

**Effects of El Niño in spatial distribution and concentration of catch and reproductive activity of anchovy in northern Chile.**

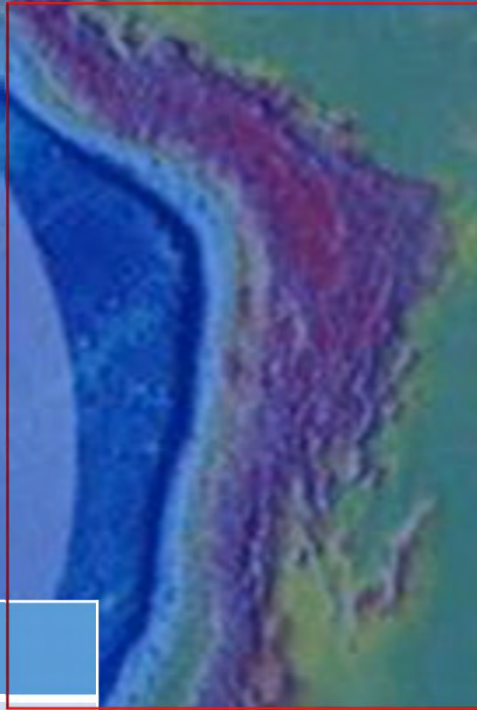
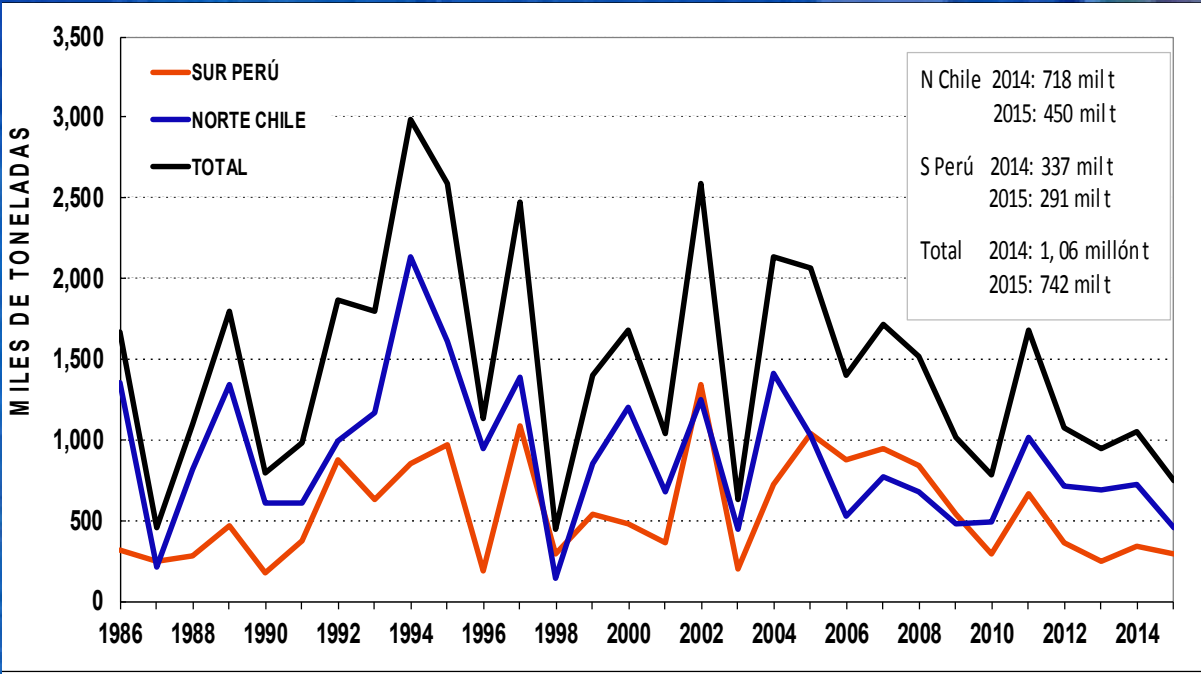
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**Symposio the small pelagic**  
Victoria , Canada. 6 – 11 de marzo 2017

# Catches for the Chile – Perú stock between 1986 - 2015

The study focuses on the anchovy (*Engraulis ringens*) stock shared between Chile and Peru.



The northern area of Chile represents more catches

Stock	1986-2005	2007-2015
South of Perú (*)	570 mil t	539 mil t
North of Chile (**)	1 millón t	652 mil t
Total	1,6 millón t	1,2 millón t

Fuente: IMARPE (\*) e IFOP (\*\*)

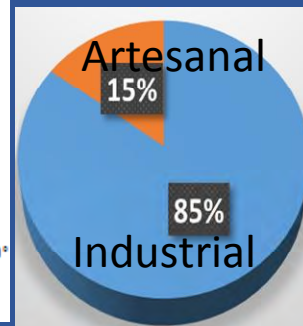
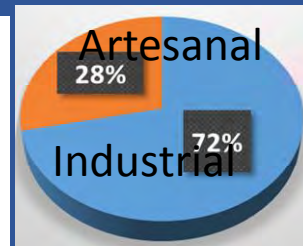
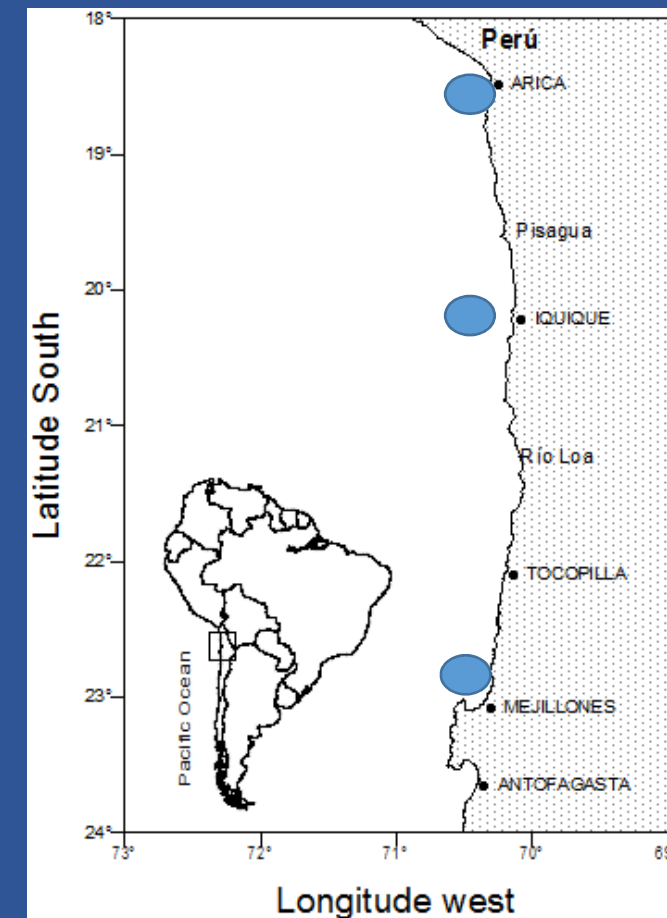


The study focuses on the anchoveta stock shared between Chile and Peru, specifically in the northern zone of Chile between 18° 21' - 24° 00' S.

## General information on the northern Chile fishery

- The information corresponds to monitoring of the fishing activity
- The collection of fishing logbooks is a census
- The biological data is collected in land sampling and aboard the vessels.
- The blue points correspond to ports of unpacking and sampling.
- The artisanal fleet concentrates the greater activity in the zone of Arica.
- This fishery is subject to management in terms of catch quotas since 2003 and reproductive closures (August - September) and recruitment (January - February).

### Study area





## Data

The information analyzed comes from the landings made by the purse-seine fleet, which is extracted from the coast up to 200 nautical miles.

### Data of fishing logbooks:

Industrial and artisanal

### Data of biological sampling:

Gonodasomatic index (GI)

Average weight (AW)

Condition factor (CF)

### Data of sampling length:

Size structure

Proportion of specimens  $\leq 11.5$  cm

### Environmental data:

Sea surface temperature Anomaly

MEI

# Methods

In order to evaluate the distribution changes, spatial indicators were used

## Center of gravity and inertia

$$CG = \frac{\sum_{i=1}^N x_i s_i z_i}{\sum_{i=1}^N s_i z_i}, \text{ and}$$

$$I = \frac{\sum_{i=1}^N (x_i - CG)^2 s_i z_i}{\sum_{i=1}^N s_i z_i}.$$

## GINI

$$SA = 2 \int \frac{Q - Q(T)}{Q} dT.$$

$$\frac{SA}{PA} + G_0 = 1,$$

## Spatial aggregation index

$$IAE = \int_0^{0.9} x - a \exp(bx) dx..$$

$$IAE = \left[ \frac{x^2}{2} - \frac{a}{b} \exp(bx) \right]_0^{0.9}$$

$$IAE = 0.405 + \frac{a}{b} (1 - \exp(0.9b))$$

## Coverage Index

$$\sum_{i=1}^n \frac{Cua \text{ captura}}{cua \text{ totales}} * 100$$

## Catch was quantified corresponding to two size groups of anchovy

- Juveniles  $\leq 11.5$  cm
- Adults  $> 12.0$  cm

How was it done?

The length structure was applied to the catch information considering the year, month, latitude and distance to the coast.

- Spatial indicators at monthly scale were determined for juveniles, adults and total

How was it done?

Following the methodology of Wolillez et al, 2006.

- Biological indicators (monthly) were calculated for juveniles, adults and the total.
- Gonadosomatic index
- Pm (Average weight)
- CF (Condition Factor)
- Environmental data
- Averages Monthly MEI and SSTA

In order to establish the association between the SSTA -MEI variables and the spatial or biological variables, the co-integration test was used according to Engle-Granger methodology.

- 1) All variables were tested by the Dickey Fuller statistic test increased for stationarity.
- 2) Cointegration and error correction models using trace value and maximum value statistics.
- 3) The causal relationships were tested through the Granger test

# Results

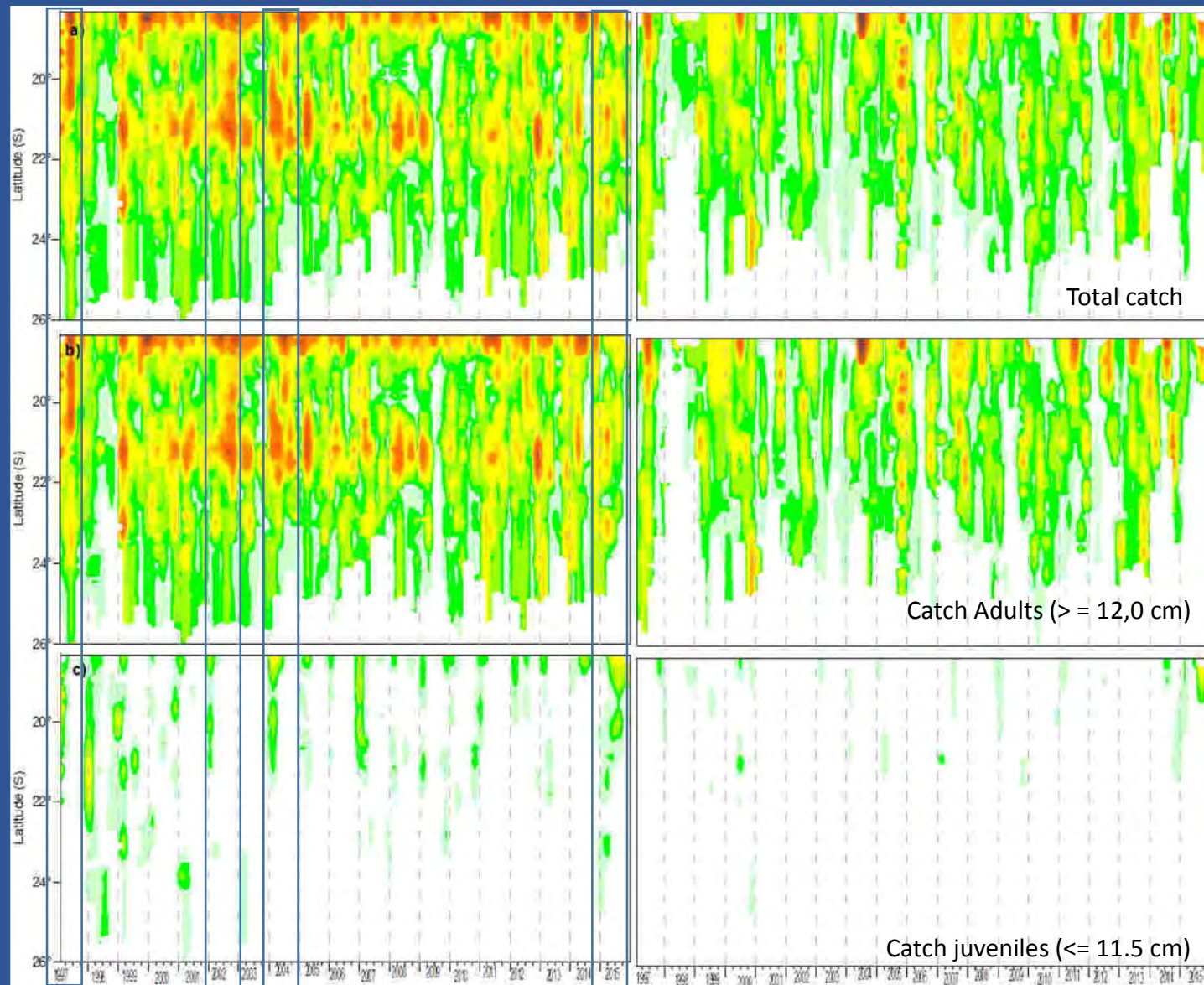
## Impact of El Niño on the fishery of Anchovy in northern Chile

- Changes in distribution: getting closer to the coast and moving to the south.
- Changes in the reproductive pattern: Deviation and changes in intensity.
- Changes in size structure: Increase in juvenile specimens.

# Changes in distribution

Coastal zone

Oceanic zone



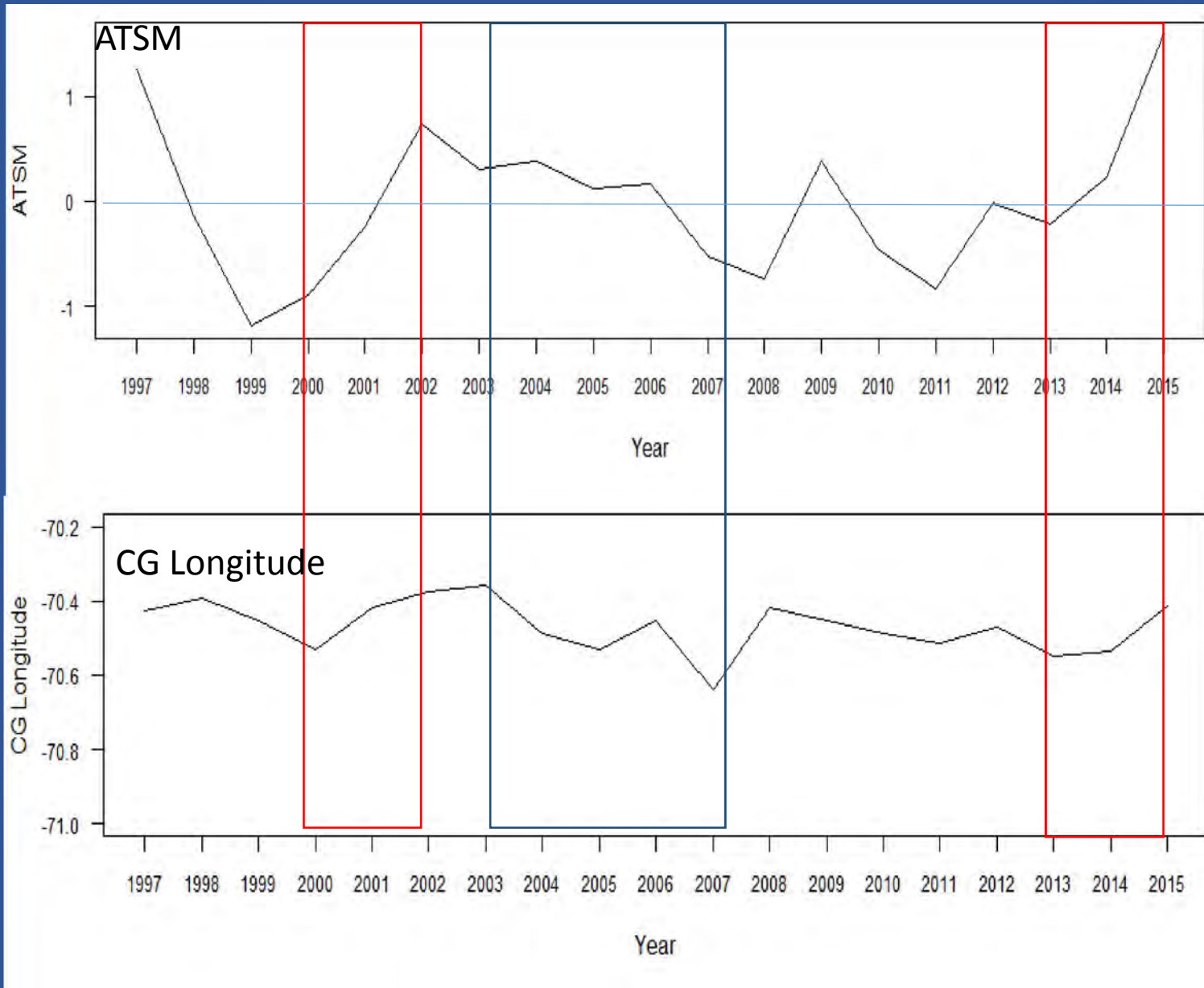
In general we can observe that anchovy catches are recorded in the first 20 miles of the coast, eventually up to 60 miles in front of Arica area (18 ° 30'S).

Adult catches exhibit a distribution with high concentration centers in front of Arica and Loa River (21 ° 25'S), meanwhile during 1997, 2002, 2004 and 2015 this distribution is continuous and to the south.

The juvenile catches present a mainly coastal distribution pattern oriented to Rio Loa north, highlighting a southerly post El Niño displacement pattern, as observed in the years 1998 and 2015.

Hovmöller diagram of the anchovy latitudinal catch between 1997 and 2015.

# Spatial indicators: Center of gravity for anchoveta in the north of Chile



Atsm Effect in Center of Gravity in Longitude :

Positive Moves towards the coast.

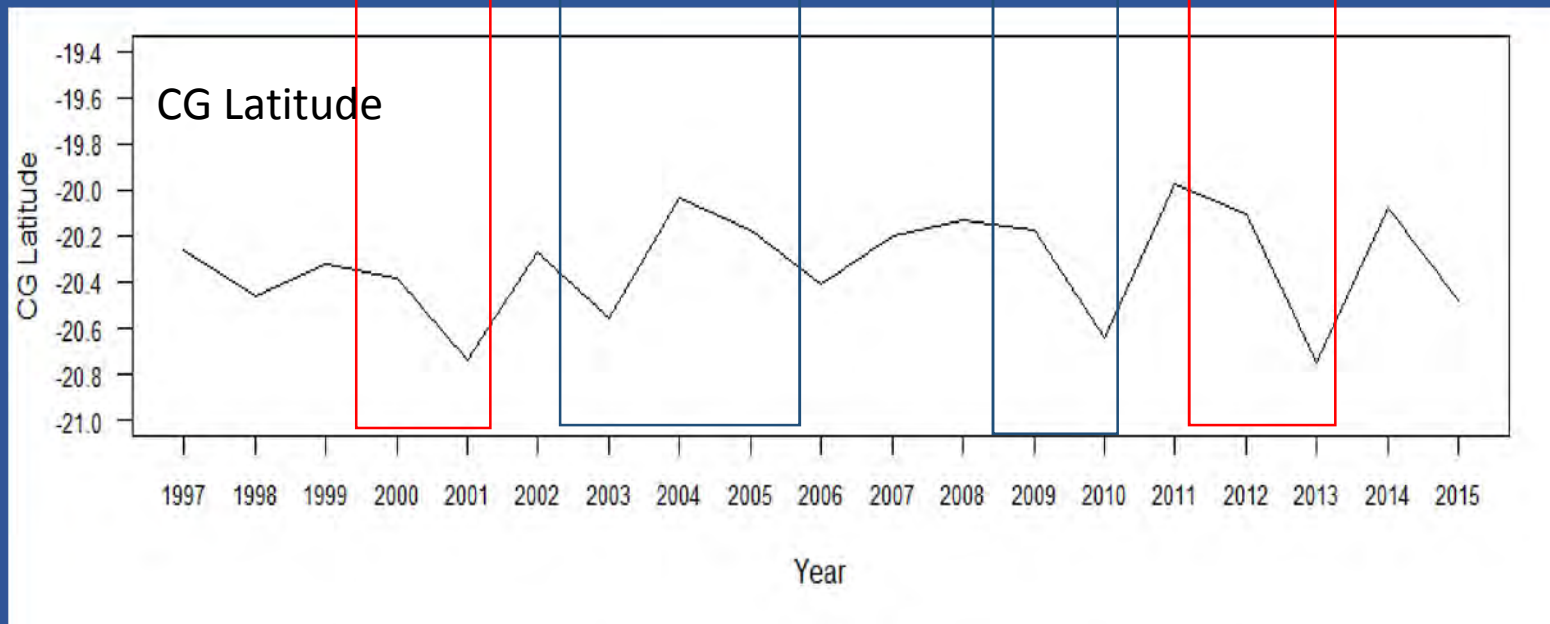
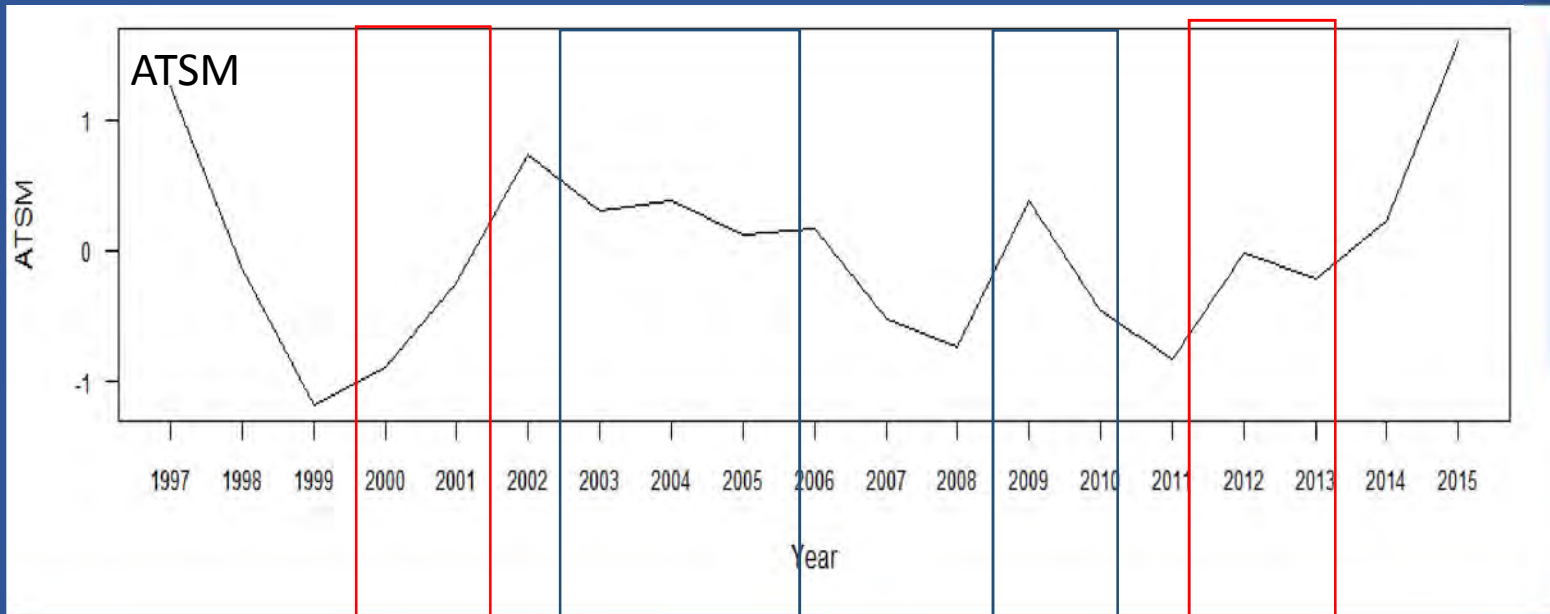
Negative It moves away from the coast.

— ATSM positive

— ATSM negative



# Spatial indicators: Center of gravity for anchoveta in the north of Chile



Atsm Effect in Center of Gravity in Latitude :

Positive: It moves to the south of the study area.

Negative: Returns north.

— ATSM positive

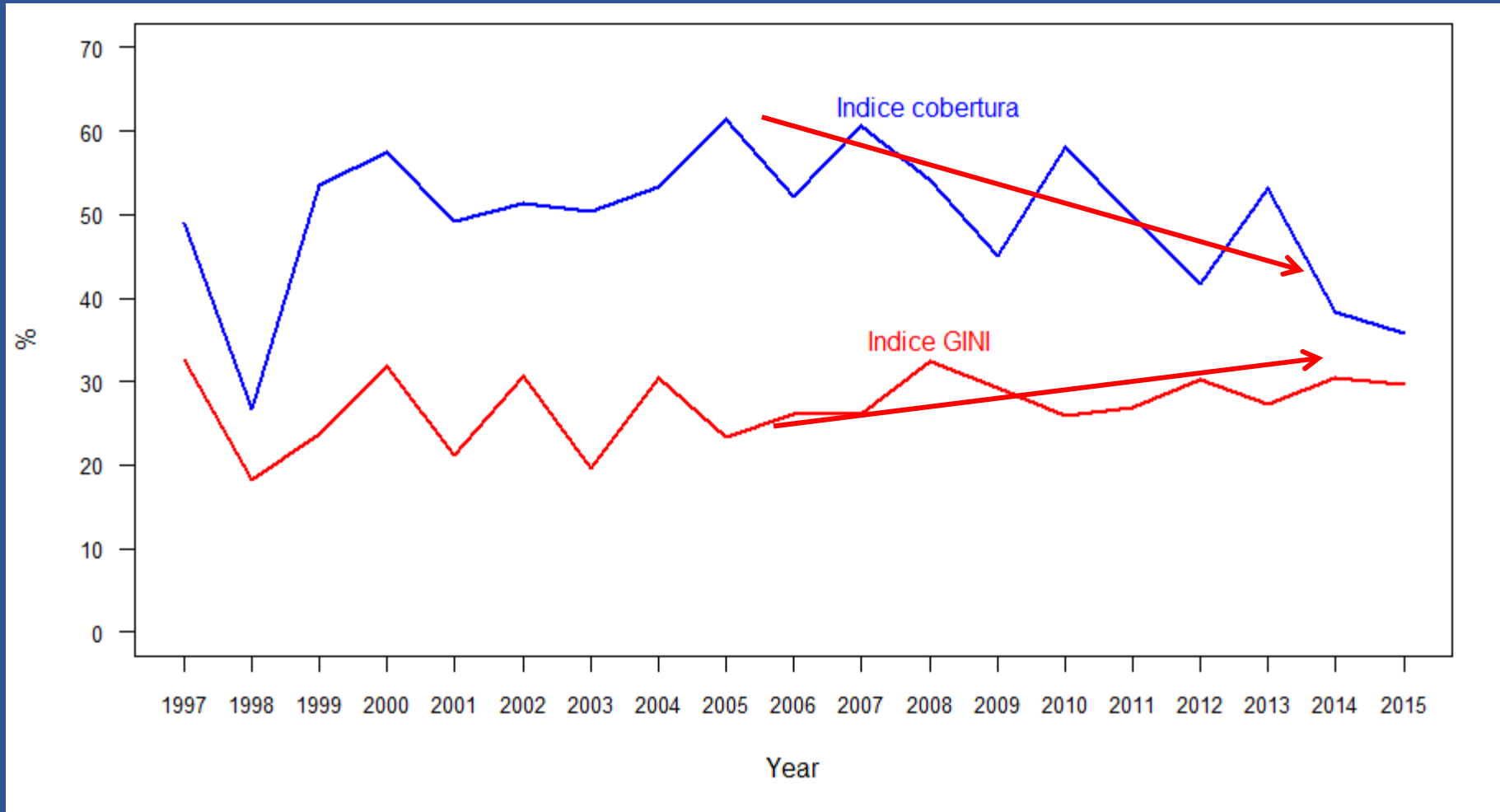
— ATSM negative

# Spatial indicators for anchovy in Northern Chile

The Gini and Coverage Index (CI) indicators show a high variability between 1997-2015.

## Note

Negative trend since 2006 for CI and positive for GINI



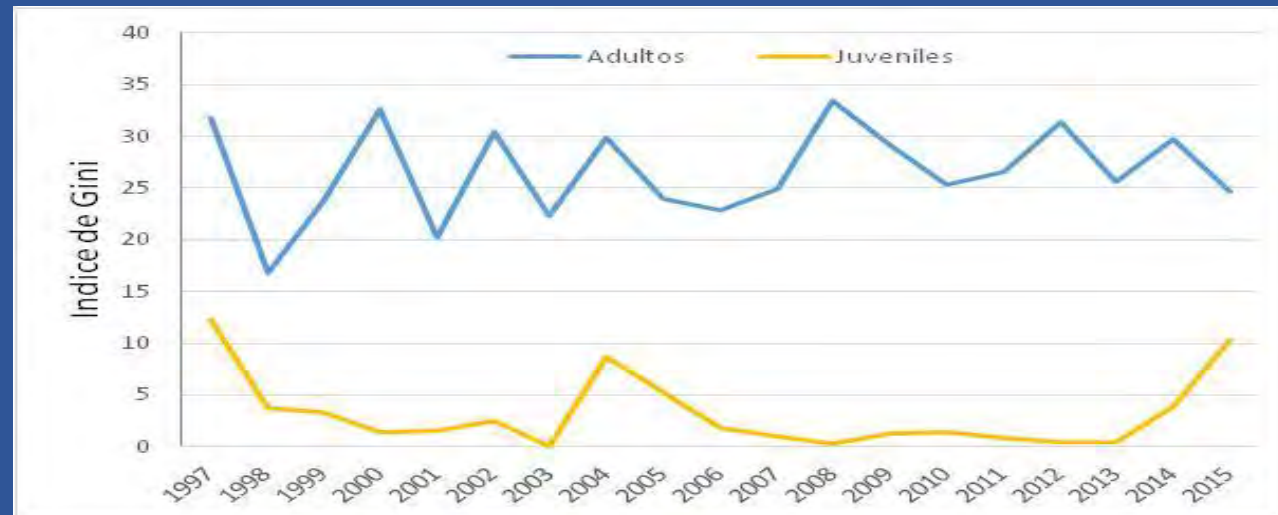
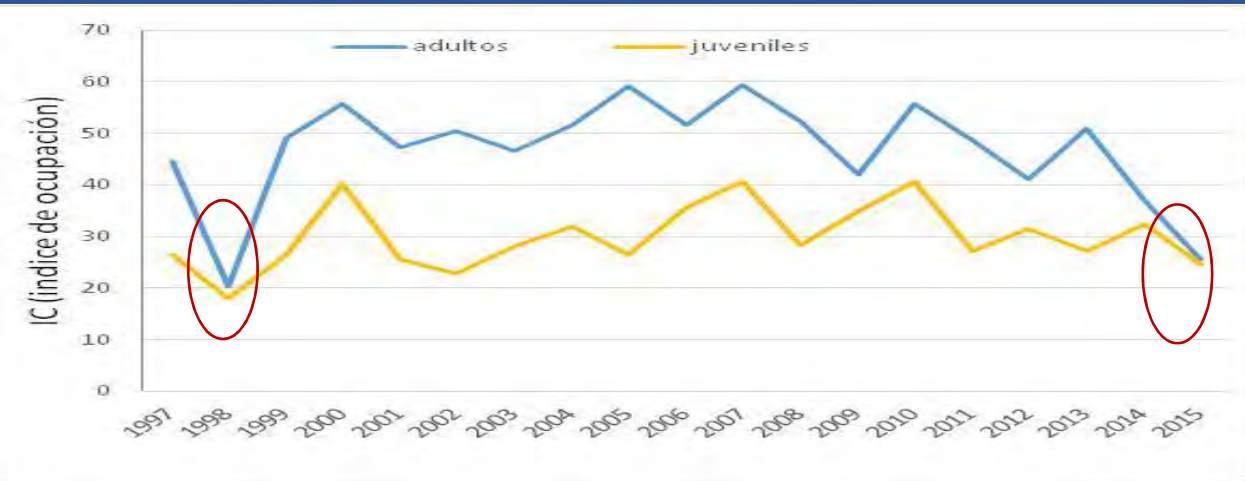
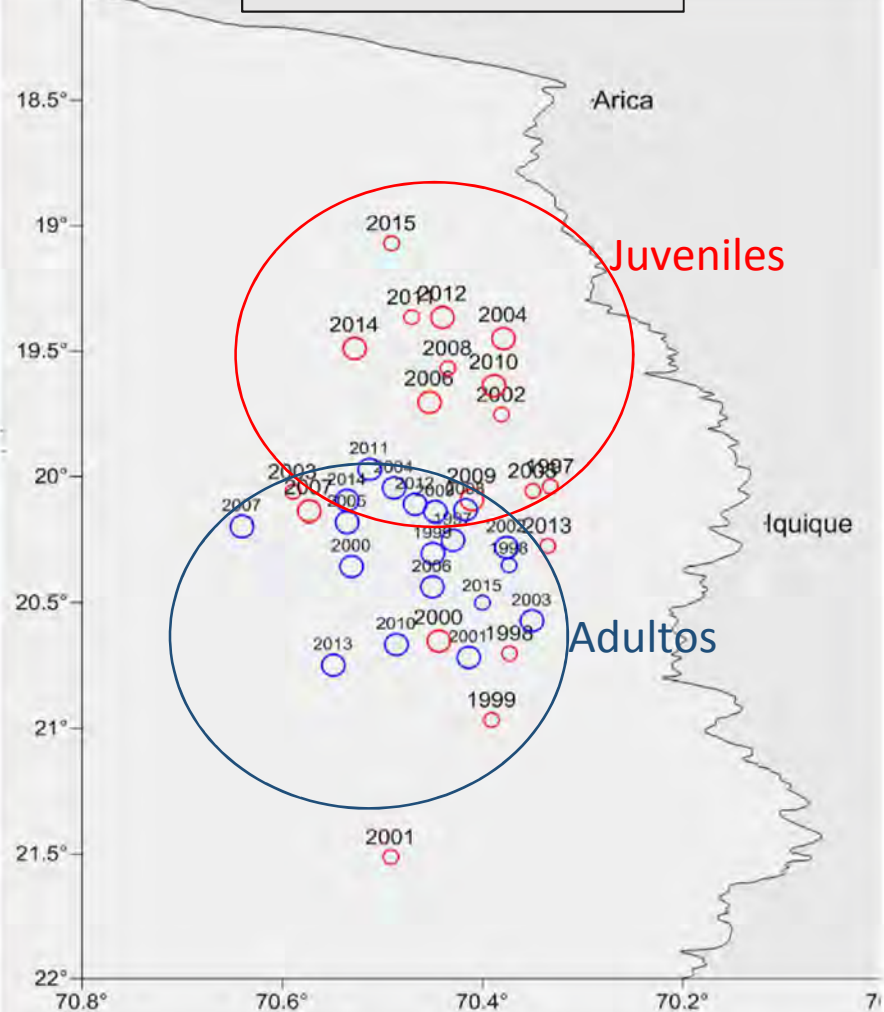
# Spatial indicators for juveniles and adults of anchovy

Cg for juveniles and adults presents a difference in the occupation of space.

**Juveniles:** They are distributed north of 20 ° 30'S  
The years 1998, 1999, 2000 and 2001 are further distributed to the south. IC and Gini values are lower.

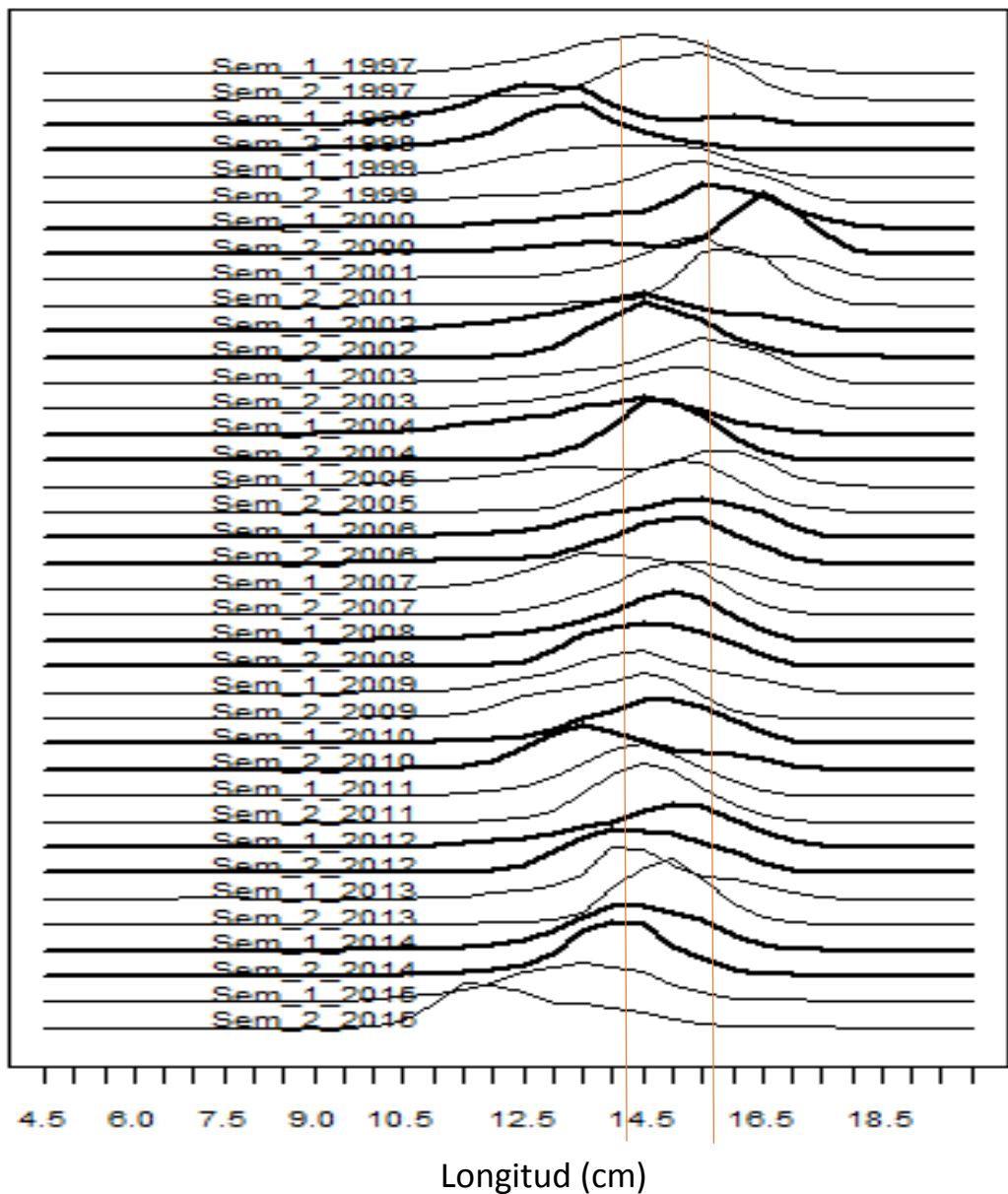
**Adults:** Cg are concentrated between 20 ° S and 21 ° S.

Centro de gravedad



How does El Niño affects the Anchovy size structure?

# Semi-annual anchovy structure between 1997 and 2015

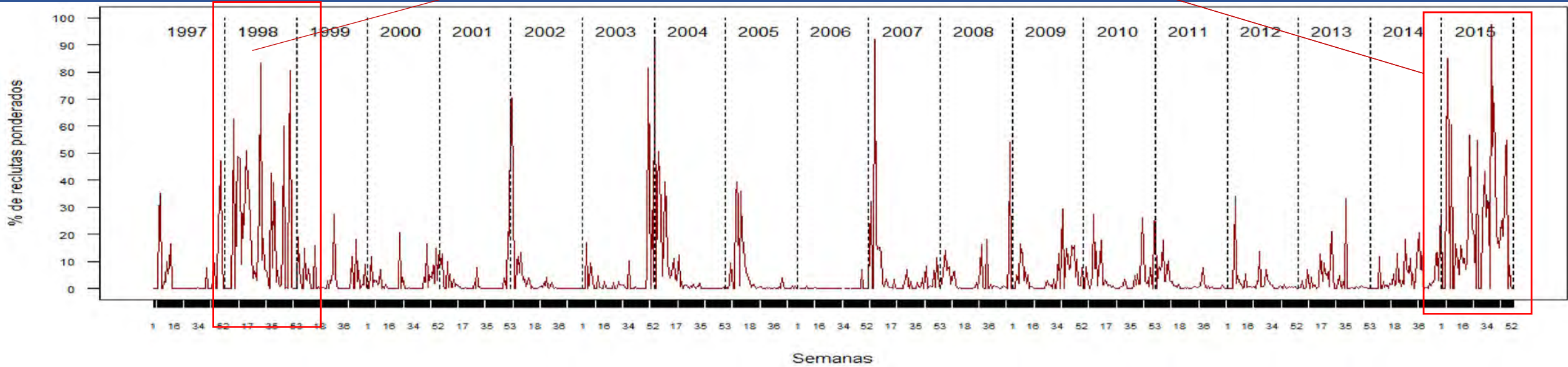


The first is to point out the typical size structures in the northern part of Chile. They are composed of medium sized specimens with mode between 13.5 and 15.0 cm.

The participation of juveniles in catches is less than 10%, with a greater presence between December and February.

Because the fishing fleet concentrates its activity on the adult fraction.

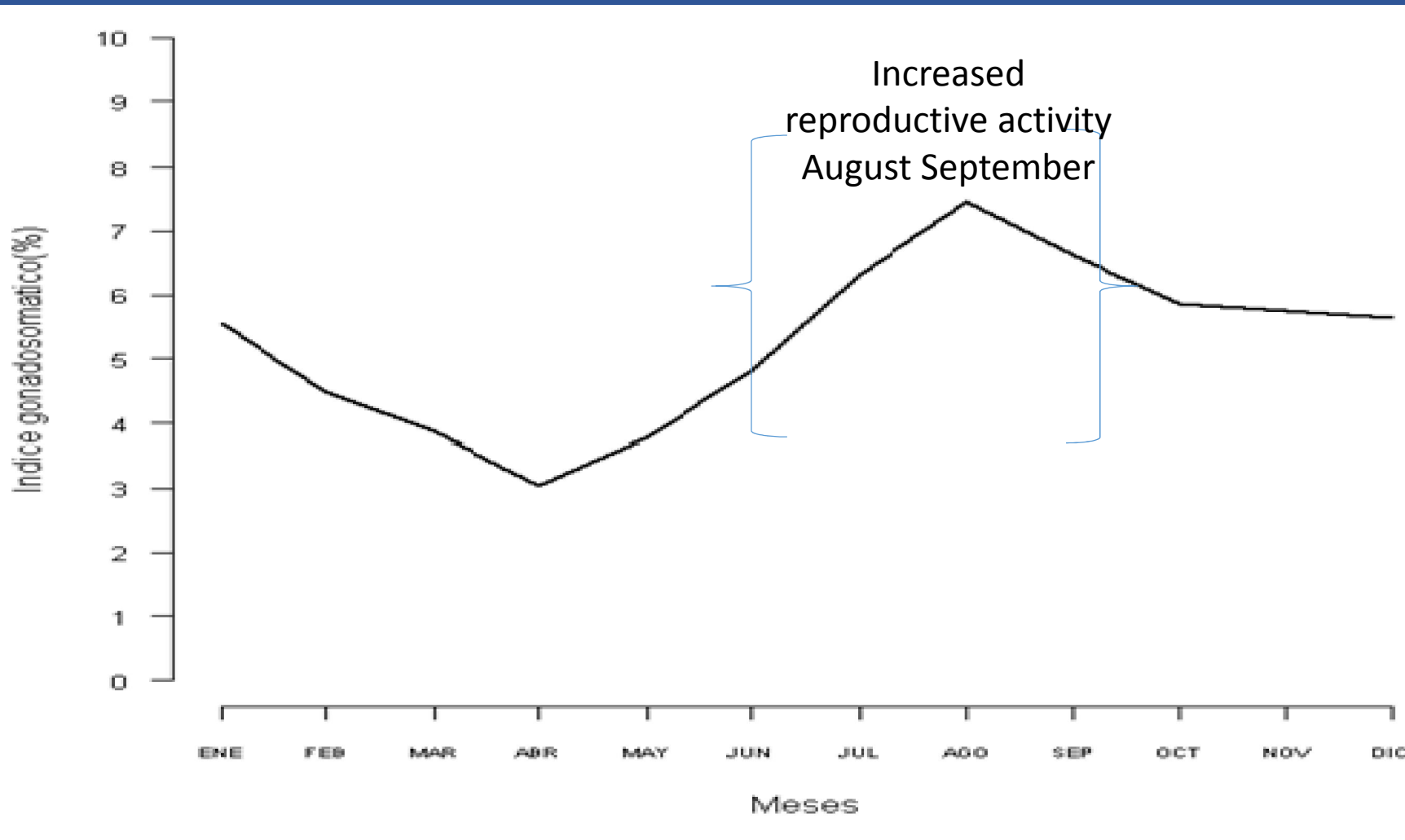
Post the Niño shows an increase in juveniles, reaching 80% of the catches.



Porcentaje de ejemplares menores a 12 cm ponderados a la captura semanal: Entre 1997-2015

How does El Niño affects Reproductive Activity in Anchovy?

- Reproductive activity presents a seasonal pattern in the northern zone of Chile

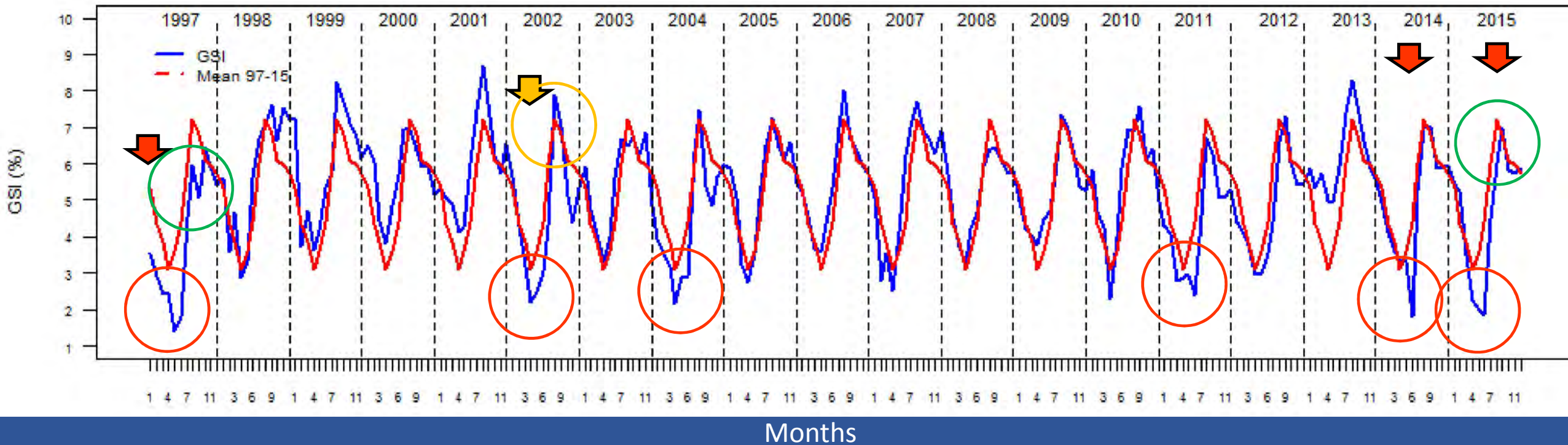


The highest activity occurs in the Southern Winter.

It is delayed or overtaken due to environmental conditions.



# Changes in Reproductive Activity through GIS

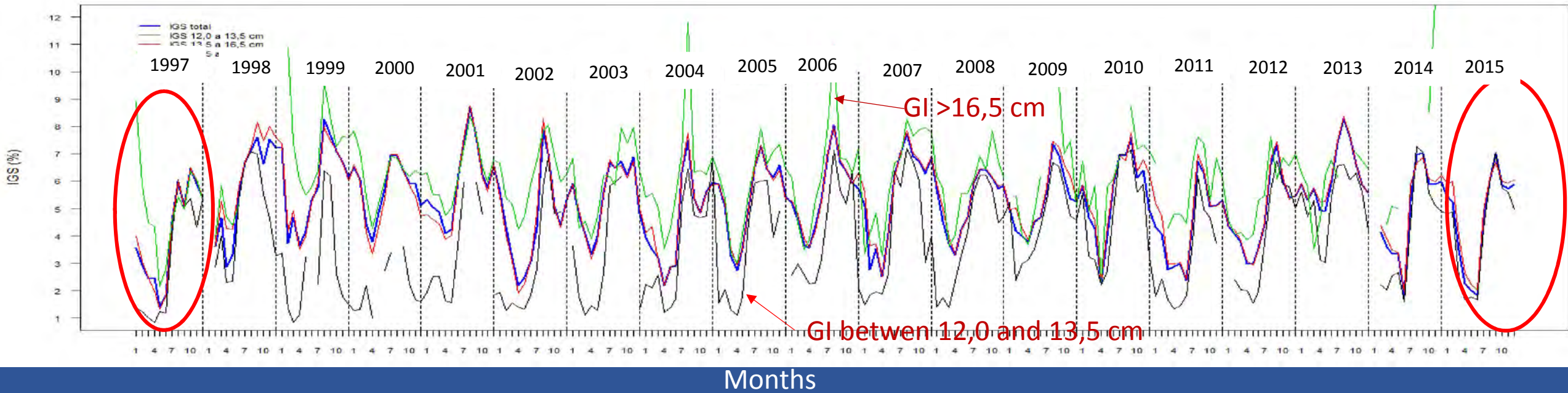


↓ Niño débil      ↓ Niño strong      — Mayor intensidad      — Menor intensidad

During El Niño, there is a delay in the onset of reproductive activity through IGS and a lower intensity, mainly in 1997 and 2015.

In 2002, the weak intensity of the process reached higher values.

# Changes in Reproductive Activity through GIS



## Stands

- Offset and lower reproductive intensity of the group of size between 12.0 to 13.5 cm.
- Greater intensity and duration of the process in the size group greater than 16.5.
- The influence of height in the reproductive process is not observed during The Niño 1997 and 2015.

## Test the cointegration

	Cointegration tests			Granger causation test		
	Trace and maximum eigen	critical values trace and eigen	Decision	F- statistc	P	Decision
Variables X=MEI Y=						
IGS2	66.56 , 53.90	19.96 , 15.57	S <sup>a</sup>	0.99	0.32	NS
IGS3	79.58 , 67.45	19.96 , 15.57	S <sup>a</sup>	0.67	0.41	NS
IGS	75.57 , 63.57	19.96 , 15.57	S <sup>a</sup>	0.65	0.42	NS
FC2	58.19 , 46.52	19.96 , 15.57	S <sup>b</sup>	0.88	0.35	NS
FC3	49.05 , 37.34	19.96 , 15.57	S <sup>b</sup>	1.31	0.25	NS
FC	98.28 , 86.44	19.96 , 15.57	S <sup>b</sup>	0.25	0.62	NS
Pm2	68.84 , 57.52	19.96 , 15.57	S <sup>a</sup>	1.18	0.28	NS
Pm3	32.60 , 23.77	19.96 , 15.57	S <sup>a</sup>	3.37	0.29	NS
PM	30.24 , 21.58	19.96 , 15.57	S <sup>a</sup>	0.50	0.48	NS
Gini	92.09 , 79.79	19.96 , 15.57	S <sup>a</sup>	0.61	0.44	NS
Cglat	100.16 , 88.19	19.96 , 15.57	S <sup>a</sup>	0.19	0.66	NS
CG long	79.08 , 68.20	19.96 , 15.57	S <sup>a</sup>	2.34	0.13	NS
IC	100.11 , 89.65	19.96 , 15.57	S <sup>a</sup>	0.08	0.78	NS
Variables X=TSM Y=						
IGS2	118.72 , 89.56	19.96 , 15.57		0.13	0.71	NS
ISG3	116.94 , 93.76	19.96 , 15.57		0.06	0.81	NS
IGS	110.91 , 86.71	19.96 , 15.57		0.03	0.87	NS
FC2	83.39 , 50.00	19.96 , 15.57		9.31	0.00	S
FC3	78.68 , 49.49	19.96 , 15.57		8.08	0.00	S
FC t	123.62 , 89.59	19.96 , 15.57		2.38	0.12	NS
Pm2	96.23 , 66.03	19.96 , 15.57		1.92	0.17	NS
Pm3	61.20 , 46.13	19.96 , 15.57		0.05	0.83	NS
PM	61.67 , 50.36	19.96 , 15.57		1.53	0.22	NS
Gini	117.55 82.93	19.96 , 15.57		0.45	0.50	NS
Cglat	119.48 , 86.76	19.96 , 15.57		0.09	0.77	NS
CG long	105.15 , 72.78	19.96 , 15.57		5.42	0.02	S
IC	131.93 , 108.46	19.96 , 15.57		0.97	0.33	NS

a Vector error correction model (VECM) found significant speed of adjustment to the long run equilibrium

b VECM did not find a significant adjustment to the long run equilibrium

# Conclusions

Adults are distributed with high concentration peak against Arica and Río Loa.

Juveniles were distributed mainly on the coast and north of the Loa River, with a greater post - El Niño presence.

The lag in reproductive activity is environmental and not associated with the size of the specimen.

The CG in length is co-integrated with the temperature anomalies (significant causality test). The CG lengths approach the coast with positive ATSM and move away with negative values.

Juvenile specimens show lower values for the IC and Gini indicators, because for the fishing fleet the target fraction is the adults avoiding the juvenile specimens.

The MEI is not co-integrated with the variables analyzed.

The SSTA is only co-integrated with factor condition and CG longitude.

