Effects of climate variability in the Gulf of California on two marine resources using satellite and fisheries data

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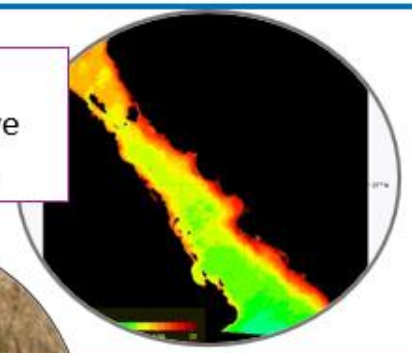
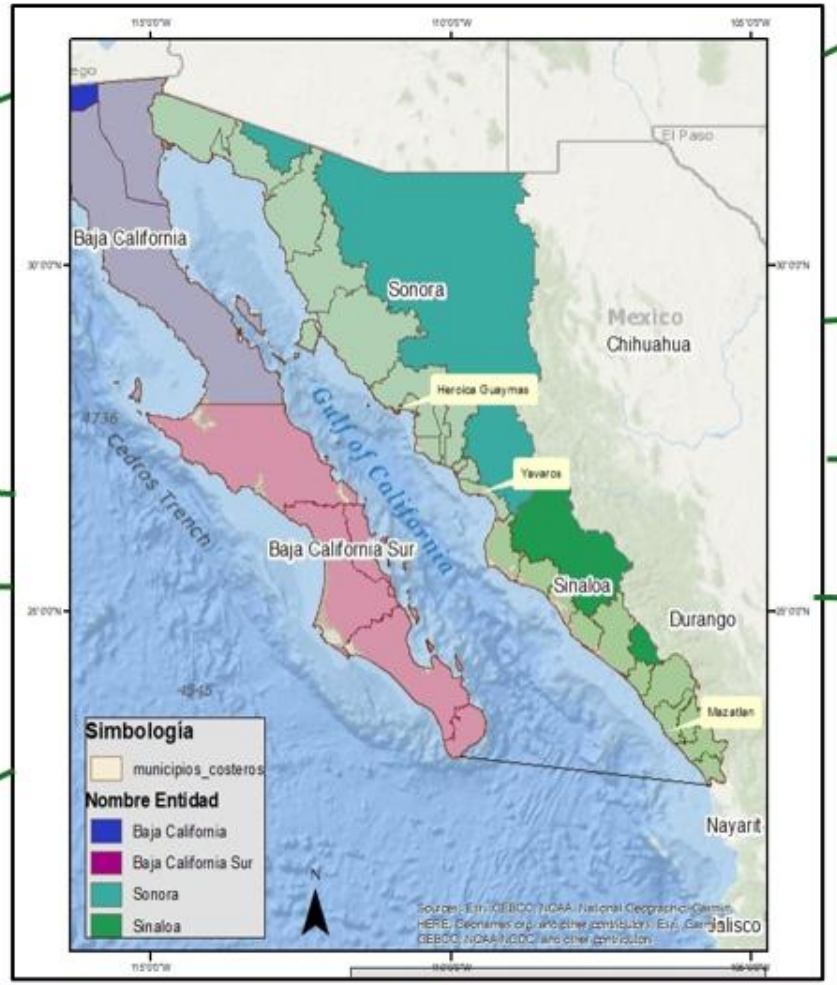
INTRODUCTION

More productive globally.



Physical and oceanographic Characteristics

High biodiversity, endemic species



Sea Surface Temperature (SST)

Chlorophyll-a Concentration [Chlo_a]

Comisión Nacional de Acuacultura y Pesca [CONAPESCA], 2014.
48% Sonora & Sinaloa
76% Gulf of California

5, 000 direct jobs. Sonora-Sinaloa

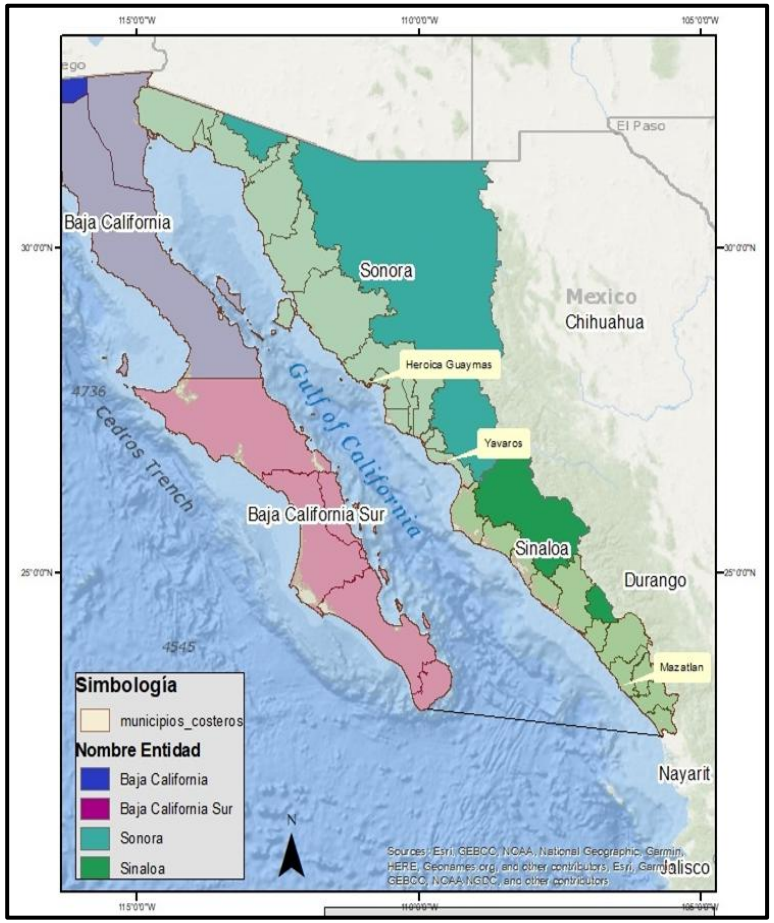
2 400 direct Jobs in Guaymas.

OBJECTIVES

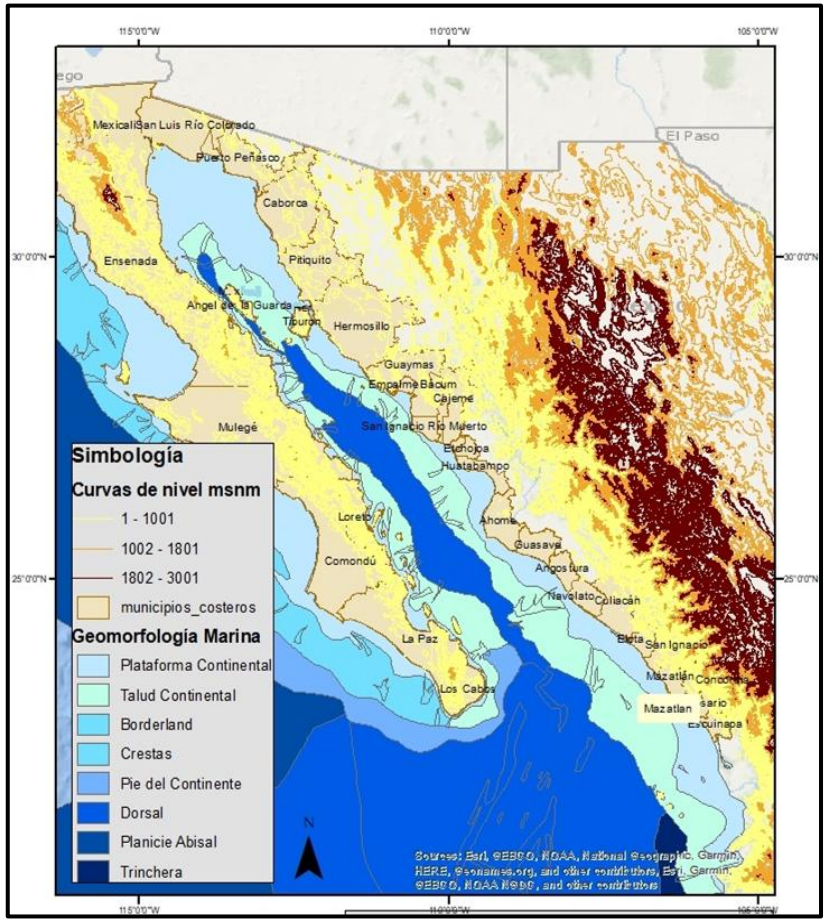
- **General:**
- To perform the spatio-temporal analysis of the relationship between the variation of SST and [Chlo_a] with the fishing production of sardines and shrimp in the Gulf of California (GC), in the period 2011-2024.
- **Particular:**
    1. To describe, in a general way, the temporal conditions of SST and [Chlo_a] of the GC.
    2. Identify the relationship between SST and [Chlo_a].
    3. To analyze the relationship between sardine and shrimp fishery production in the study regions defined by INAPESCA with the variables of SST, NSST and [Chlo_a], as appropriate.
- **Hypothesis**
- Sardine and shrimp fish production in the Gulf of California in the period 2011-2024 correlates with the environmental variables of SST, NSST, and [Chlo_a].

STUDY AREA

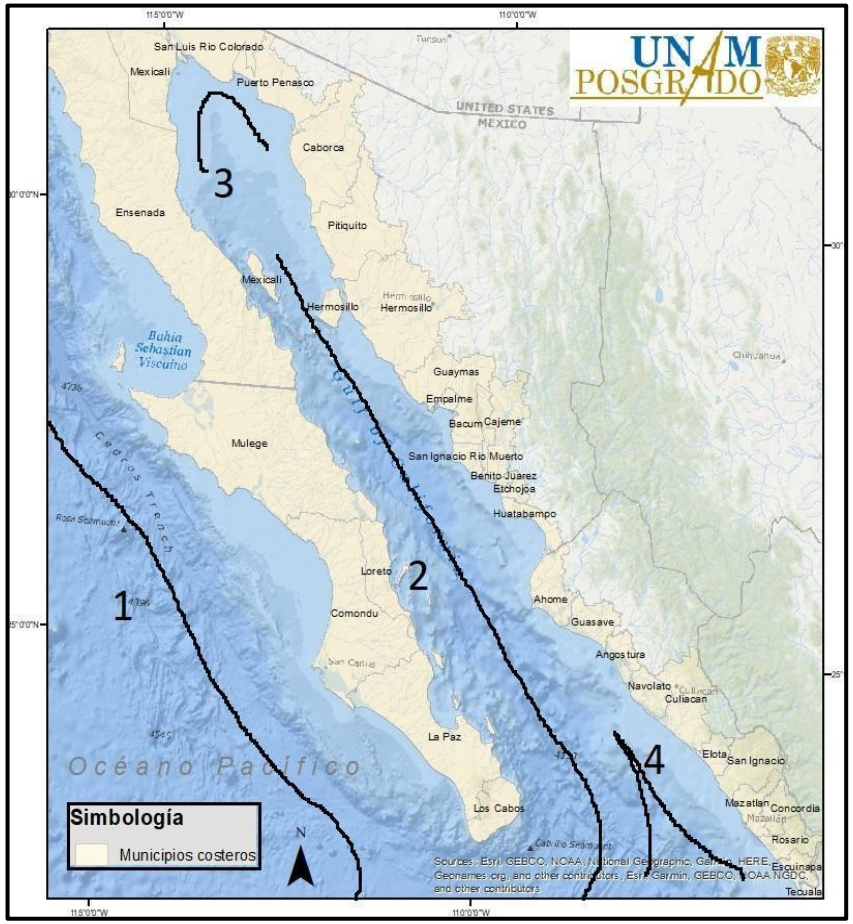
Definition of the Study Area



Bathymetry and Topography



Oceanographic Characteristics



1) California current, 2) Gulf of California current, 3) Gyres, 4) Costa Rica.current

Species under study

SARDINE
Sardinops sagax caeruleus

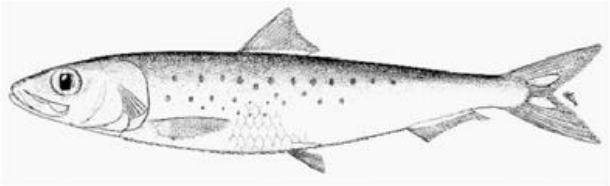
- Minor pelagic.
- Phytoplankton.

Monterrey Sardine (*Sardinops sagax caeruleus*):

- 30% pelagic.
- 77% of sardines

Marketing:
15% canned.
10% fresh consumptiont.
75% flour and oil

Common name	Scientific name
Monterey sardine	Sardinops sagax caeruleus
Anchovy	Engraulix mordax
Threadfin sardine	Opisthonema libertate
Slender thread herring	Opisthonema bulleri
Middling thread herring	Opisthonema medirastre
Mackerel	Scomber japonicus
Pacific anchovy	Cetengraulis mysticetus
Japonese sardine	Etrumeus teres
Little charro anchovy	Trachurus symmetricus
Flatiron herring	Oligoplités refulgens

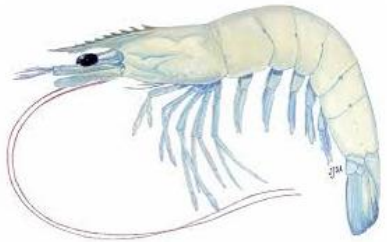


Sardina Monterrey (***Sardinops sagax caeruleus***).
Fuente: Froese y Pauly (2007), www.fishbase.org (febrero 2019).

SHRIMP
Penaeus stylirostris

- Small boats-coastal area.
- Early stages of planktonic life, adult benthic.
- Blue shrimp (*Penaeus stylirostris*).

Common name	Scientific name
Blue shrimp	Penaeus stylirostris
White shrimp	Penaeus vannamei
Brown shrimp	Farfantepenaeus californiensis
Glass shrimp	Farfantepenaeus brevirostris



Camarón azul (***Penaeus stylirostris***).
Fuente: OSPESCA. https://climapesca.org/2018/09/06/litopenaeus-stylirostris/ (febrero, 20

METHODOLOGY

(1) MODIS Image Analysis

(2) Fishing Regions

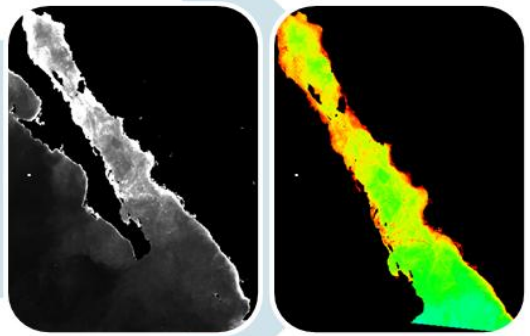
(3) Integrated statistical analysis

METHODOLOGY (1)

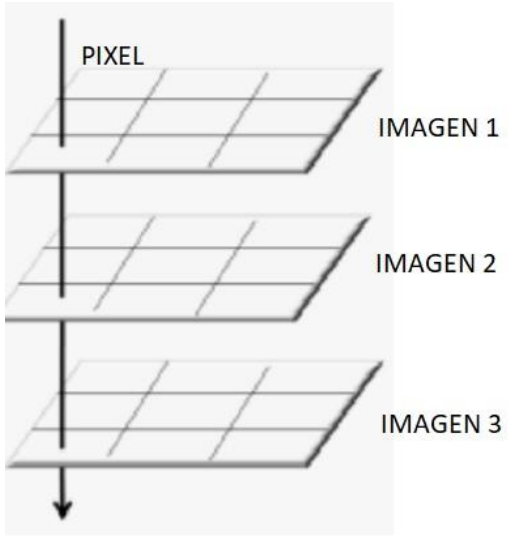
MODIS Data

Descarga de imagenes satelitales MODIS
-Temperatura TSM y TSMN
- Clorofila

Recorte del area de estudio de las 504 imagenes.



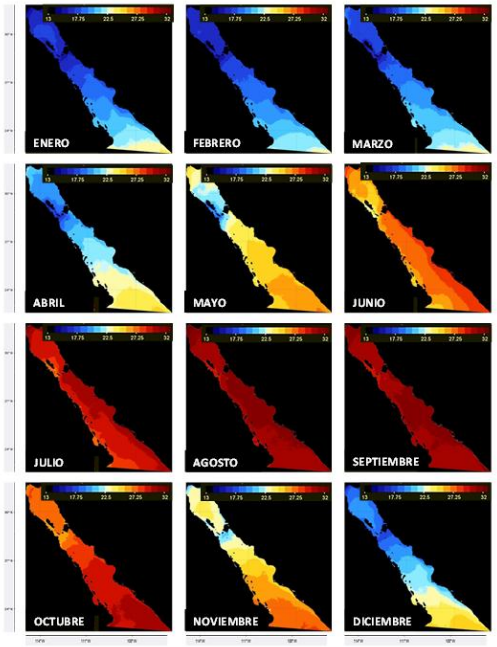
- 168 images per variable (SST, NSST and [Chlo_a]).
- 12 months for 14 years.
- Level 3 processing.
- CONABIO: 1km



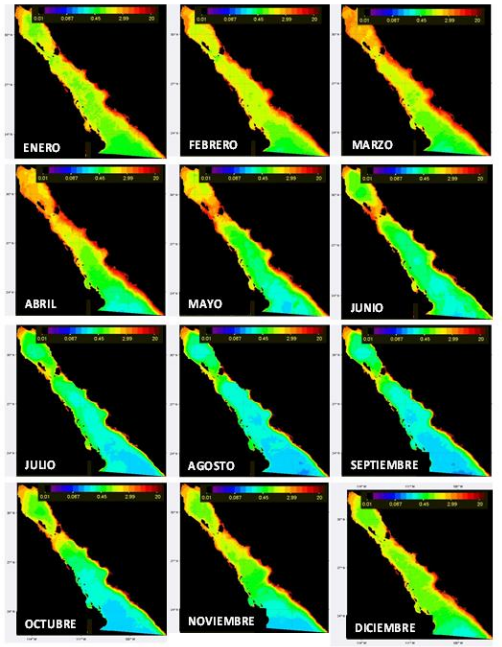
2011-2019 Spatial resolution: 1 km.

Fishing regions

SST



[CHlo_a]



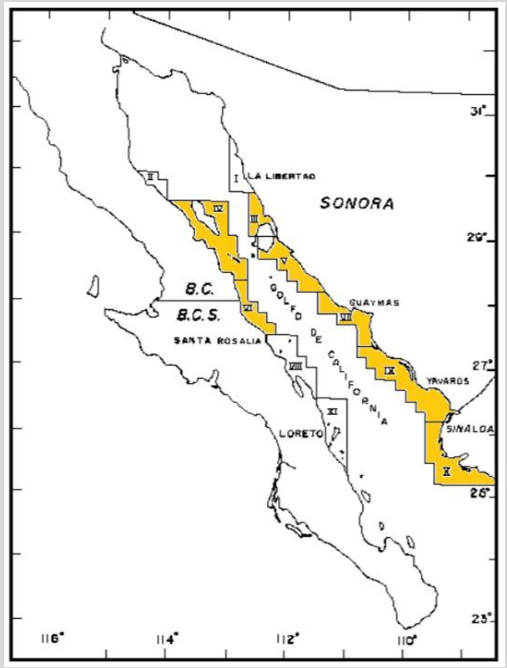
Monthly average $(\mu) = (\sum_{n=1}^{14}(Vm_n))/14$

Monthly anomaly $= \sum_{n=1}^{14}(Vm_n) - \mu$

METHODOLOGY (2)

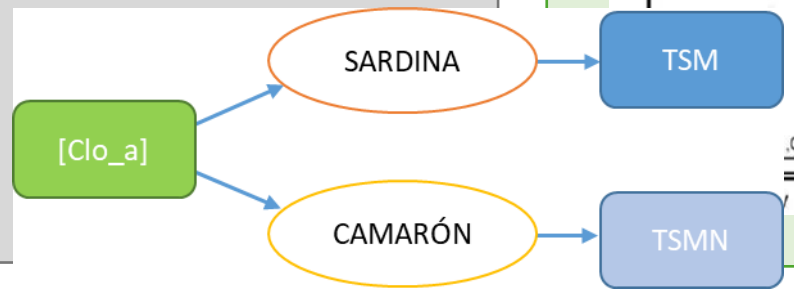
Fishing regions

SARDINE



1. Proposed areas have INAPESCA registration:
2. Are outside of Marine Natural Protected Araeas.
3. Exclude a perimeter strip to the coastline of 2.5 km.
4. NOM-003-SAG/PESC-201
5. 2 500 extraction points.

Source: INAPESCA and CRIP.



SHRIMP

1. 1 nautical mile (1.8 km).
2. NOM-002-PESC-2013
3. Disembarkation sites within the GC.
4. Must correspond to the áreas defined by INAPESCA.
5. Must avoid the core área of the Upper Gulf NPA.
6. 2 800 puntos extracción.

Source: Plan de Manejo de la Pesquería de Camarón del Pacífico Mexicano. INAPESCA

METHODOLOGY

Fishing statistics

Anuarios estadísticos, CONAPESCA. 2005-2018

By fishing area

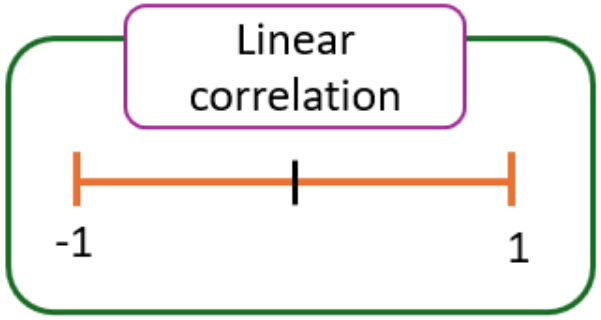
Sum of live weight, zone, month

SST, NSST, [CHlo_a]

MODIS

Average per fishing area

Average, zone, month.



Cross Correlation or Sample Cross Correlation Function (SCCF).

Analysis of the relationship between variables with a time lag

RESULTS

a. IMAGES

- Sea Surface Temperature (SST).
- Chlorophyl-a Concentration [Chlo_a]

b. Fishing zones

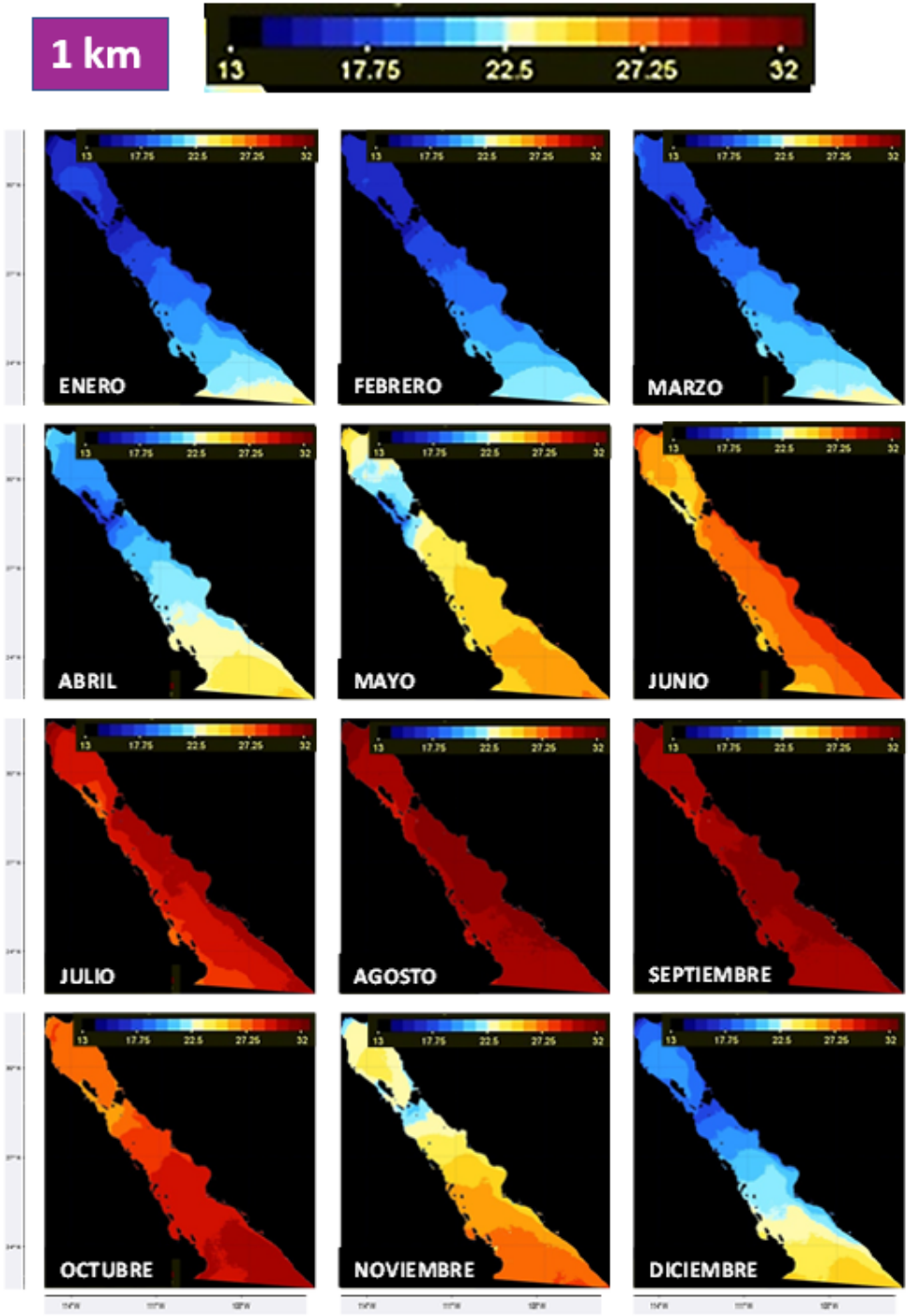
SARDINE

SHRIMPS

Images

- Sea Surface Temperature (SST)

Monthly averages for the period: 2011-2024
Winter conditions of 13-23 °C prevail from November to May.
February the lowest temperatures in the entire GC.
Temperatures between 13-16 °C.
August and September have the highest temperatures, reaching 32°C.

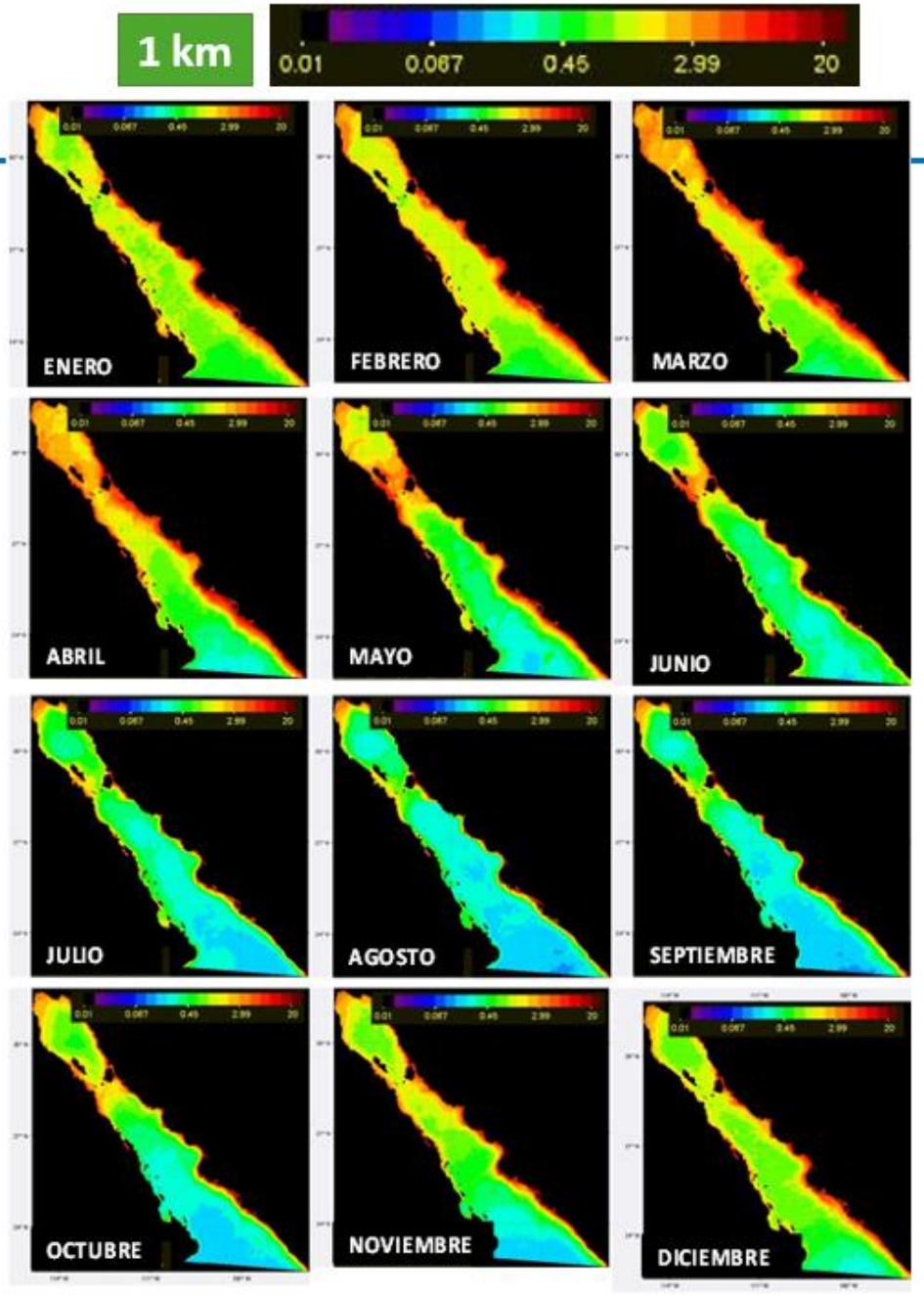


Images

- Chlorophyll-a concentration [Chlo_a]

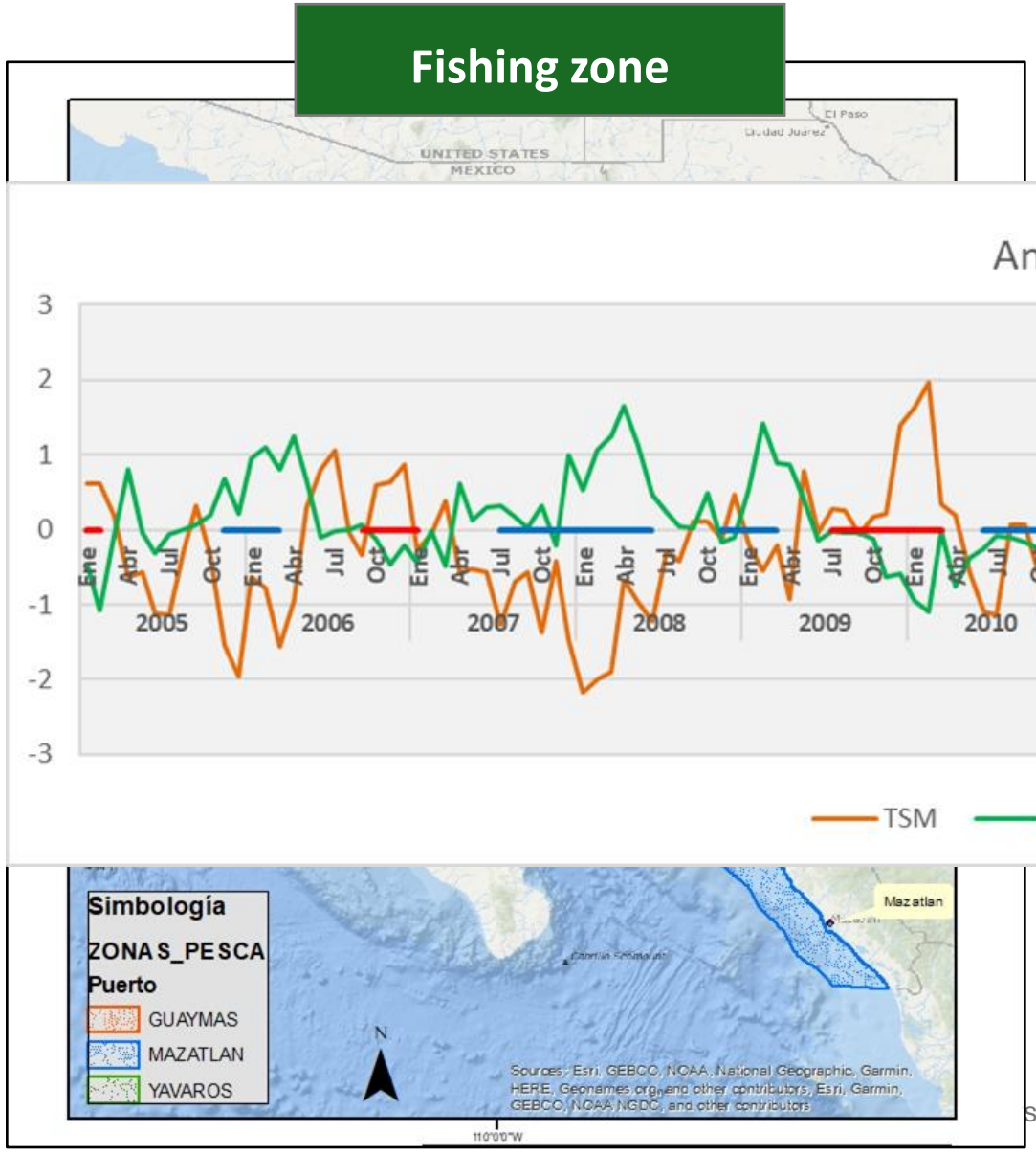
- 0.1-0.5 mg/m^3 (purple-blue)
- 0.7-1.9 mg/m^3 (sky blue-green)
- 2-17 mg/m^3 (yellow-red)

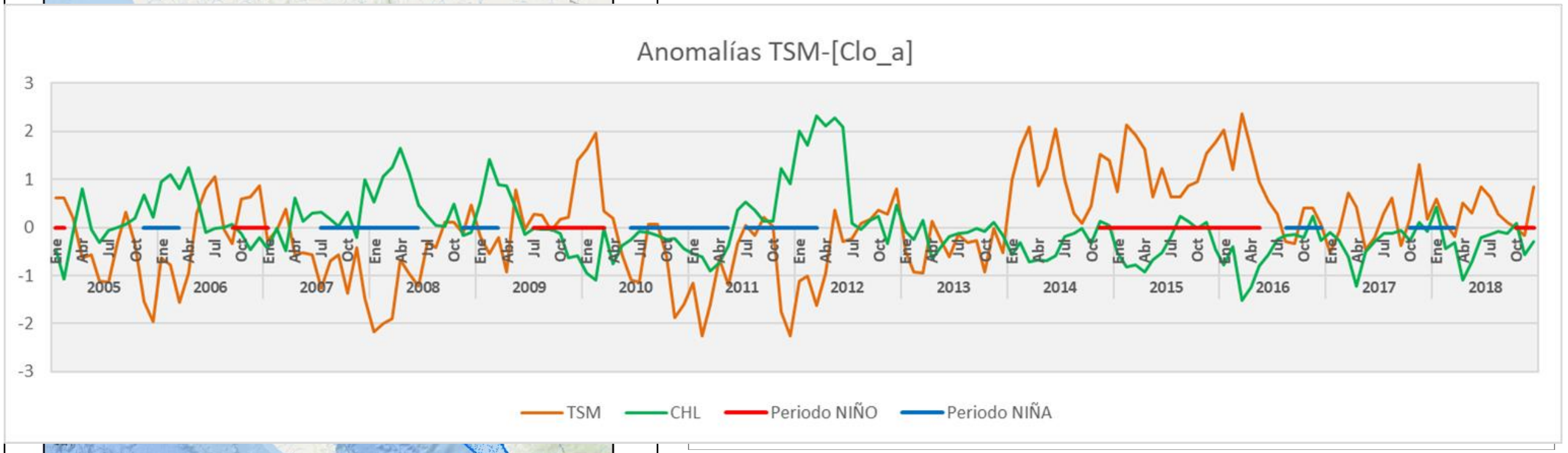
- Seasonal variabilty.
- July to september: lower [Chlo_a], (≤ 0.5 mg/m^3) and higher SST values.
- November to may: higher [Chlo_a].
- March-april: highest [Chlo_a] values ~ 15 mg/m^3.



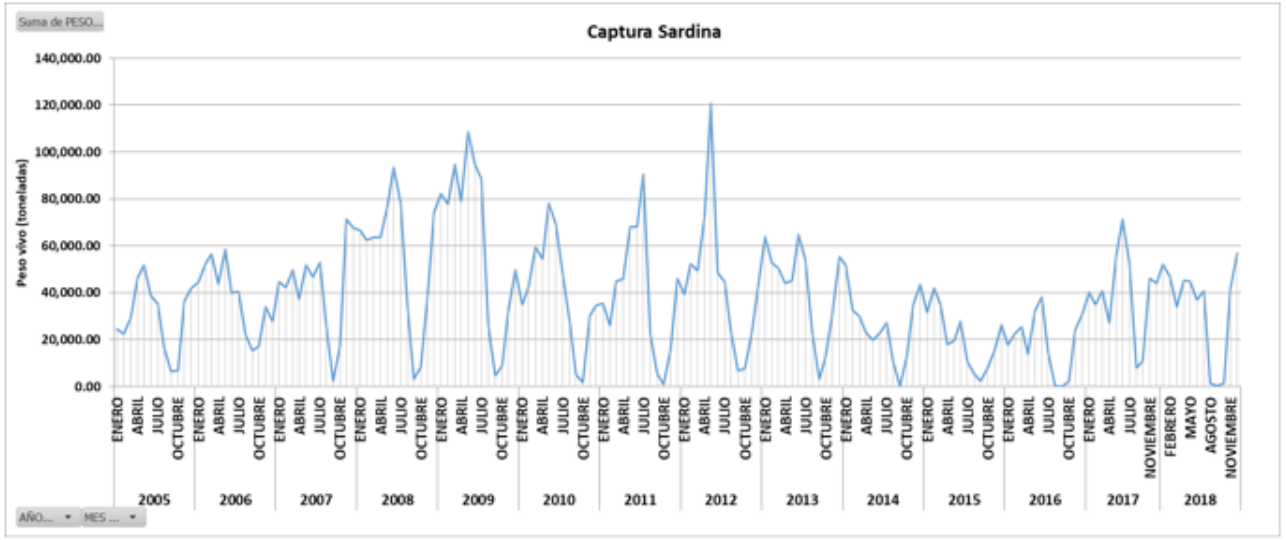
Fishing zone: SARDINE

Fishing zone

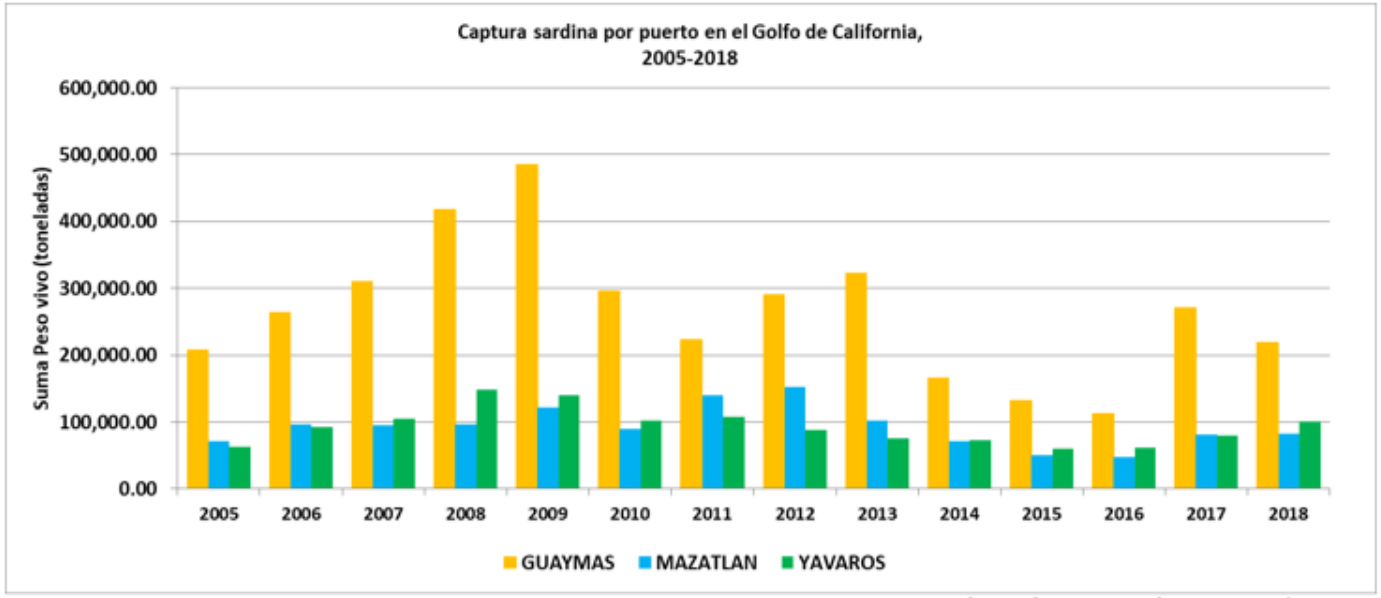


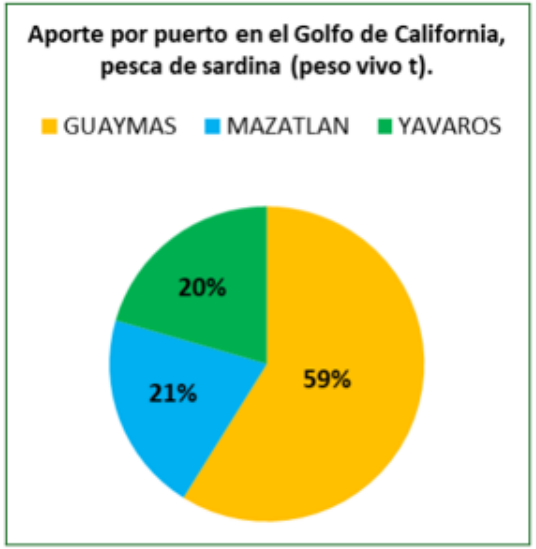


SARDINE



Sitio Desembarque	Suma PESO VIVO (t) SARDINA	Porcentaje%
GOLFO DE SANTA CLARA	14701.11	0.23236121
GUAYMAS	3716913.01	58.74
MAZATLAN	1298421.06	20.52
PUERTO PEÑASCO	550.31	0.008
SAN FELIPE	119.03	0.001
TOPOLOBAMPO	157.58	0.002
YAVAROS	1295974.88	20.48
Total general	6326837.01	100





SARDINE

GENERAL SARDINA

TSM-[Clo_a]

Cross Correlations

Series Pair:TSM with Clo_a

Lag	Cross Correlation	Std. Error[a]
-7	.473	.079
-6	.646	.079
-5	.636	.078
-4	.440	.078
-3	.105	.078
-2	-.273	.078
-1	-.577	.077
0	-.724	.077
1	-.692	.077
2	-.515	.078
3	-.213	.078
4	.145	.078
5	.449	.078
6	.611	.079
7	.599	.079

[Clo_a]-Sardina

Cross Correlations

Series Pair:Clo_a with Sardina

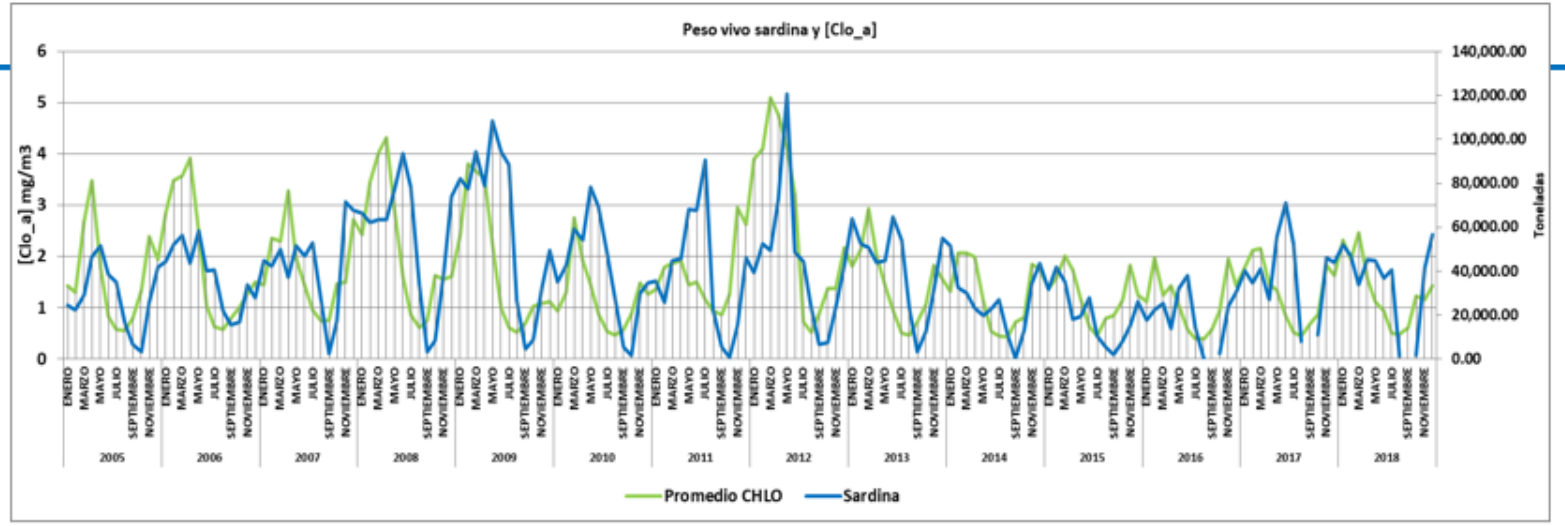
Lag	Cross Correlation	Std. Error[a]
-7	-.173	.079
-6	-.313	.079
-5	-.294	.078
-4	-.197	.078
-3	-.099	.078
-2	.046	.078
-1	.273	.077
0	.485	.077
1	.659	.077
2	.642	.078
3	.480	.078
4	.172	.078
5	-.150	.078
6	-.291	.079
7	-.280	.079

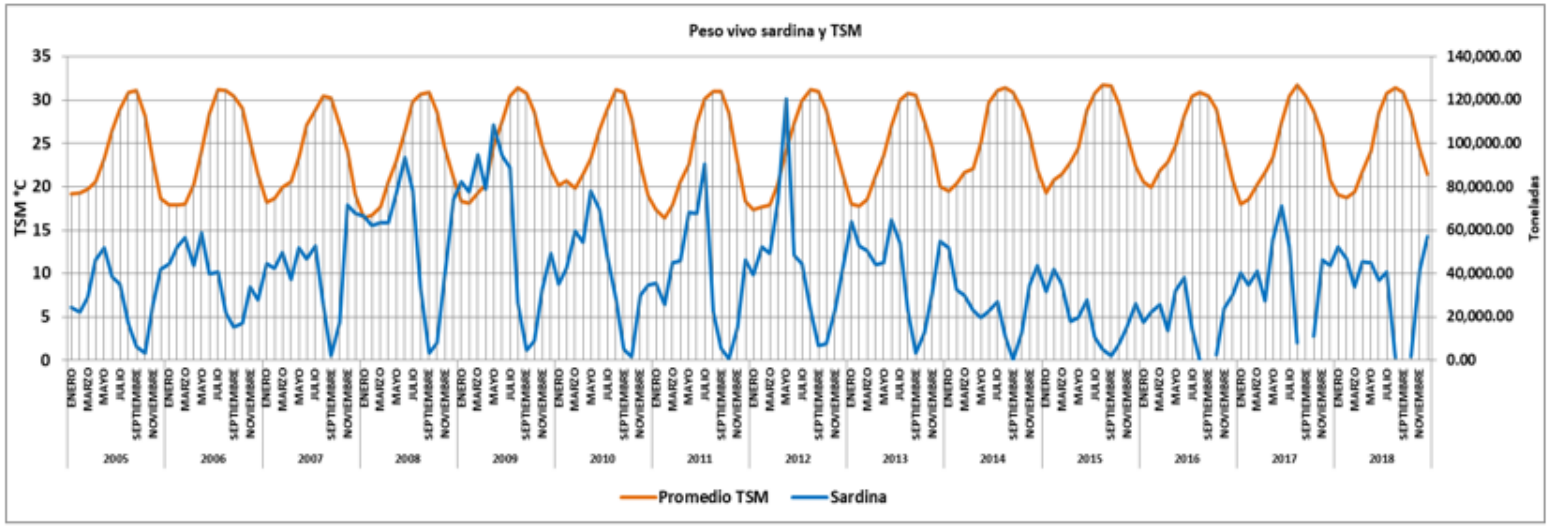
TSM-Sardina

Cross Correlations

Series Pair:TSM with Sardina

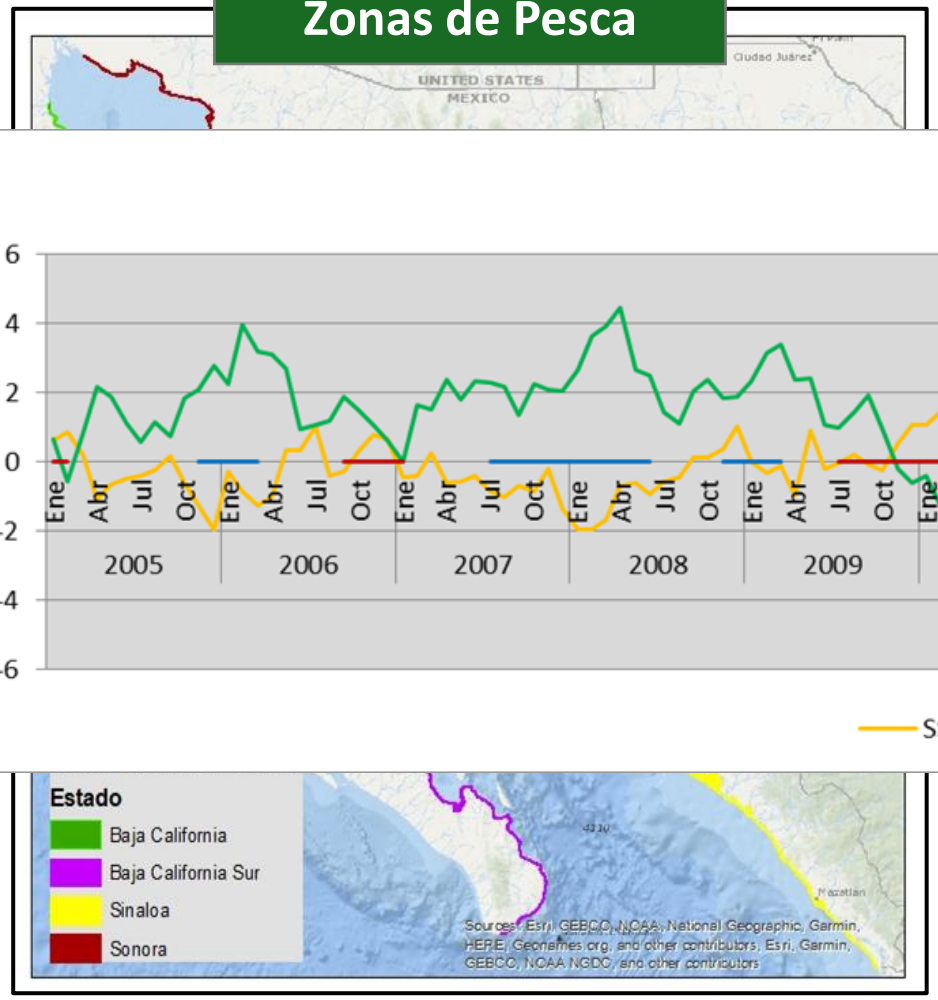
Lag	Cross Correlation	Std. Error[a]
-7	.054	.079
-6	.263	.079
-5	.437	.079
-4	.494	.078
-3	.401	.078
-2	.166	.078
-1	-.143	.078
0	-.423	.077
1	-.582	.078
2	-.585	.078
3	-.433	.078
4	-.213	.078
5	.042	.079
6	.275	.079
7	.439	.079

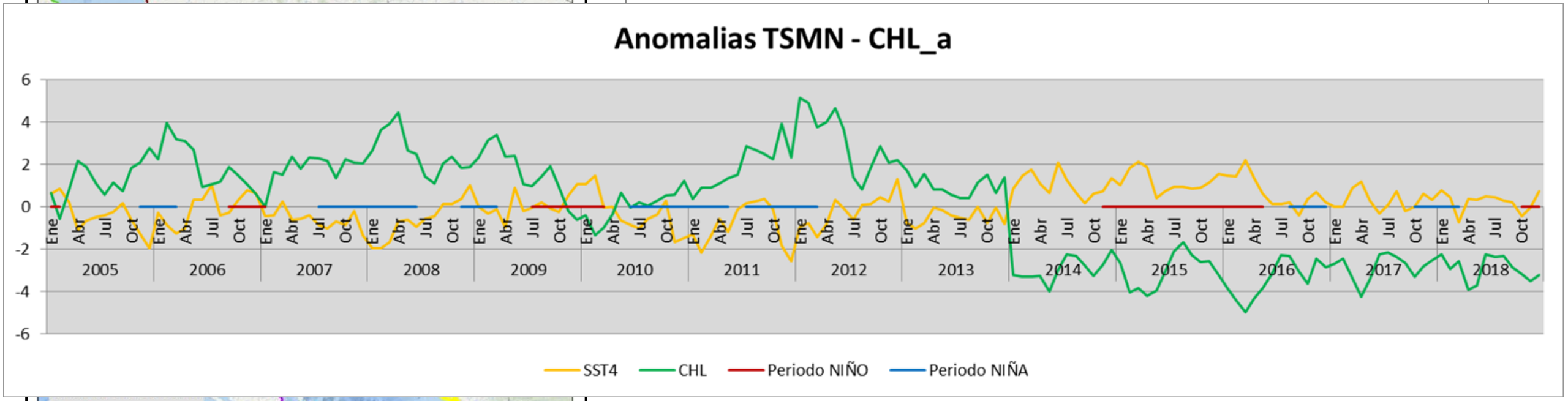




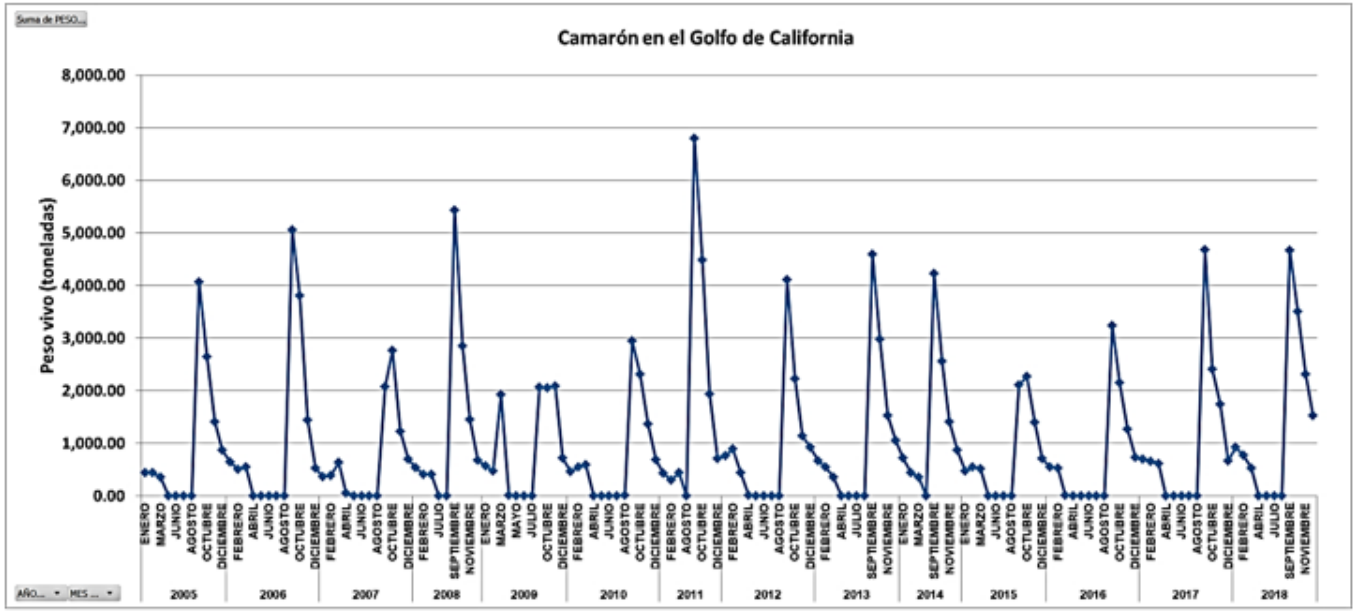
FISHING ZONES: SHRIMPS

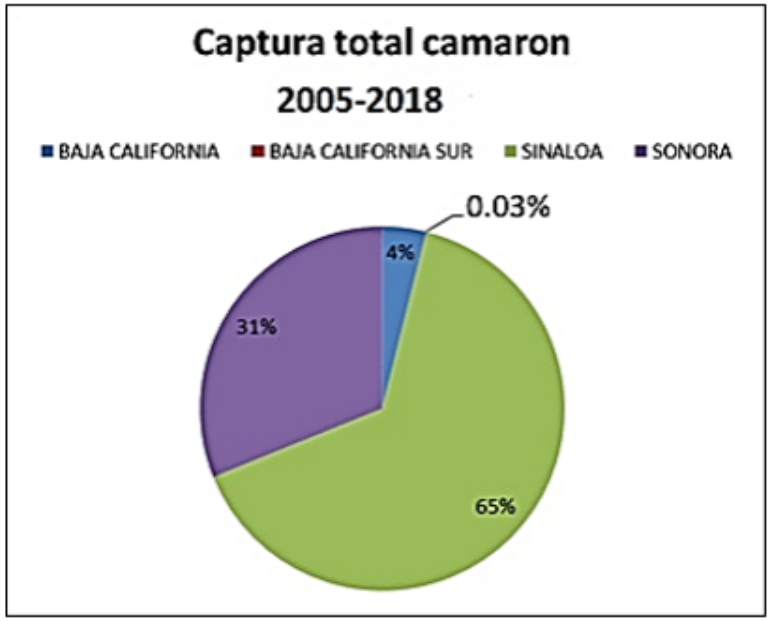
Zonas de Pesca

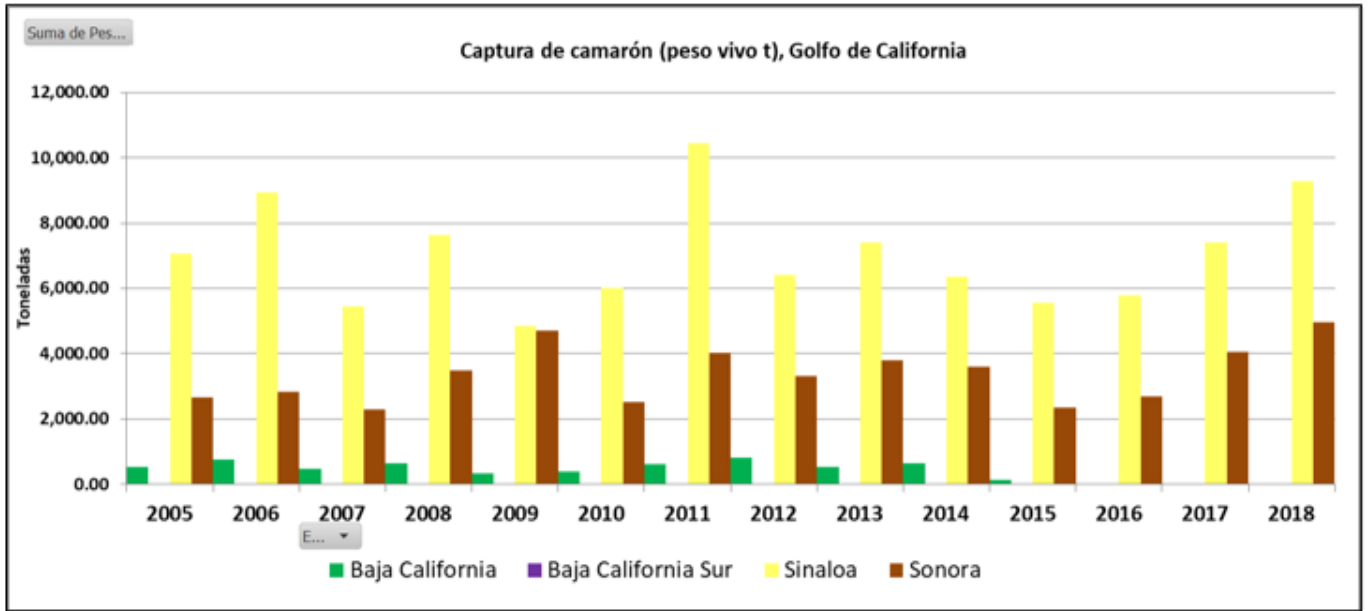




SHRIMP


Suma de PESO...
Camarón en el Golfo de California
Peso vivo (toneladas)
8,000.00
7,000.00
6,000.00
5,000.00
4,000.00
3,000.00
2,000.00
1,000.00
0.00
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018


Captura total camaron
2005-2018
BAJA CALIFORNIA
BAJA CALIFORNIA SUR
SINALOA
SONORA
0.03%
4%
31%
65%


Suma de Pes...
Captura de camarón (peso vivo t), Golfo de California
Toneladas
12,000.00
10,000.00
8,000.00
6,000.00
4,000.00
2,000.00
0.00
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Baja California
Baja California Sur
Sinaloa
Sonora

SHRIMP

GENERAL CAMARÓN

TSM-[Clo_a]

Cross Correlations

Series Pair:TSMN with Clo_a

Lag	Cross Correlation	Std. Error[a]
-7	.195	.079
-6	.242	.079
-5	.190	.078
-4	.049	.078
-3	-.131	.078
-2	-.293	.078
-1	-.390	.077
0	-.408	.077
1	-.358	.077
2	-.257	.078
3	-.104	.078
4	.056	.078
5	.178	.078
6	.219	.079
7	.172	.079

[Clo_a]-Camarón

Cross Correlations

Series Pair:Clo_a with Camaron

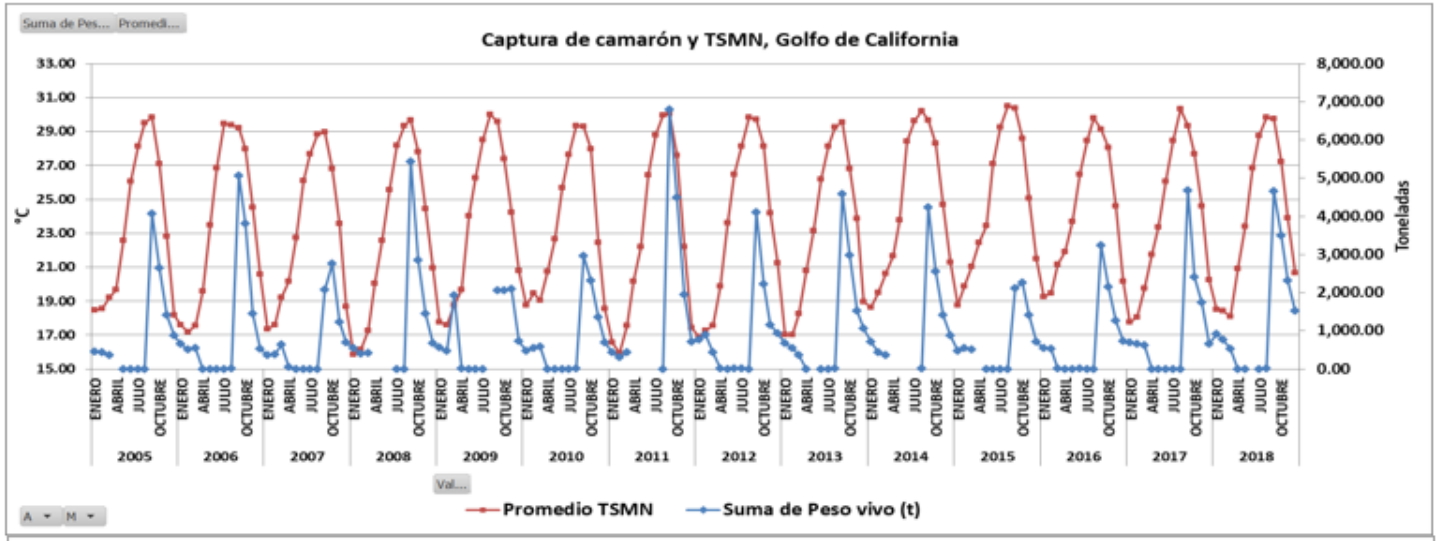
Lag	Cross Correlation	Std. Error[a]
-7	-.117	.105
-6	.088	.105
-5	.199	.104
-4	.124	.104
-3	.010	.103
-2	.000	.103
-1	-.034	.102
0	-.114	.102
1	.088	.102
2	.158	.103
3	.063	.103
4	-.005	.104
5	-.004	.104
6	-.054	.105
7	-.143	.105

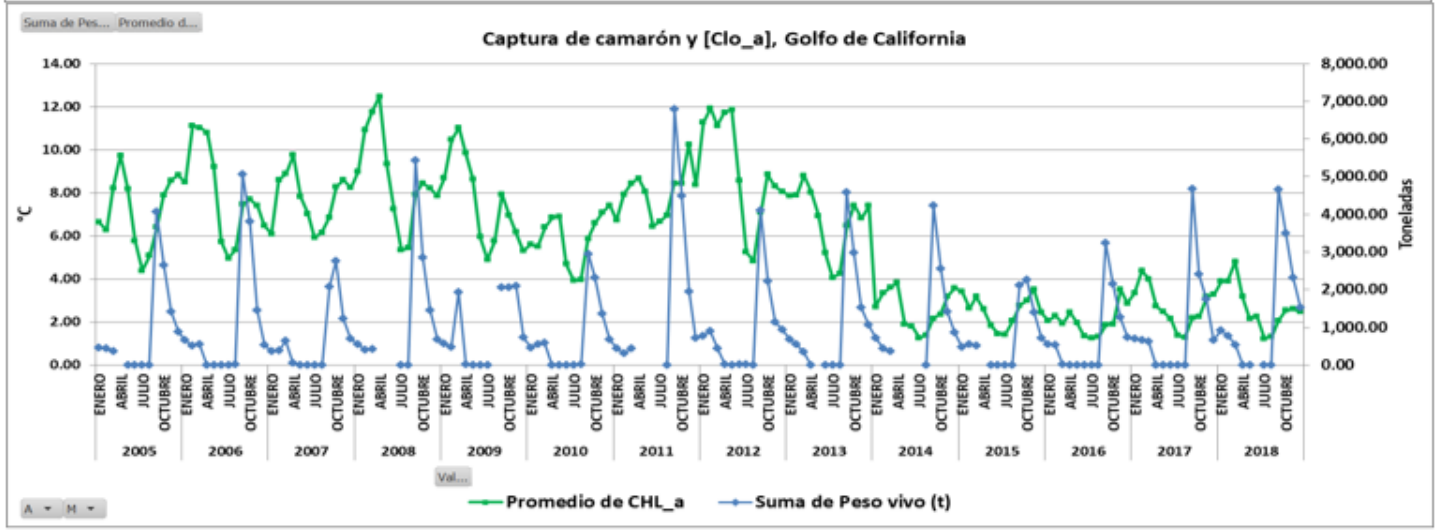
TSM-Camarón

Cross Correlations

Series Pair:TSMN with Camaron

Lag	Cross Correlation	Std. Error[a]
-7	.767	.105
-6	.220	.105
-5	-.273	.104
-4	-.548	.104
-3	-.504	.103
-2	-.123	.103
-1	.421	.102
0	.857	.102
1	.200	.102
2	-.344	.103
3	-.602	.103
4	-.494	.104
5	-.099	.104
6	.415	.105
7	.756	.105





RESULTADOS SARDINA

ZONA	Correlación TSM-[Clo a]	Correlación [Clo a]-Pesca Sardina	Correlación TSM-Pesca Sardina
GENERAL 	r = -0.724	r = 0.659 1 Lag	r = -0.582 1 Lag
GUAYMAS 	r = -0.629	r = 0.550 1 Lag	r = -0.401 2 Lag
YAVAROS 	r = -0.744	r = 0.317 1 Lag	r = -0.265 0 Lag
MAZATLÁN 	r = -0.692	r = 0.507	r = -0.453

acional

RESULTADOS CAMARÓN

ZONA	Correlación TSMN-[Clo a]	Correlación [Clo a]-Pesca Camarón	Correlación TSMN-Pesca Camarón
GENERAL	r= -0.408	r= -0.114	r= 0.857
BAJA CALIFORNIA SUR 	r= -0.566	r= 0.185 0 Lag	r= 0.164 1 Lag
BAJA CALIFORNIA 	r= -0.402	r= 0.338	r= 0.061
SONORA 	r= -0.395	r= 0.118	r= 0.636
SINALOA 	r= -0.321	r= 0.056	r= 0.672

CONCLUSIONS

Working hypothesis was fulfilled: the fishing production of sardines and shrimp in the Gulf of California, in the period of 2011-2024, presents a correlation with the environmental variables SST, NSST and [Chlo_a]. Sardine has the better correlations Shrimp correlates better with the NSST variable, for the area of Sonora and Sinaloa, which are the main producing states of this resource.

SARDINE

- Presented the best cross correlation (cc) with the variables of SST and [Chlo_a]
- [Chlo_a] and sardine fishing (r = 0.659) first lag
- SST and sardine fishing (r = -0.582) no lag

SHRIMP

- Variables NSST and [Chlo_a] had a relatively low cross correlation (r= 0.408), with no lag
- [Chlo_a] and shrimp fishing (r = -0.114)
- NSST and shrimp fishing (r = 0.857)

SATELLITE IMAGES

- Relationship SST and [Chlo_a] is inverse.
  - -0.717 (1 km) -0.845 (4 km) in the first lag
- They are of great importance for studying sea surface conditions.