What indicators for answering the "simple" question:

How is the population of Jack Mackerel evolving in the SPO ?

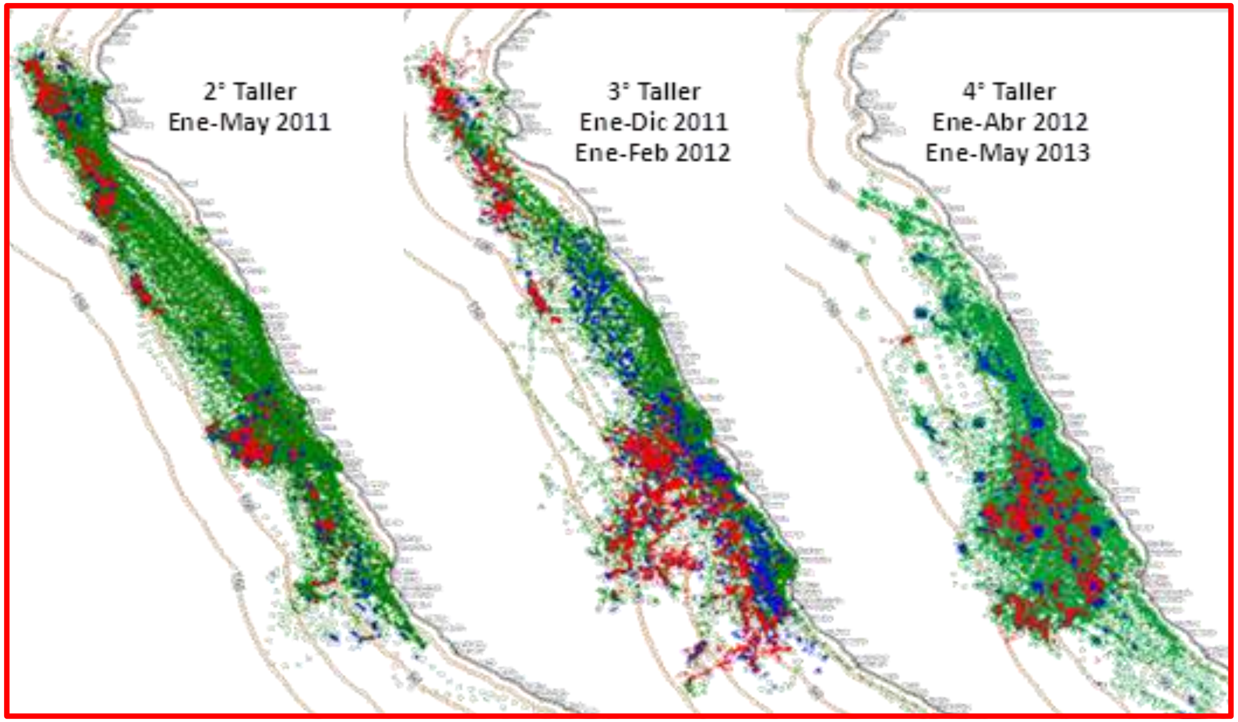
This requires studies on:

1. **The interactions between the CJM and the environment**
2. **The interactions between the CJM and the fishery**
3. **The major biological characteristics of CJM and their variability**

Some examples from the series of
S.N.P. WORKSHOPS ON DIAGNOSIS ON THE STATUS OF THE CHILEAN JACK MACKEREL (*TRACHURUS MURPHYI*) IN THE PERUVIAN FISHERY
March 2011; June 2011; June 2012; June 2013

Sociedad Nacional de Pesquería

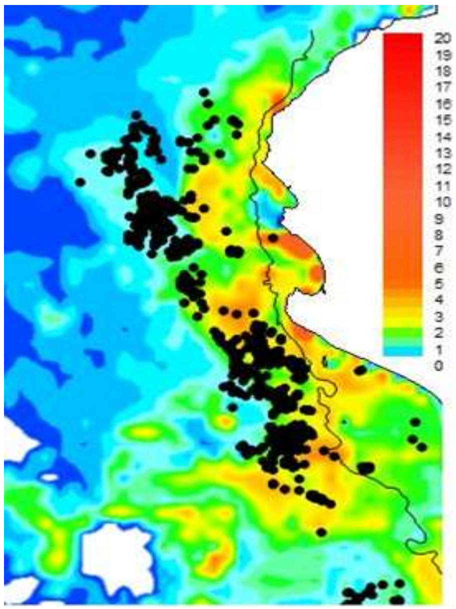
1. The interactions between the CJM and the environment



Distribution of fishing operations of the industrial fleet, during years 2011, 2012 and 2013. Red dots displays the set actually performed and reported; blue dots displays sets that were not reported. Green dots display the hourly position of all the vessels as recorded through VMS (SISESAL).

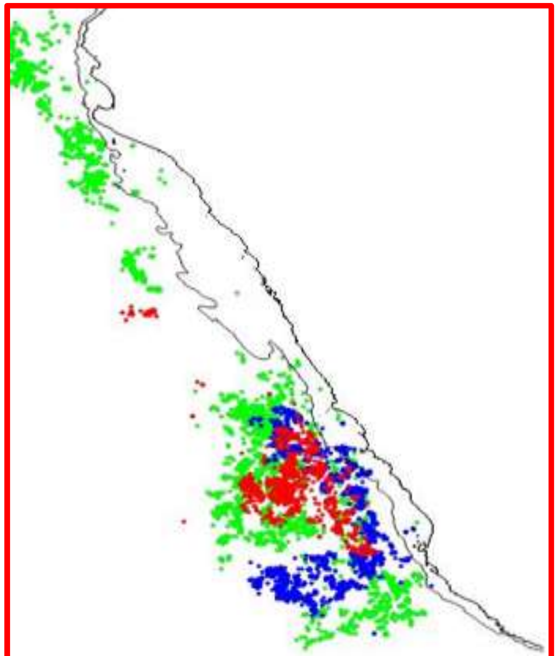
- Definition and mapping of the habitat
- the environmental limits and preferenda

Some examples of results on the relationships between the main characteristics of the environment and the CJM distribution (obtained using data from the fleet)



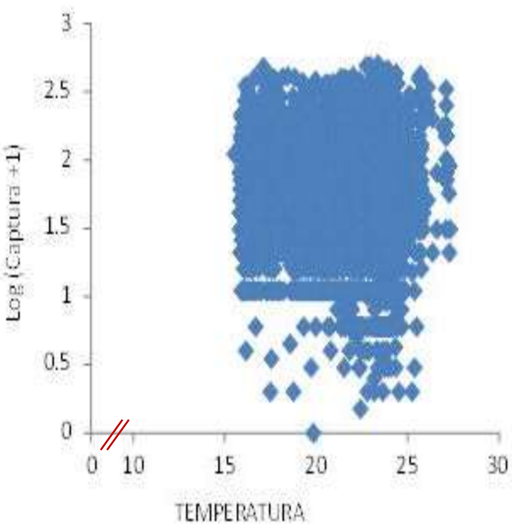
Distribution of the sets in the north of Peru in relation with the Chlorophyll a.

Highest concentrations of jack mackerel found in the surroundings of the high concentrations of Chl-a, within a range of 0.13 to 5.0 µg/Lt.m.



Purse seine sets on jack mackerel and mackerel in 2011 (green dots), 2012 (blue dots) and 2013 (red dots) along the Peruvian coast:

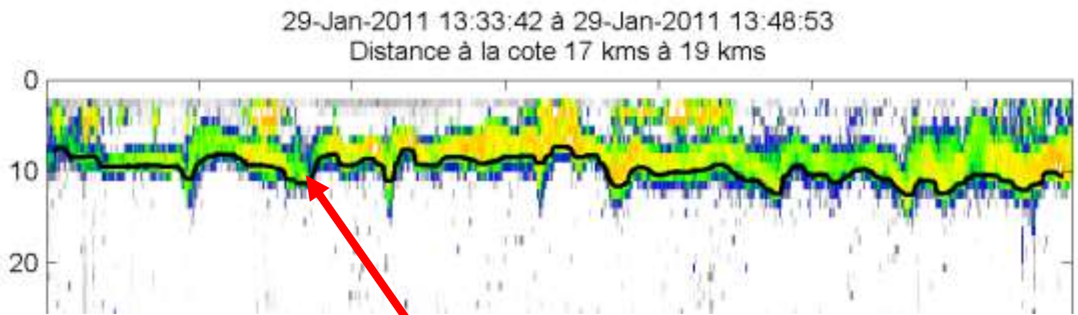
CJM are not observed above the continental shelf



Relationships between catch per set and SST (2011 to 2013)

Fish are not observed in waters below 15º and above 28º

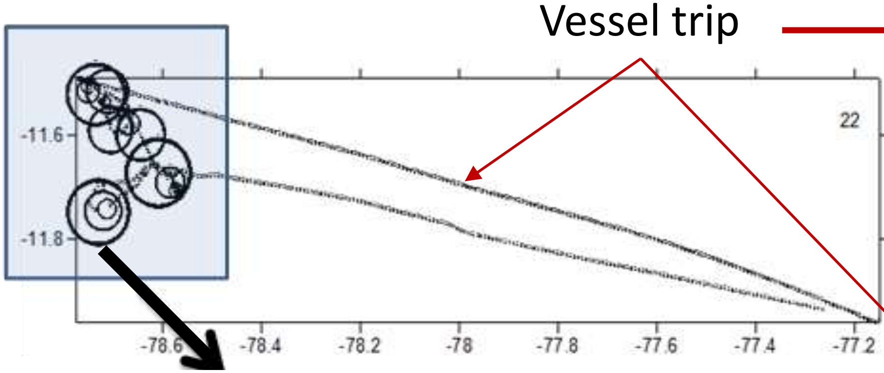
Effect of the oxycline depth (not studied yet in the workshops)

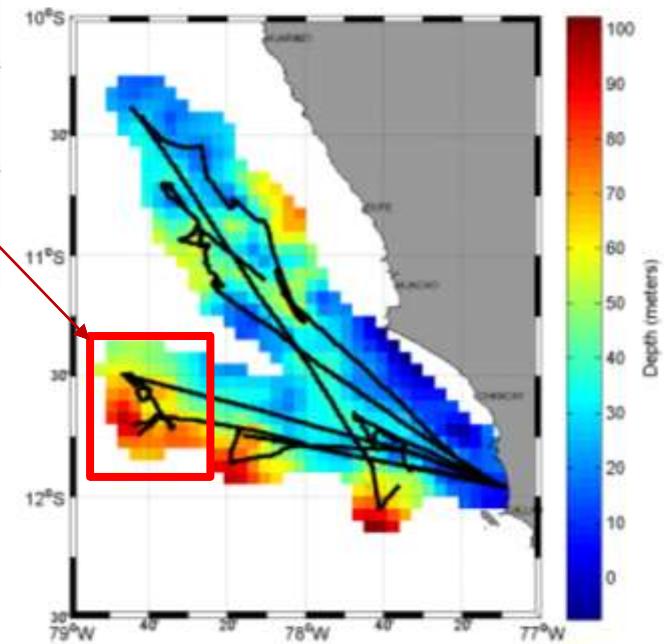


Oxycline (automatically identified for each ping)

Vessel trip

Oxycline depth mapping





100

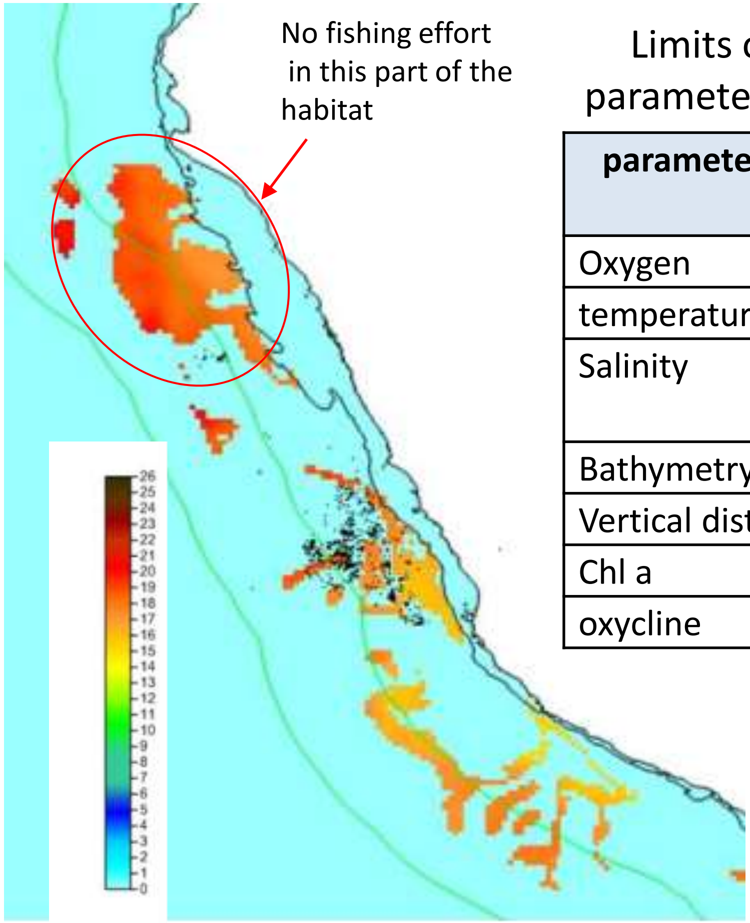
40

0 m

CJM density (Sa)

CJM is not found in areas where oxycline depth < 40 m

Definition and mapping of the potential habitat



Probability plot of the map of potential habitat of CJM during the 1st semester 2013. Black dots represent the fishing sets.

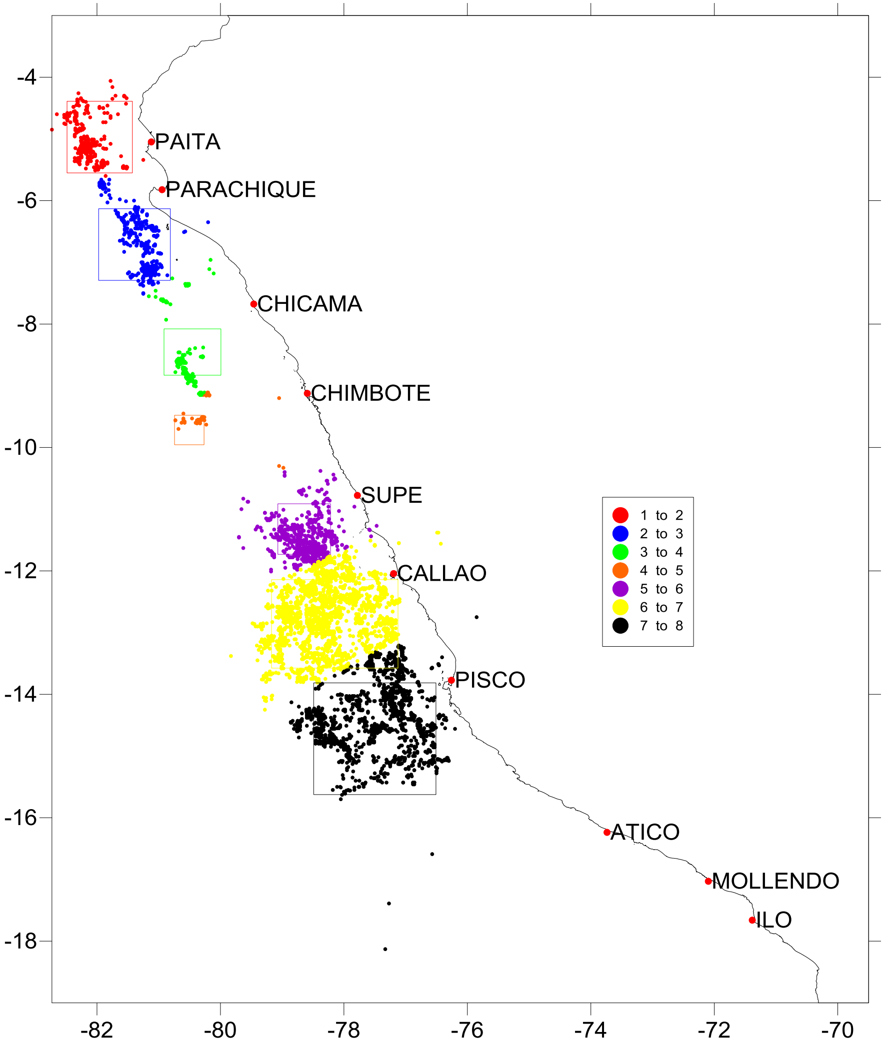
Limits of the jack mackerel habitat for the main environmental parameters (measured for the Peruvian area during the workshop)

parameter	Lower limit	Upper limit	Lower preferendum	Upper preferendum
Oxygen	0.1 ml/l	-	0.2 ml/l	-
temperature	9º	26º	15º	20º
Salinity	<minimum observed	>maximum observed	34.9	35.1
Bathymetry	-	150 m	-	-
Vertical distr.	400	0	-	-
Chl a	0.07mg/m3	26 mg/m3	0.1	?
oxycline	-	30 m	-	40 m

Indicators to be added:

3D distribution of DO
CJM biomass
ENSO situation
Water mass characteristics
Overall biomass (trophic structure)
Community structure
Biological issues; etc.

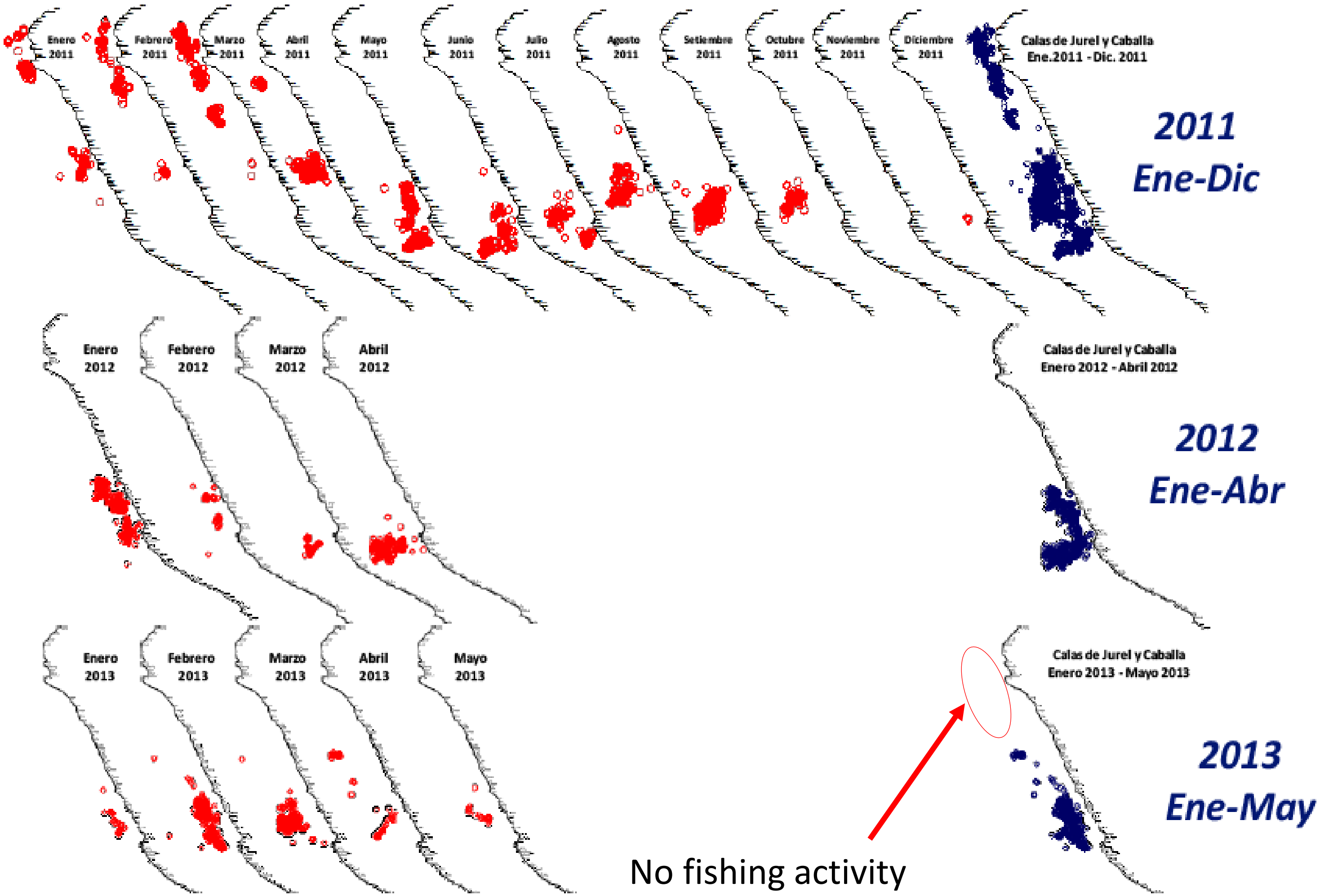
2. The interactions between the CJM and the fishery



Gathering of the 6000 sets (2011-2012-2013) in regions. The dimension of the squares represents the distribution area in each region.

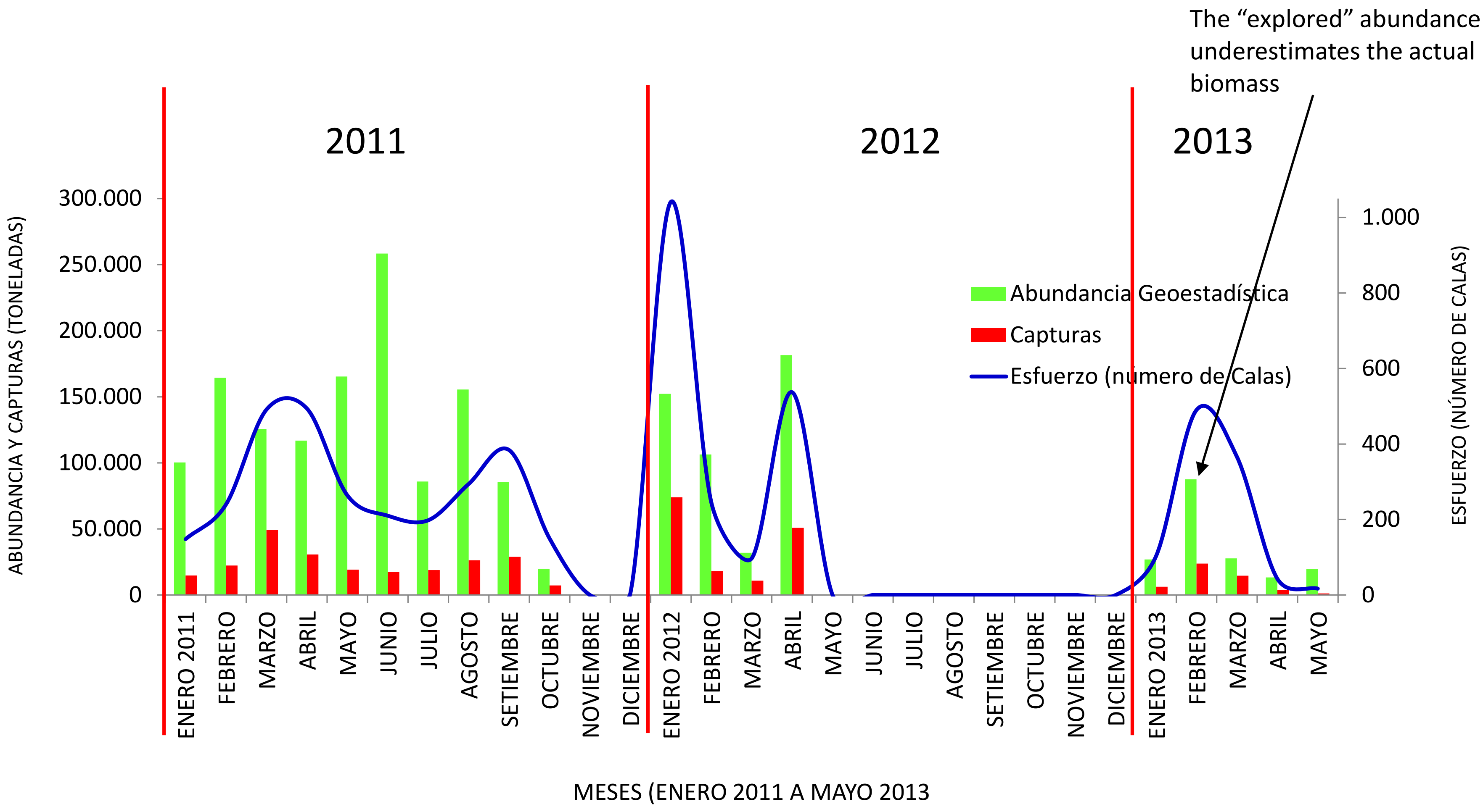
Displays the effect of fish distribution on the fishery strategies (impact on CPUE significance)

Location of fishing effort for years 2011 to 2013

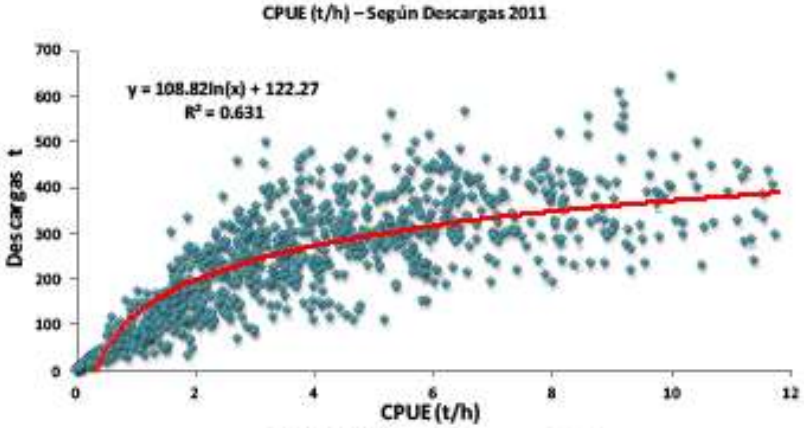


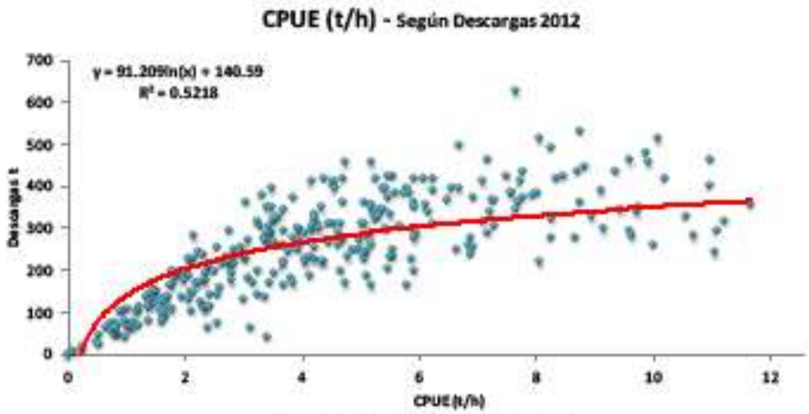
No fishing activity in the northern part of the habitat. WHY?

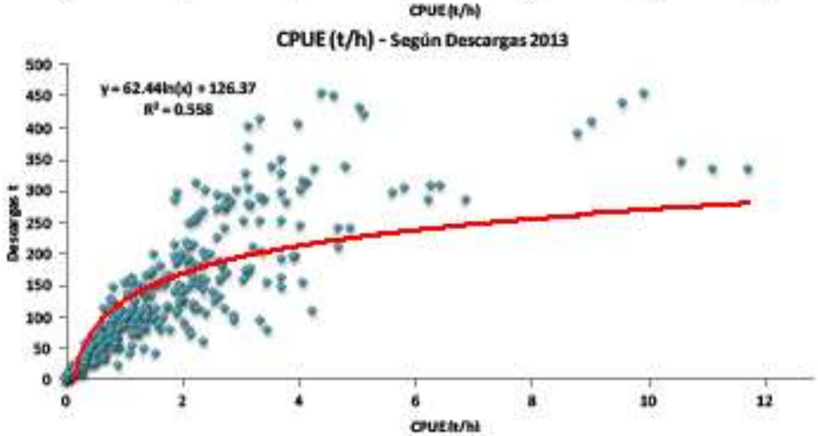
Estimated abundance (from fishing vessel acoustics and geostatistics) related to catch and effort



Relationship catch - CPUE







2011

CPUE

min	0.01
media	**3.50**
max	11.77

2012

CPUE

min	0.00
media	**3.95**
max	11.66

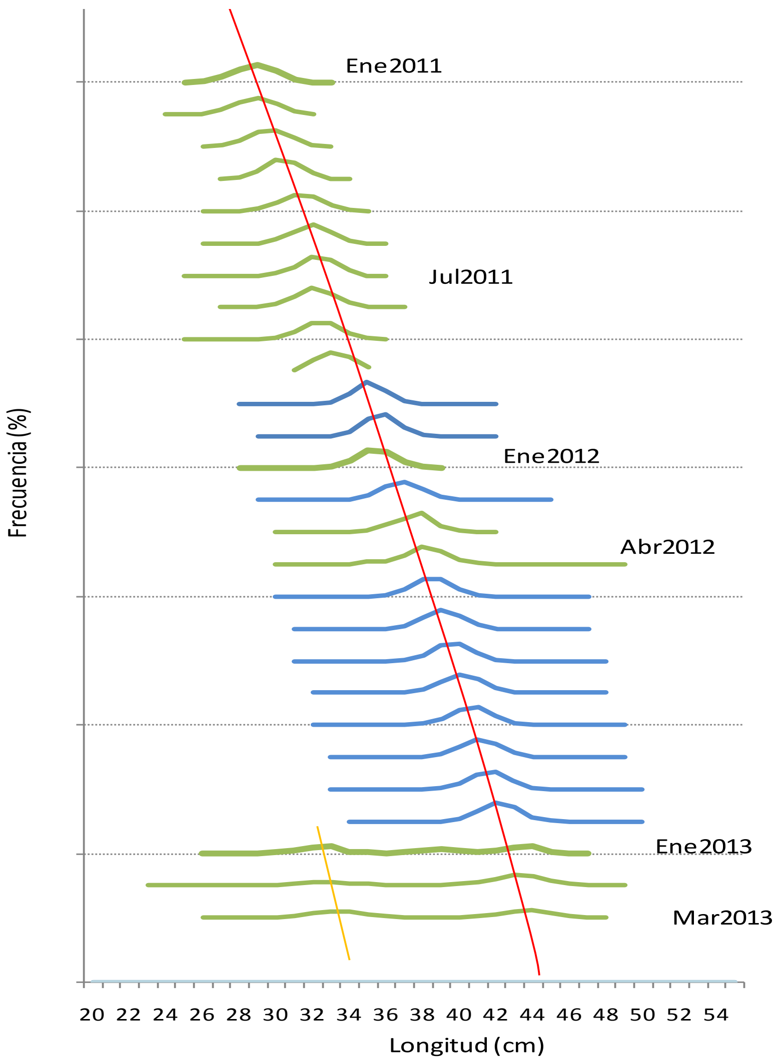
2013

CPUE

min	0.00
mediana	**1.34**
max	11.71

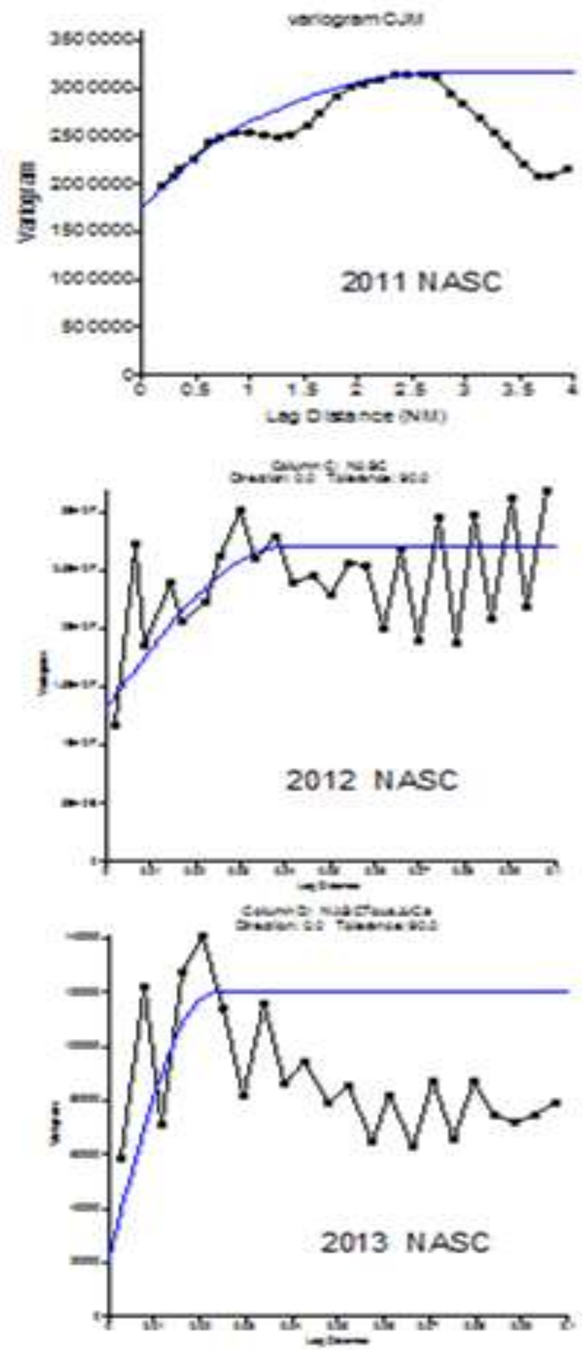
CPUE lower in 2013: why ?

3. The major biological characteristics of CJM and their variability



Monthly structure of length distribution from January, 2011 to March, 2013. Green: actual observations; blue: calculated length structure using growth equations (Dioses, 1995) during the closure of the fishery. Results are given in total length measurements.

A new cohort has been recruited in 2013



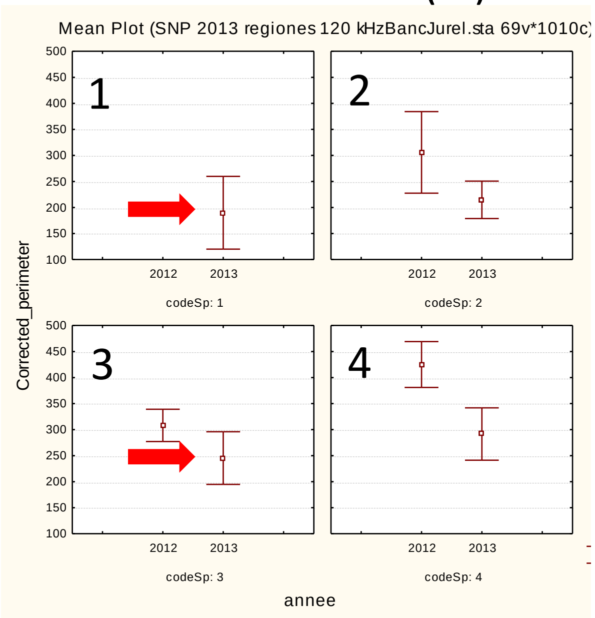
Variograms of cluster dimensions for years 2011, 2012 and 2013

Year	Cluster diameter (NM)
2011	2.5
2012	2.4
2013	1.4

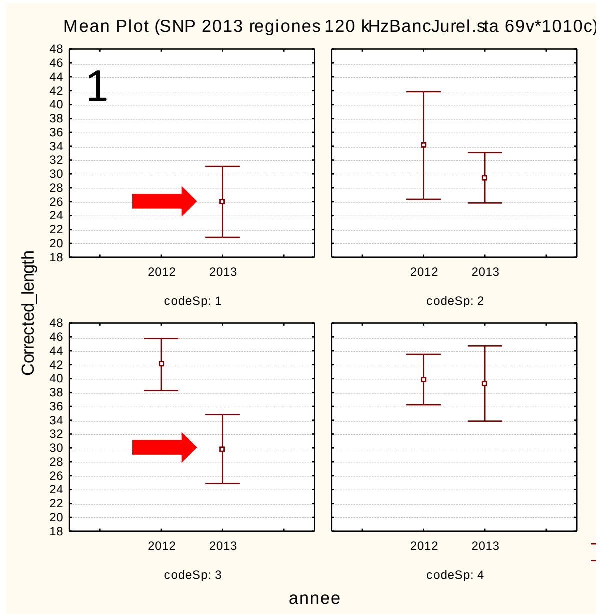
Clusters were significantly smaller in 2013 compared to 2011 and 2012 (why?).

We know also that clusters, school dimensions and relative proportions of aggregation types are affected by the climatic conditions (El Niño)

PERIMETRO (m)



EXTENSION (m)

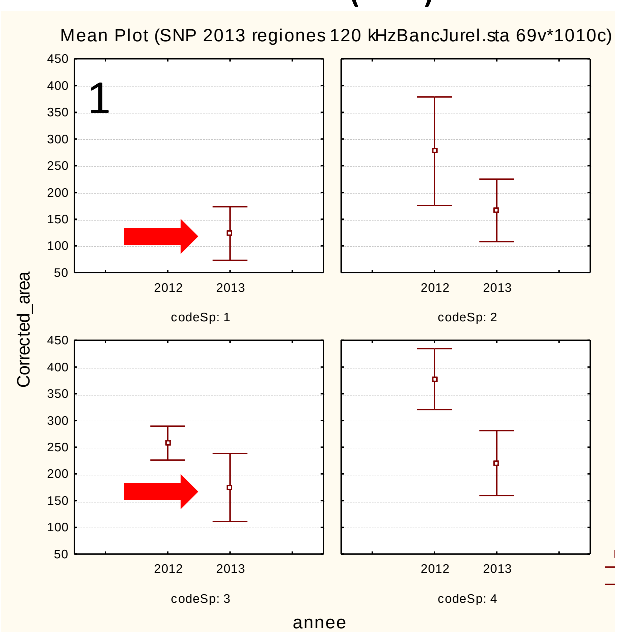


School indicators for CJM and mackerel, 2011 and 2013 (perimeter, diameter, area and log [NASC]).

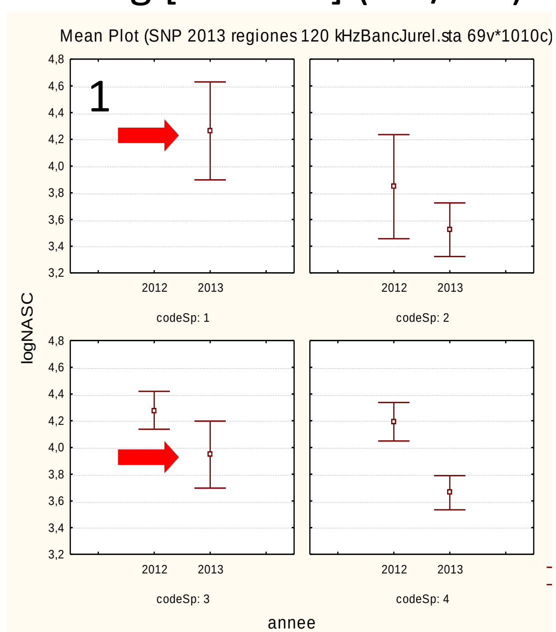
CodeSp1=mackerel;
CodeSp2= mackerel+CJM; CodeSp3= CJM;
CodeSp4="big fish".

Red arrows: mackerel and CJM in 2013

AREA (m2)



Log [NASC+1] (m2/m3)



Species	mackerel	Jack mackerel
Surface	125	180
Length	26	30
Perimeter	190	250
NASC (log)	4.25	3.90

Mackerel schools smaller and denser than Jack Mackerel schools

CJM schools smaller in 2013 than in 2012: why? (impact on CPUE)

List of indicators collected and analyzed during the workshops (non including catch data)

Sea Surface Temperature	A	Satellite data, maps, absolute values, anomalies
Sea Surface Salinity	A	Satellite data, maps, absolute values, anomalies
Chlorophyll	A, B	Satellites maps, stations, models
Currents	A, B	Satellites maps, stations, buoys, ADCP, models
Schools (acoustics)	B, C	Dimensions, biomasses, density, locations, morphology, internal structures (acoustic data)
Clusters of schools (acoustics)	B, C	Dimensions, aggregations (acoustic data)
Fish abundance (acoustics)	B, C	Acoustic density and abundance, catches, CPUE, at different spatial and temporal scales (from instant to year)
Biometry (biological sampling)	C	Length-age structure of the catch, demographic dynamics in the fishing area, etc.
Fishers strategy and activities	C	
DO (acoustics)	C	Not yet integrated as indicator but will be used in the future.

A: international data; B: data from scientific surveys: C: data from fishing vessels

Other necessary indicators (to be completed and discussed)

- **Dynamics of water masses (eddies, ENSO, Kelvin, water masses, etc.)**
- **spawning, eggs and larvae (distribution, aggregations, location, abundance, etc.)**
- **Juveniles and pre-recruits caught in the fishing operations**
- **Typology of aggregations and proportions of aggregation types**
- **Dispersion and behavioural indices of CJM in its different biological phases**
- **Trophic patterns (stomach contents, micronekton biomass, feeding behaviour)**

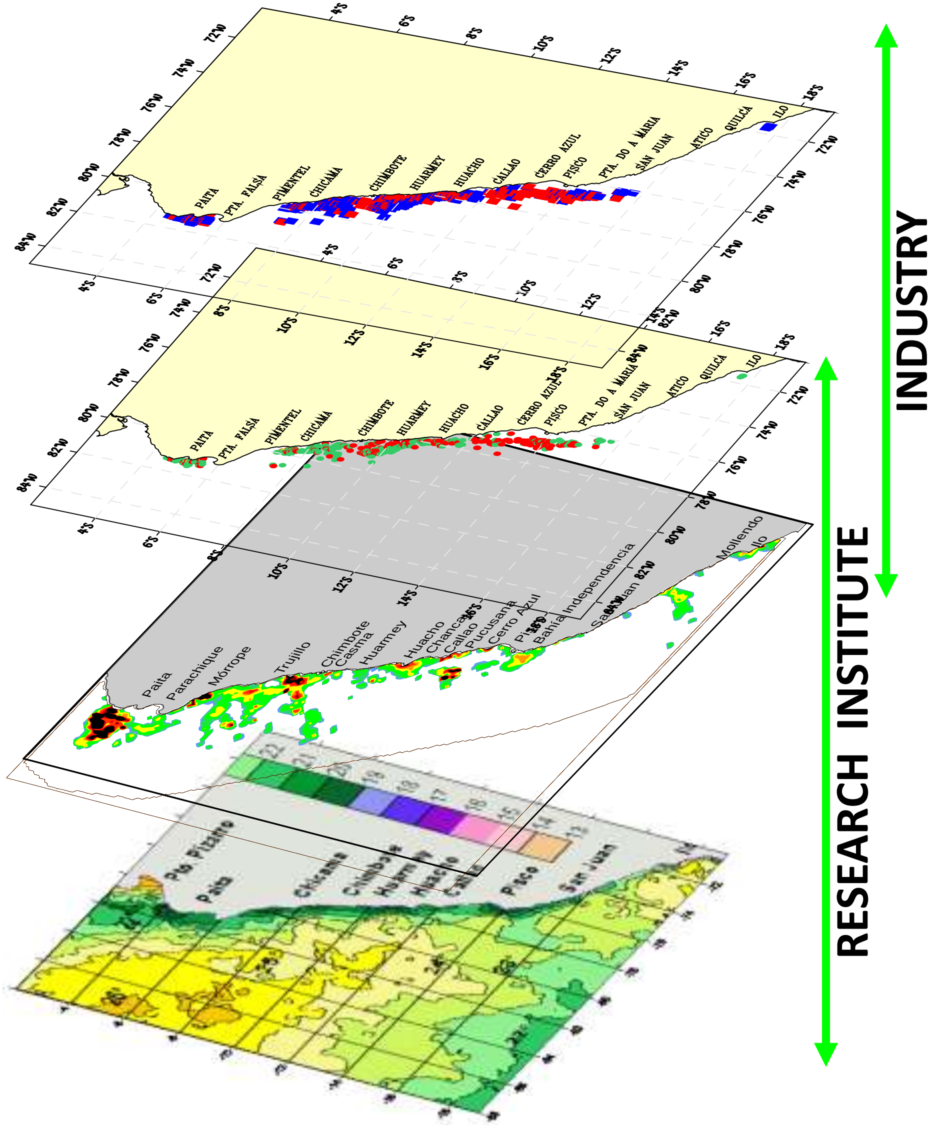
CONCLUSIONS AND RECOMMENDATIONS

- The synthesis of direct and indirect information **from research and fishing vessels** allows a continuous monitoring of the population structure and spatial dynamics. A list of indicators should be collected as a routine activity by SPRFMO members.
- **Acoustic indicators** that are likely to improve the understanding of the population biology, e.g. 3D structure of the dissolved oxygen, abundance, densities, aggregation characteristics, trophic levels, etc. should be collected in fishing vessels where such activity is possible.
- Indicators on **reproduction and recruitment**, i.e. eggs, larvae and pre-recruits should be collected routinely in dedicated surveys and aboard fishing vessels when possible.
- The definition and mapping of the **potential habitat** is essential to support the fishery in its activities and to measure the fish abundance and location. Research for improving the PH definition using data obtained from the fleet (acoustic, fishery, biometry, etc.) and from other sources (satellites, oceanographic stations, hydrological models, scientific surveys, etc.) should be developped.
- It is essential that such monitoring **covers the whole distribution area** of the species. This must be done through a common protocol established for the various CJM fisheries.
- **It is recommended that an international workshop be organized by SPRFMO/SC in order to define the list of relevant indicators to be collected through a common protocol applicable to all the fisheries.**

THE END

Origin of data

- Catch data
- Acoustic data from fishing vessels
- Observers onboard
- Scientific acoustic surveys
- Biological surveys
- Oceanography
- Climate studies



Type of indicator

- Evaluation cpue/density
- Interactions fish/fishery
- Dynamics/recruitment
- Ecology
- Behaviour micro-scale
- Abundance estimates and distribution area
- Biology, interaction fish/environment
- Definition of the potential habitat