOMZ, black line) along the transect (top panel), where the horizontal red segments correspond to different structures detected using the wavelet analysis.

Results (4)

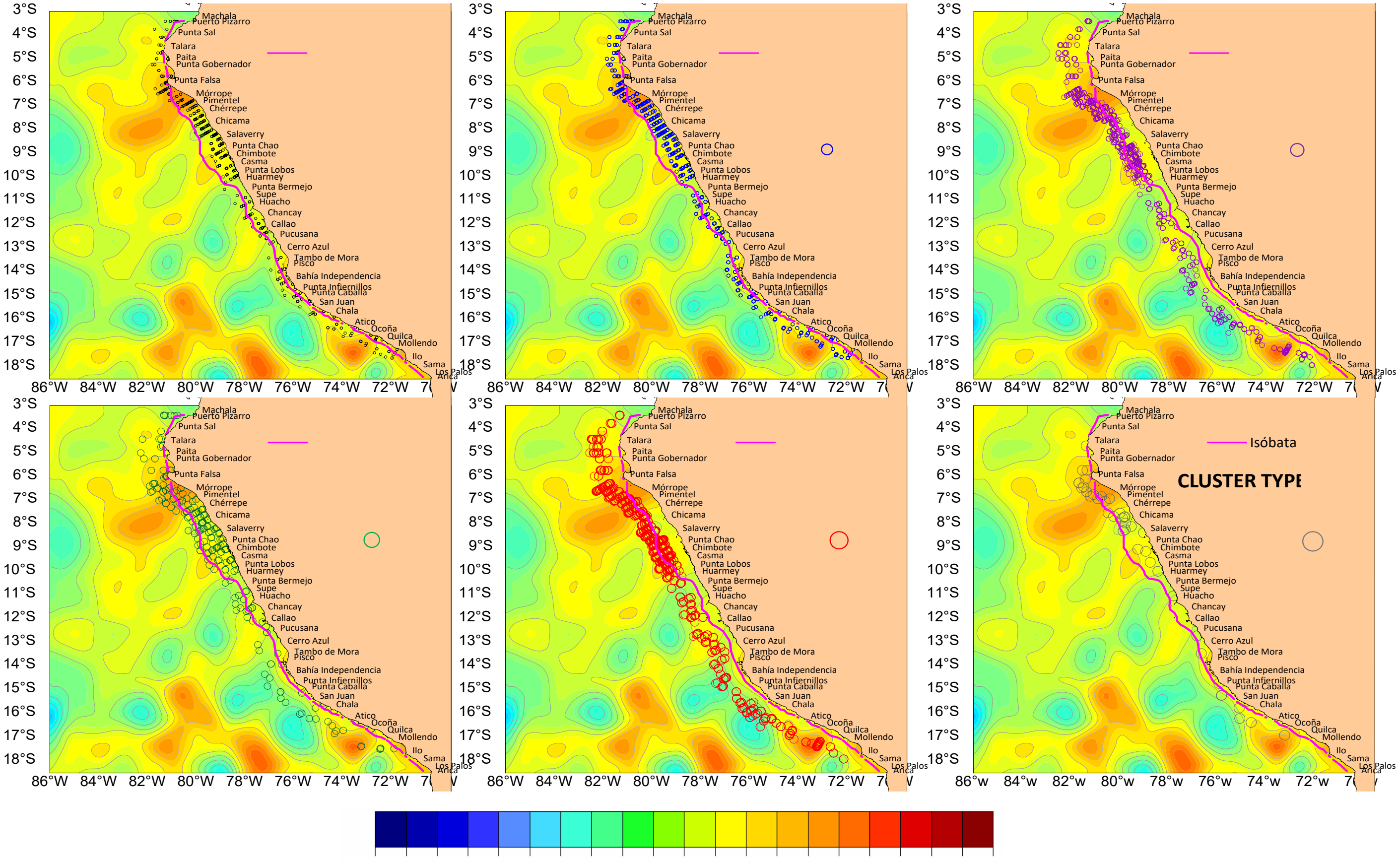
- Relationship between the depth of the upper limit of the oxygen minimum zone (ULOMZ) and the acoustically measured biovolume of macrozooplancton (euphausiids, copepods).



Left panel: overlap of an SLA image with transects surveyed by IMARPE during summer 2011 (indicated by black lines). The red and orange areas correspond to convergence processes (anticyclonic eddies) and the light blue and green areas correspond to divergence processes (cyclonic eddies). Right panel: relationship between ULOMZ (m) and biovolume of macrozooplankton (g/m3) along a sample transect (in n.mi.), where it is noted that the highest values of biovolume are reached at deeper ULOMZ.

Results (5)

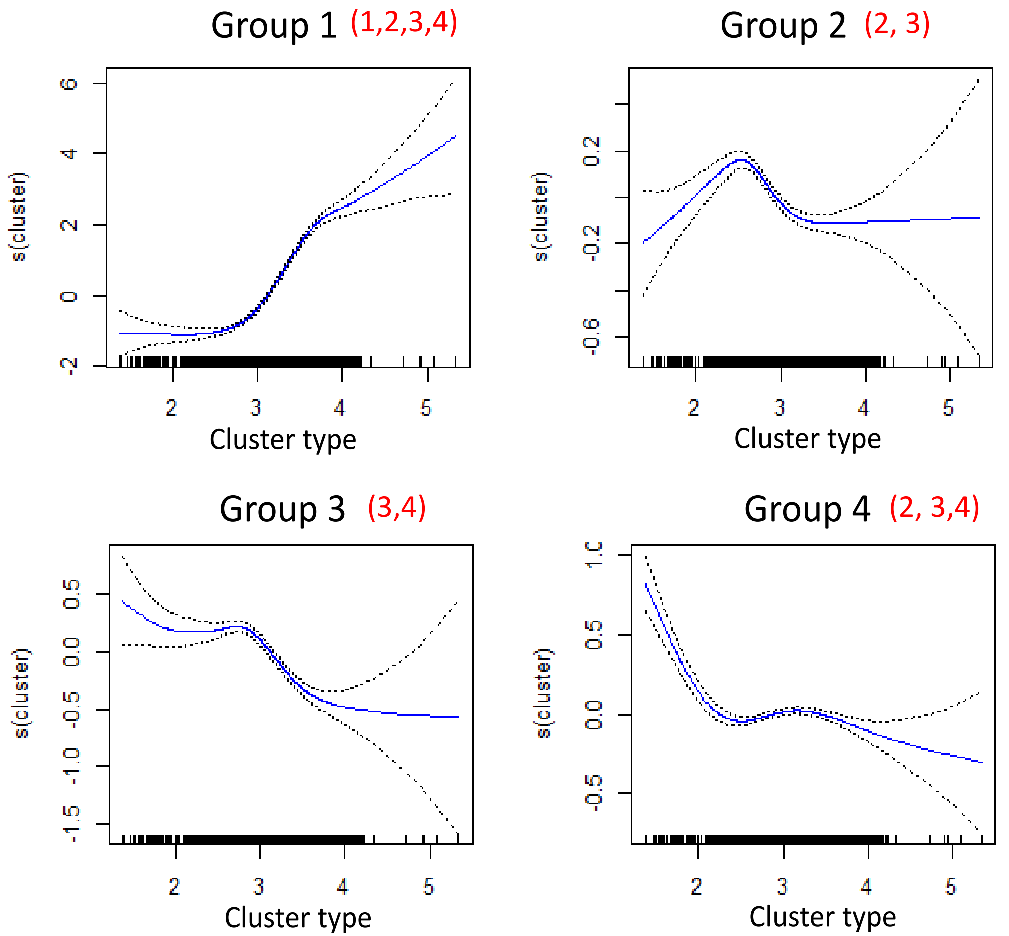
- Pre-definition of probable fishing areas using information on sub-mesoscale structures.



The six type of sub-mesoscale structures (classified by clusters) superimposed on the averaged SLA image obtained during the summer acoustic survey 2011 (cyclonic eddies correspond to negative values while anticyclonic eddies correspond to positive values). Each panel contains the location of detected internal structures represented by different colors and size symbols. Clusters type 1 are smaller and clusters type 6 are larger.

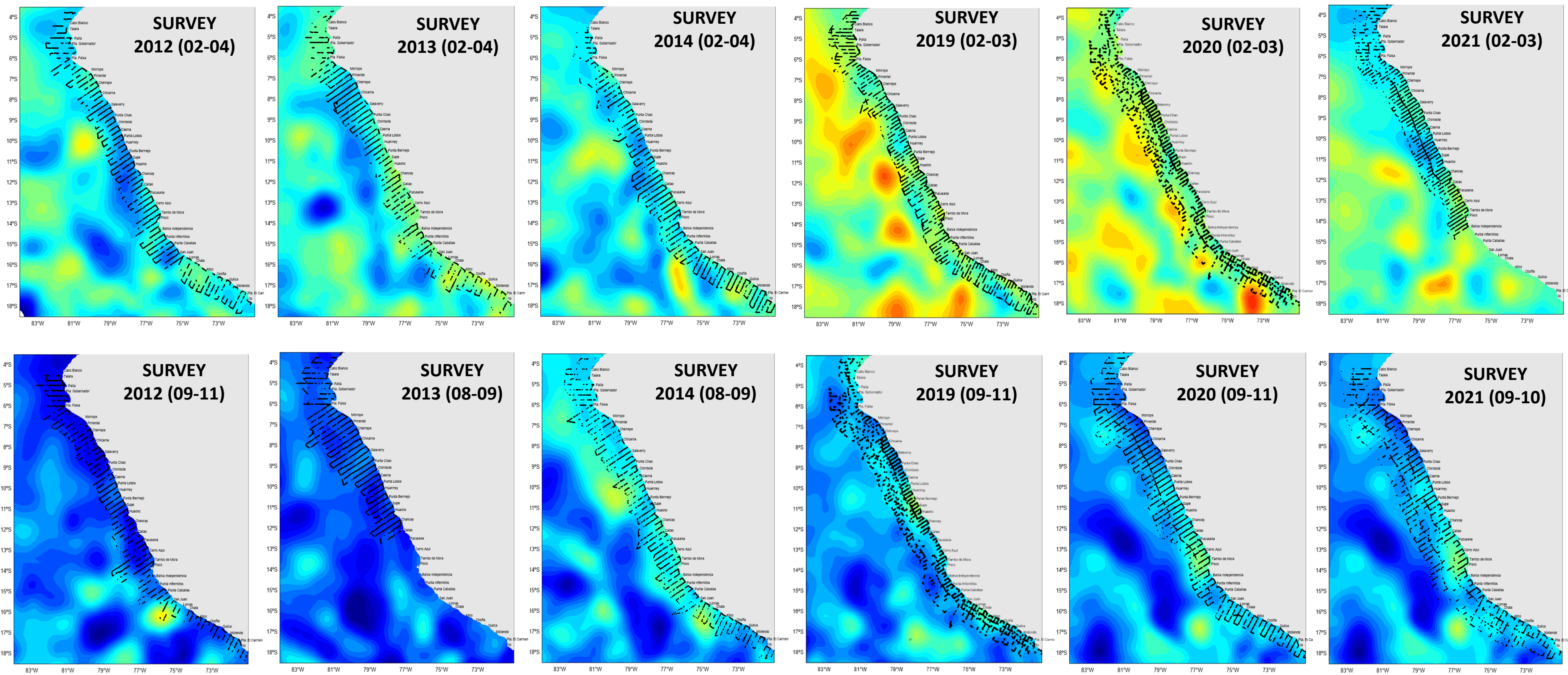
Results (6)

- Correlation of the six identified structures with four group of species detected during surveys



GAM analysis results based on the logarithmic value of NASC by groups of species (blue lines) according to cluster types. **Group 1** (coastal): anchoveta (*Engraulis ringens*), white anchovy (*Anchoa nasus*), red squat lobster (*Pleuroncodes monodon*) and catfish (*Galeichthys peruvianus*); **Group 2** (oceanic): jack mackerel (*Trachurus murphyi*) and chub mackerel (*Scomber japonicus*); **Group 3:** mesopelagic fishes; and **Group 4**: jumbo flying squid (*Dosidicus gigas*).

Discussion



Detected sub-mesoscale structures by surveys (2012-2021) over averaged SLA images.

- Large number of detected structures in every scenario/year/season.
- Large scale vorticity (eddies) not related to sub-mesoscale structures.
- SLA is then a limited predictor of CJM availability.

Conclusions

- To detect the ULOMZ is key: Higher concentration of macrozooplankton and fish, including CJM matches the areas where the ULOMZ is deeper and coincident with internal sub-mesoscale structures.

- Higher concentration of macrozooplankton and fish in the zone of convergence between cyclonic and anticyclonic eddies.

- From the above it can also be concluded that:

  - SLA is useful for predicting fishing grounds of CJM just under certain circumstances (e.g. across positive values and when vorticity occurs near the shelf break).

  - The group “2” of species including CJM and chub mackerel have a high degree of correspondence with the so-called cluster types 2 (internal waves) and type 3 (sub-mesoscale structures).