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Chilean Jack Mackerel
Workshop

DISTRIBUTION OF CHILEAN JACK MACKEREL EGGS AND LARVAE IN THE SOUTHEASTERN PACIFIC OCEAN

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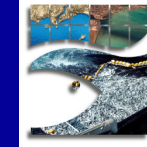
CHILEAN JACK MACKEREL WORKSHOP (CHJMWS)

Santiago, June 30 – July 3th 2008

FAMILY : Carangidae
SCIENTIFIC NAME : *Trachurus murphyi* (Nichols)
COMMON NAME : jurel, jurelillo
INTERNATIONAL NAME : Chilean Jack mackerel, Horse mackerel



BACKGROUND

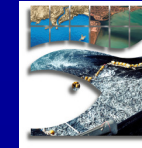


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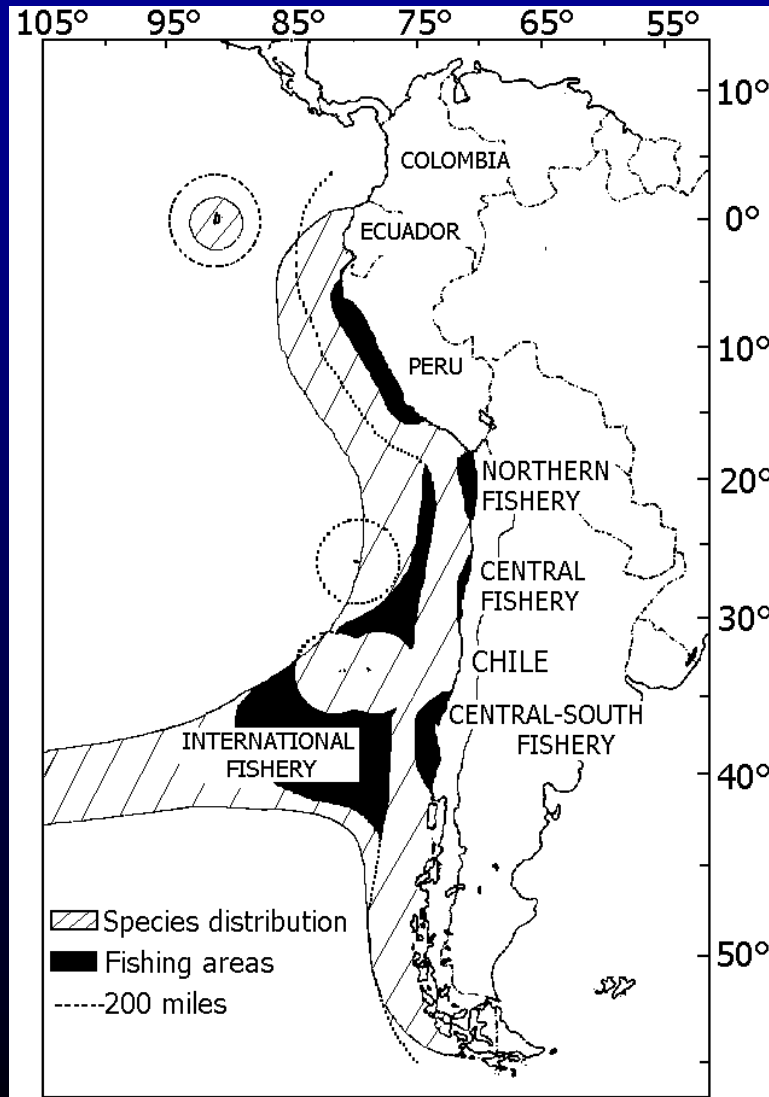
- Chilean jack mackerel (*Trachurus murphyi*) is a migrating pelagic species which inhabits the Southern Pacific Ocean, and constitutes the most important fishery for Chile.
- Exhibits a strong seasonal migration pattern:
 - an offshore migration towards the oceanic reproductive habitat in spring mainly located in oceanic waters off central Chile (32°-40°S) and beyond 90°W.
 - an onshore migration during the late summer related to coastal food availability in coastal waters.
- During fall and winter, this species aggregates compact schools inside the Chilean EEZ, being more available for the Chilean purse-seine fleet.
- Spawning occurs mainly between October and December, although it can extend from September to February.

In this contribution, we describe the spatial distribution of jack mackerel eggs and larvae for the 1999-2007, and we attempt to examine the relationships between early stages densities and environmental conditions during the spawning period in oceanic waters off central Chile.

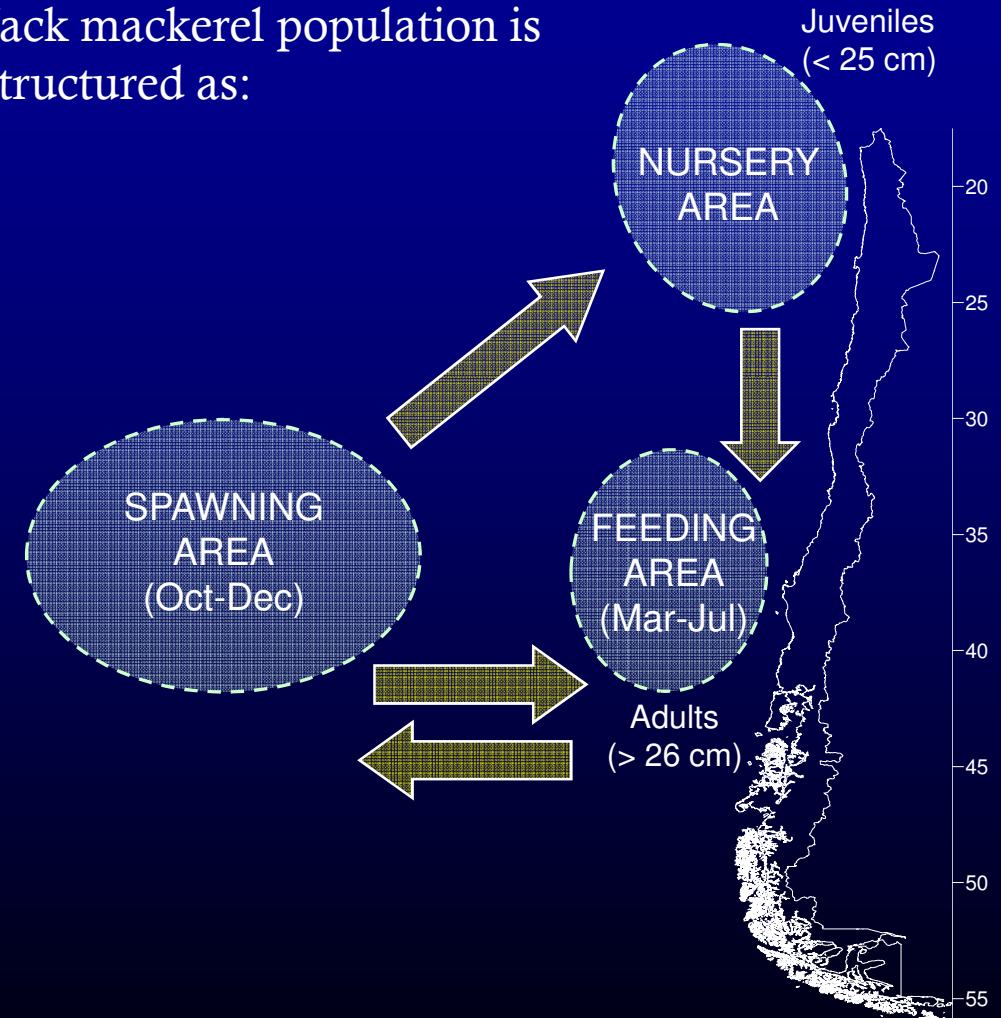
DISTRIBUTION AND FISHERIES

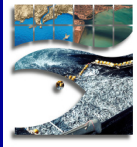


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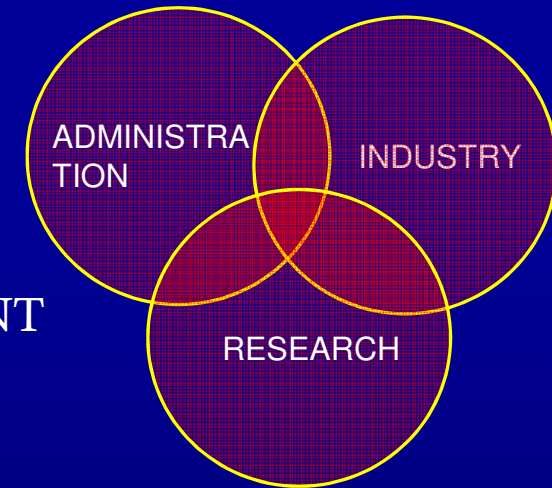


CONCEPTUAL MODEL:
Jack mackerel population is
structured as:



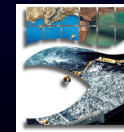


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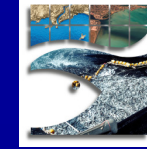


THIS STUDY COULD NOT HAVE BEEN POSSIBLE WITHOUT THE JOINT EFFORT OF THREE DIFFERENT ORGANIZATIONS:

- THE GOVERNMENT OF CHILE (UNDERSECRETARIAT OF FISHERIES AND FISHERY RESEARCH FUND) WHO HAS PRIORITIZED A DECADE OF HIGH SEA STUDIES ON THE JACK MACKEREL SPAWNING REGION OFF CENTRAL CHILE.
- THE LOCAL FISHING INDUSTRY, WHO PROVIDED 8-10 FISHING VESSELS FOR DEVELOPING CRUISES IN A HUGE SPAWNING REGION OFF CENTRAL CHILE.
- THE SCIENTIFIC GROUP, LED BY THE FISHERY RESEARCH INSTITUTE (WITH THE PARTICIPATION OF IFOP, U. CONCEPCIÓN, U. CATHOLIC CONCEPCIÓN), WHICH HAS STUDIED THE DISTRIBUTION OF JACK MACKEREL EGGS AND LARVAE, AS WELL AS REPRODUCTIVE ASPECTS, BIOLOGICAL-FISHING DATA, ENVIRONMENTAL INFORMATION, SCHOOLS STRUCTURE, AND THE ASSESSMENT OF SPAWNING BIOMASS, AND THEIR INTERANNUAL VARIABILITY IN THE OCEANIC AREA OFF CENTRAL CHILE.



OBJECTIVES



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To determine relative abundance indexes of jack mackerel eggs/larvae in the oceanic waters off central Chile, and to characterize the reproductive condition and the spawning area.

QUESTIONS TO SOLVE

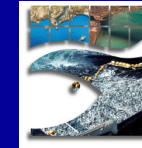
Which is the main spawning region for jack mackerel stock?

Which is the abundance of eggs/larvae in the oceanic waters off central Chile?

Which is the behavior of Chilean jack mackerel reproductive schools in oceanic waters?

It is possible to assess the spawning biomass with the DEPM?

SAMPLING DESIGN



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ANNUAL CRUISES:

- Study period: Spawning peak (November) of 1999 - 2007.
- Study area: 75-92°W; 33-39°S (1000 nm from the coast).
- Cruise period: 8-12 days.
- Number of stations: > 650.
- Fishing vessels: 5-10 vessels from the local purse-seine fleet.

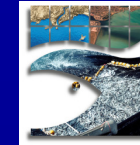
ICHTHYOPLANKTON SAMPLING:

- WP-2 nets (0.6 m, 303 μ m mesh size)
- Vertical tows (100 m to surface)
- Stratified tows (100-75, 75-50, 50-25, 25-0 m)

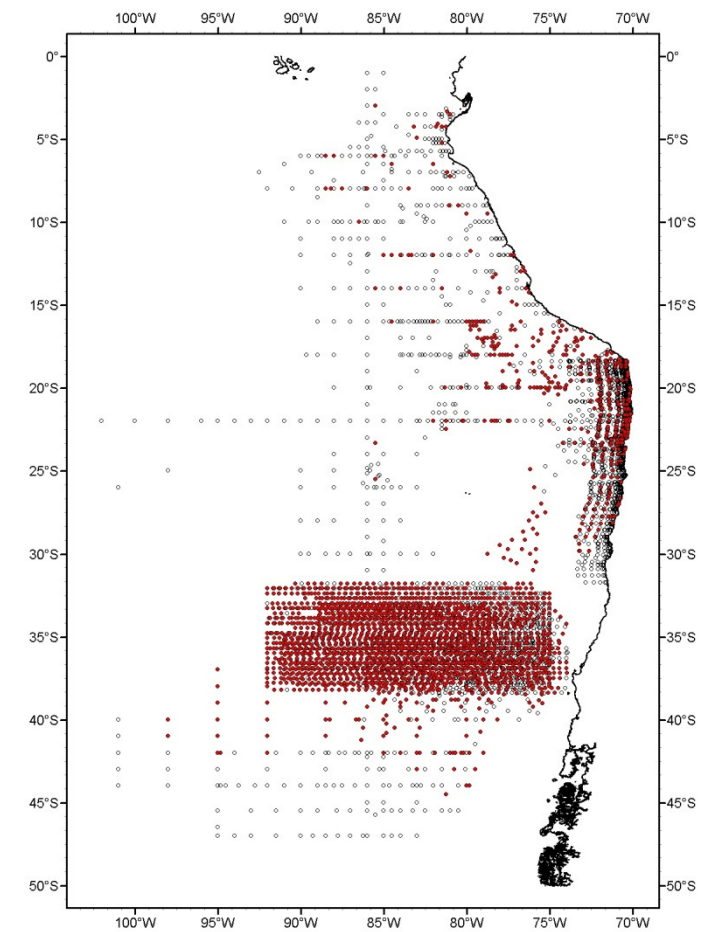
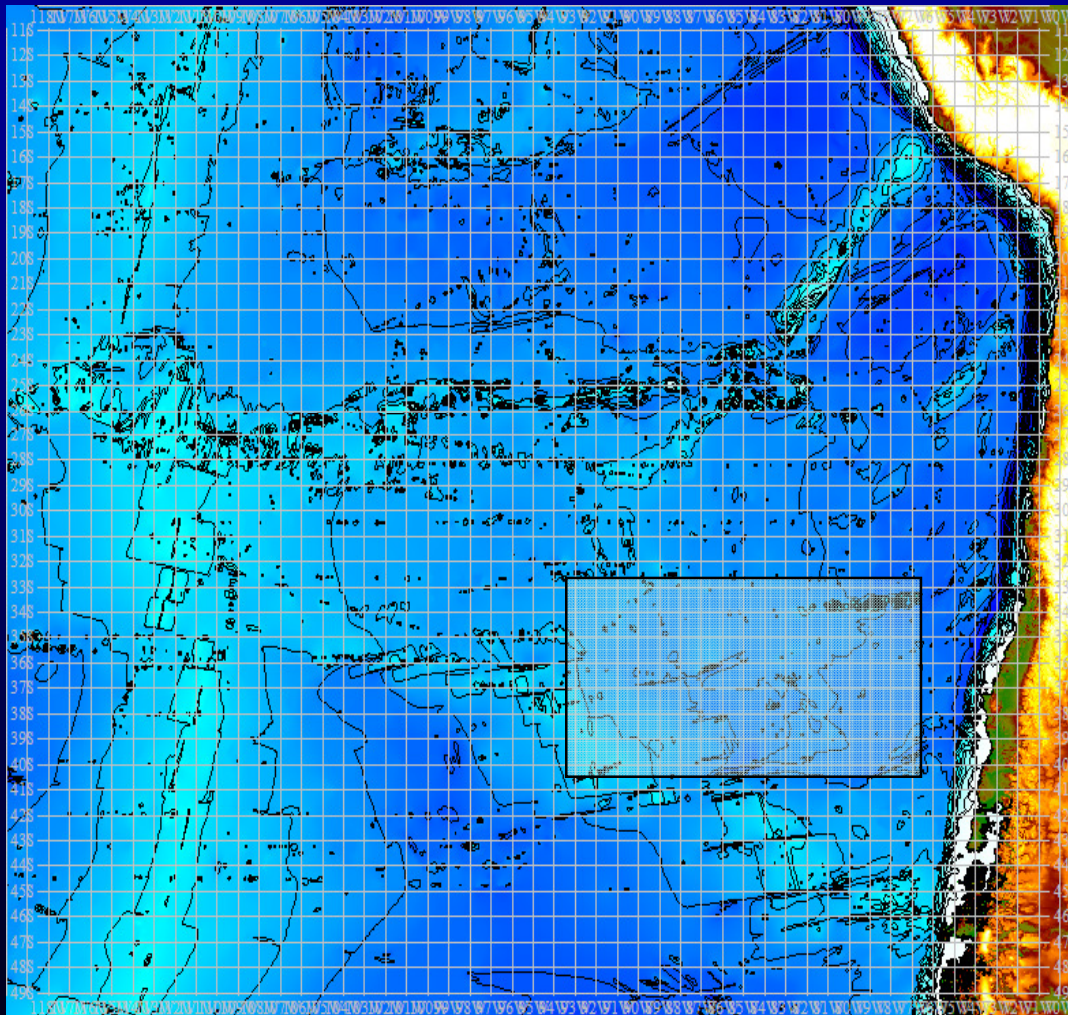
PHYSICAL FIELD:

- SST, wind, MSLA.
- Turbulence index, geostrophic currents.

STUDY AREA



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SAMPLING AND ANALYSIS

FOR EACH STATION:

- Analysis of total planktonic sample (separating and counting all eggs & larvae presents in samples).
- Identifying the jack mackerel eggs/larvae, as well as the other components of the ichthyoplanktonic assemblage.
- Determination of different stages of jack mackerel eggs and larvae.
- Analysis of spatial distribution (geostatistical techniques).
- Analysis of association between eggs/larvae and environmental conditions (EOF, GAM, others).

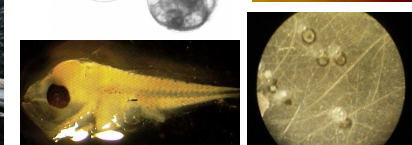
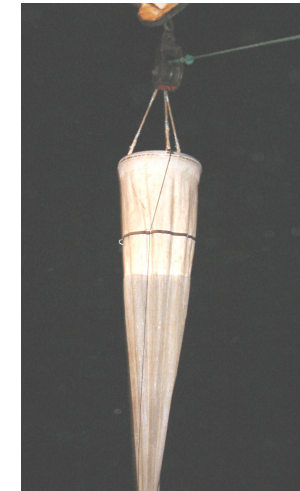
ENVIRONMENTAL CONDITIONS

- CTDO data
- Satelital information: SST (Pathfinder, Modis), Chlorophyll (Modis), Wind (QuikScat), Geostrophic velocities (AVISO).

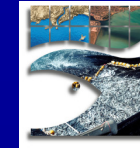
Fishing vessels



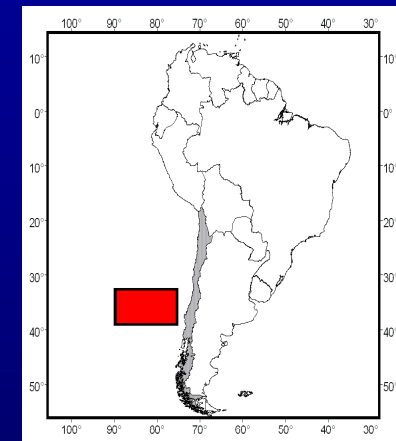
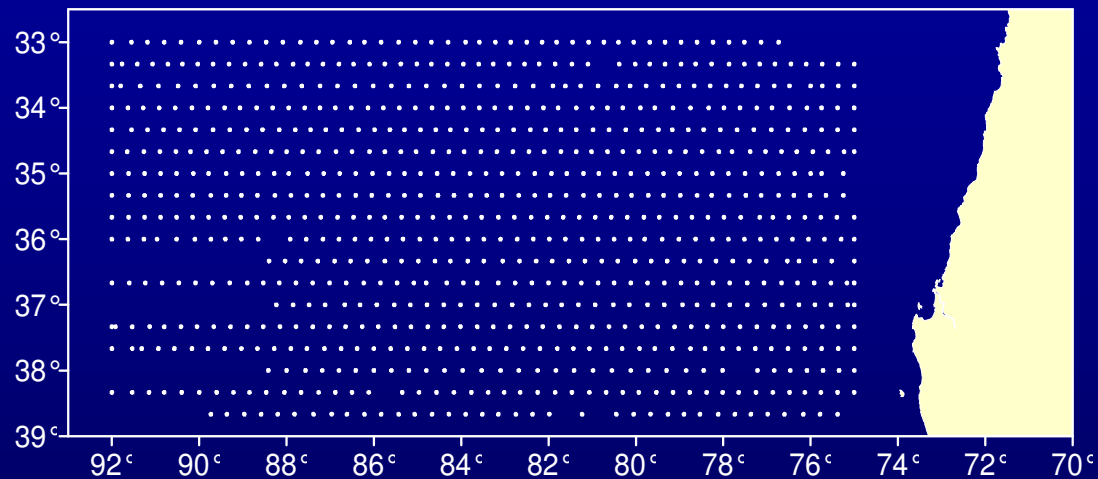
Ichthyoplankton
sampling



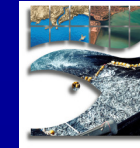
SUMMARY OF CRUISES



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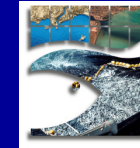


CRUISES	LATITUDE (°S)	LONGITUDE (°W)	STUDY AREA (mn ²)	VESSELS	TRANSEC T DESIGN	DIST. BETWEEN TRANSECTS
Dec. 1998	33°00' - 39°00'	75°00' - 86°00'	231.340	5	Zig-Zag	75 mn
Nov. 1999	33°06' - 38°12'	75°00' - 92°00'	284.526	9	Lineal	18 mn
Dic. 1999	35°03' - 38°24'	74°00' - 86°00'	114.917	6	Lineal	18 mn
Nov. 2000	32°06' - 37°48'	75°00' - 92°00'	261.815	10	Lineal	18 mn
Nov. 2001	31°48' - 36°54'	75°00' - 92°00'	257.280	9	Lineal	18 mn
Nov. 2003	33°00' - 38°00'	75°00' - 92°00'	317.568	8	Lineal	20 mn
Nov. 2004	31°40' - 38°00'	75°00' - 92°00'	403.980	10	Lineal	20 mn
Nov. 2005	33°00' - 38°40'	75°00' - 92°00'	356.320	9	Lineal	20 mn
Nov. 2006	33°00' - 38°50'	74°00' - 92°00'	391.755	9	Lineal	20 mn
Nov. 2007	30°00' - 35°50'	74°00' - 92°00'	400.432	5	Lineal	20 mn



ABUNDANCE INDEX FOR CHILEAN JACK MACKEREL EGGS

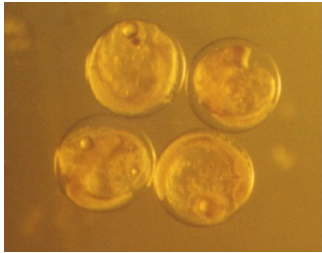
	1998	1999-n	1999-d	2000	2001	2003	2004	2005	2006	2007
Total Stations	173	751	363	880	661	694	910	784	791	445
(+) Stations	125	546	212	660	478	419	658	326	308	118
%	72, 3	72, 7	58, 4	75, 0	72, 3	60, 4	72, 3	41, 6	38, 9	26, 5
Mean Density (D)	317, 9	561, 7	266, 3	444, 2	640, 2	132, 0	373, 5	98, 4	111, 3	39, 8
Var (D)	1903, 2	3618, 6	400, 9	413, 9	1781, 8	97, 6	763, 0	87, 9	183, 0	31, 7
Mean Dpos	440, 0	772, 6	455, 9	592, 2	885, 8	218, 7	516, 6	236, 7	285, 8	150, 2
Var (Dpos)	3653, 6	6550, 4	1177, 8	603, 1	2956, 0	222, 6	1347, 5	408, 7	1046, 8	311, 8
Dpos (max)	3917, 7	26844, 1	3501, 4	5199, 1	11353, 0	2900, 2	14465, 4	4420, 9	4633, 2	1167, 1



ABUNDANCE INDEX FOR CHILEAN JACK MACKEREL LARVAE

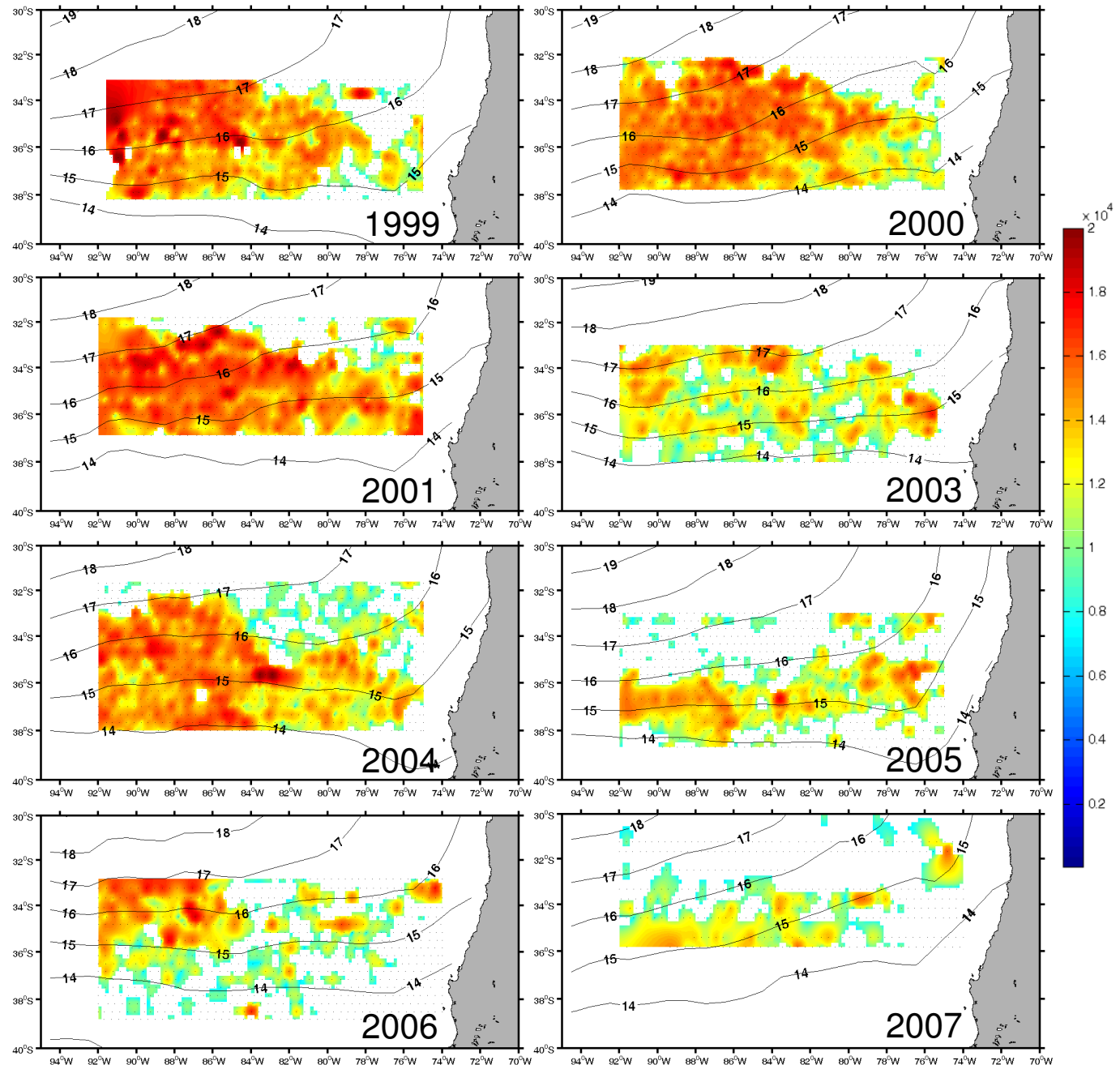
	1998	1999-d	2000	2001	2003	2004	2005	2006	2007
Total Stations	173	363	880	660	694	910	784	791	445
(+) Stations	101	207	678	503	270	483	367	205	134
%	58,4	57,0	77,0	76,2	38,9	53,1	46,8	25,9	30,1
Mean Density (D)	243,0	152,0	265,9	242,5	49,9	97,6	87,0	37,0	65,1
Var (D)	1130,5	134,7	149,4	164,1	19,2	43,9	45,1	16,1	103,7
Men Dpos	416,2	266,5	345,2	318,2	128,4	183,9	185,8	142,7	216,2
Var (Dpos)	3330,5	415,0	211,3	234,7	89,8	122,9	155,9	166,5	904,4
Dpos (max)	2802,6	2157,4	3395,3	2864,8	1379,3	1697,7	2122,1	1379,3	2723,3

SPATIAL DISTRIBUTION OF EGGS. NOVEMBER 1999-2007



High densities were reported between 33-37° S, and westward to 82-84° W, showing that the bulk of jack mackerel spawning occurs 400-500 nm offshore.

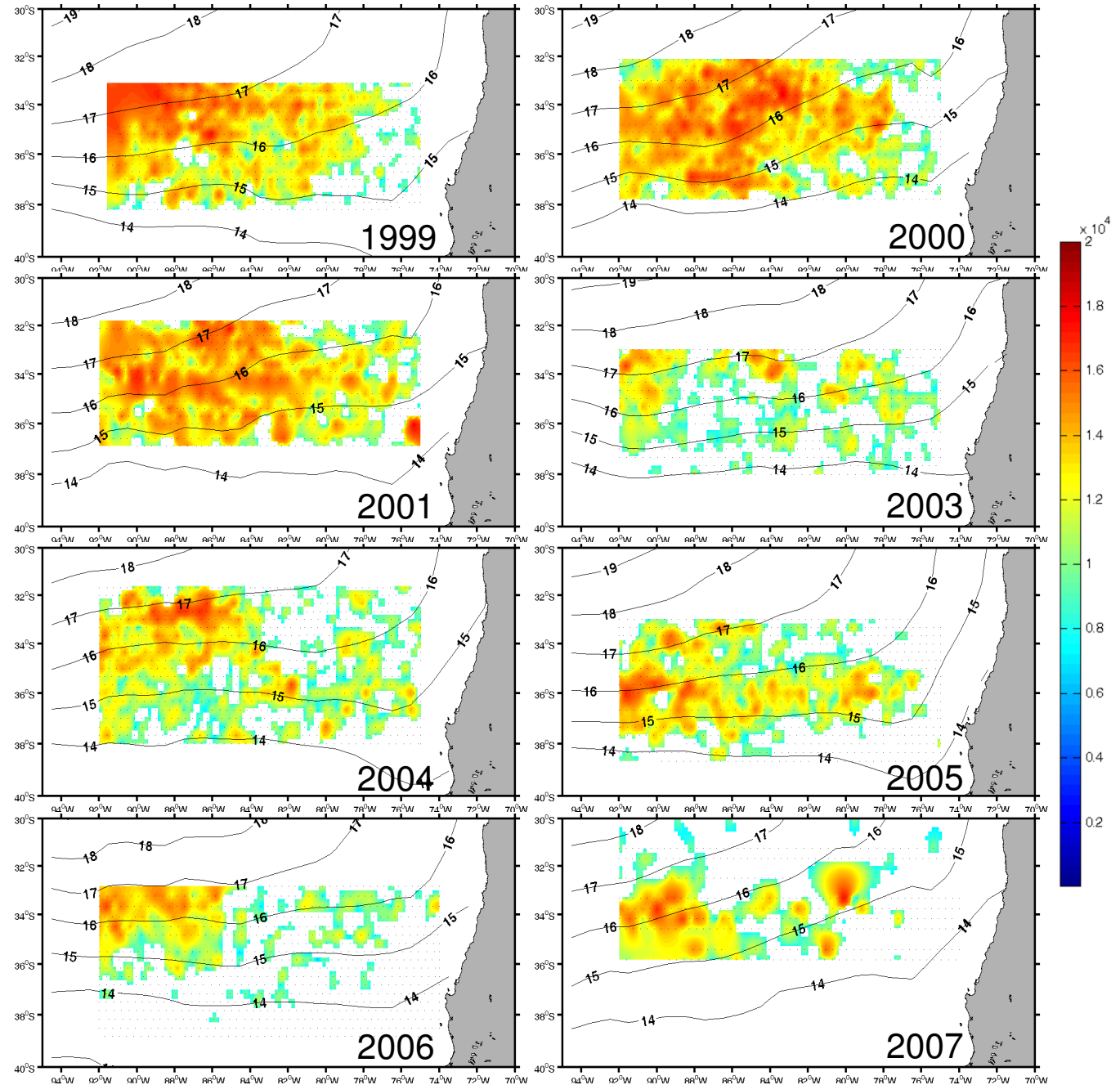
Since 2005, low densities were observed in the study area.

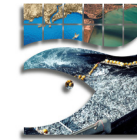


SPATIAL DISTRIBUTION OF LARVAE. NOVEMBER 1999-2007

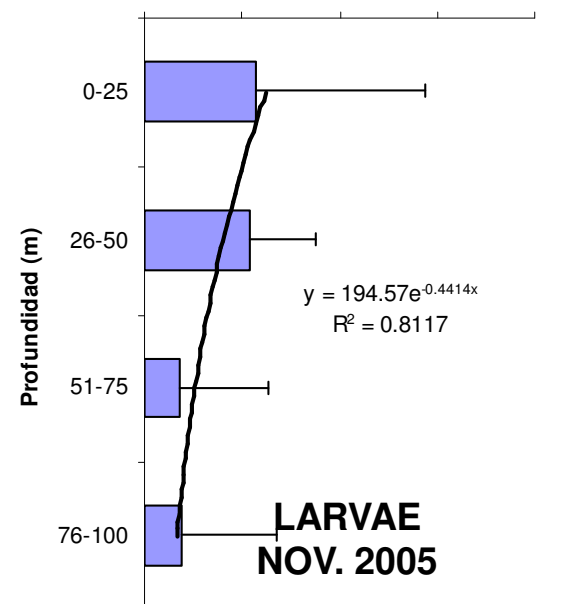
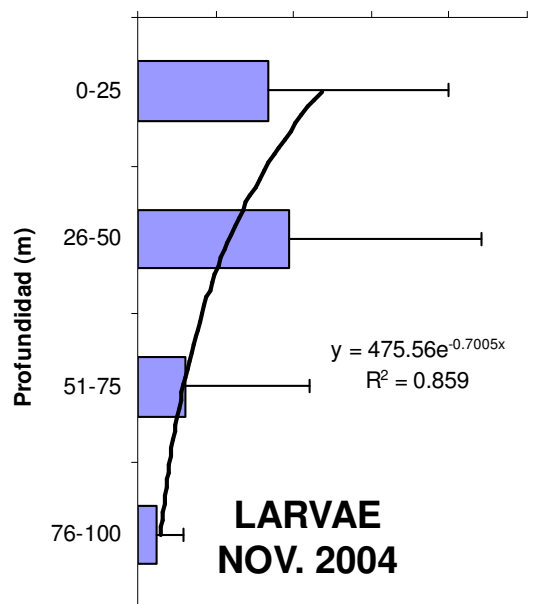
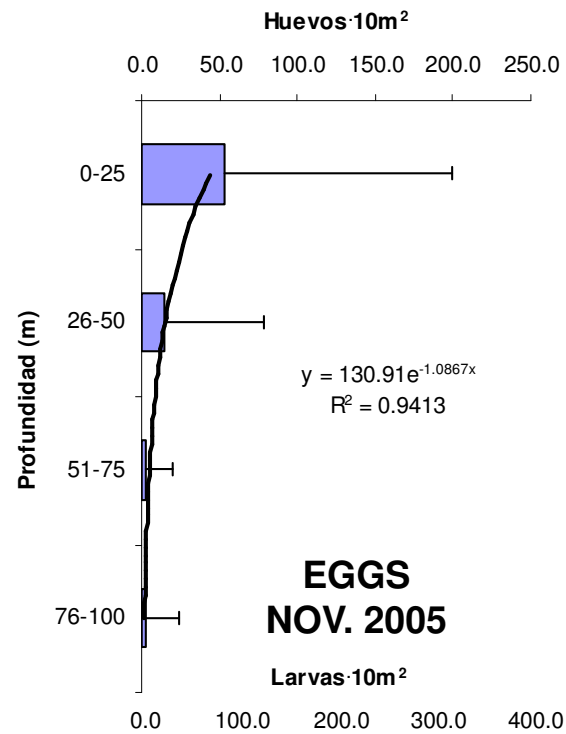
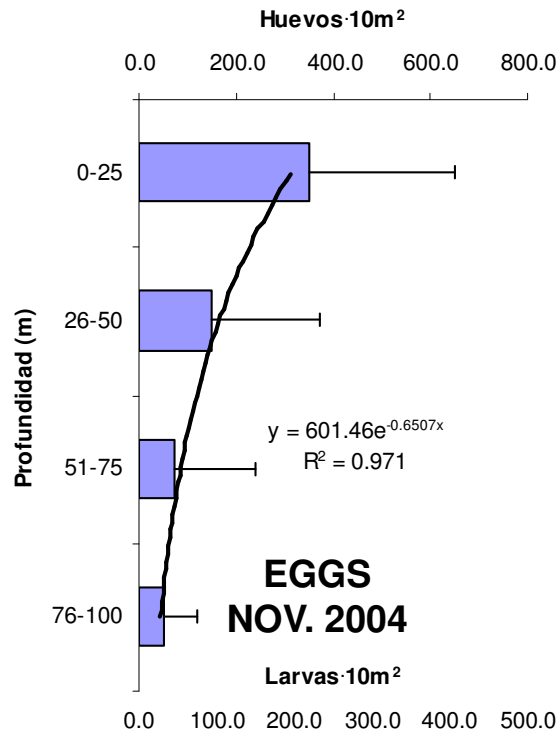


Distributional pattern of larvae shows a east-west gradient with high concentrations confined in the western part of study area ($>82^{\circ}\text{W}$).





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VERTICAL
DISTRIBUTION OF
CHILEAN JACK
MACKEREL EGGS
AND LARVAE

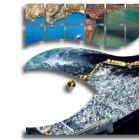


Table 3. Average density, consistency, and numerical dominance of *Trachurus murphyi* eggs and larvae, winter surveys (1981-2007).

E SPECIE	Año	Crucero	Número de estaciones positivas	Densidad promedio por estaciones			Constancia o Frecuencia %	Dominancia numérica %
				Número de huevos	Totales	Positivas		
<i>Trachurus murphyi</i>	1981	247(3)E1CA	11	504	14	46	29,7	0,5
	1983	277(3)E3CP	0	0	0	0	0,0	0,0
	1984	286(3)E4CP	4	662	14	171	6,2	1,7
	1985	299(3)E5CP	2	295	4	148	2,4	0,0
	1986	305(3)E6CP	1	294	3	294	1,2	0,0
	1987	310(3)E7CP	25	3607	44	144	30,5	2,6
	1988	318(3)E8CP	44	34230	349	778	44,9	7,1
	1989	326(3)E9CP	16	2378	24	149	16,3	0,4
	1990	334(3)E0CP	9	933	10	104	9,2	0,3
	1991	338(3)E1AM	7	633	7	93	7,1	0,2
	1992	354(3)E2CP	57	10444	76	183	41,3	3,0
	1993	362(3)E3CP	51	16379	138	321	47,9	5,9
	1994	370(3)E4CP	28	4566	38	163	23,5	0,6
	1995	383(3)E5CP	0	0	0	0	0,0	0,0
	1996	394(3)E6CP	4	575	17	144	11,8	1,0
	1997	404(3)E7CP	5	2452	72	490	14,7	1,6
	1998	415(3)E8CP	0	0	0	0	0,0	0,0
	1999	425(3)E9CP	6	714	14	119	12,0	0,7
	2000	436(3)E0CP	0	0	0	0	0,0	0,0
	2001	447(3)E1CP	0	0	0	0	0,0	0,0
	2002	456(3)E2CP	10	698	12	69	16,9	0,1
	2003	464(3)E3CP	3	1110	21	370	5,7	0,2
	2004	471(3)E4CP	9	1333	25	148	16,7	0,2
	2005	477(3)E5CPAM	9	2009	37	223	16,7	0,4
	2006	487(3)E6AM	5	668	12	134	9,3	0,3
	2007	502(3)E7AM	12	3699	41	217	19,0	0,8

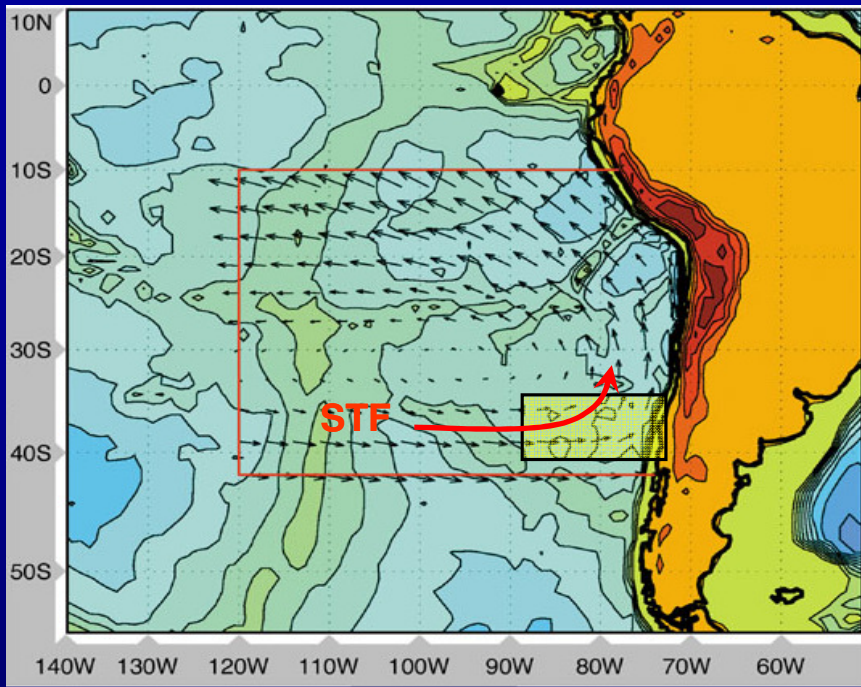
LARVAS								
E SPECIE	Año	Crucero	Número de estaciones positivas	Densidad promedio por estaciones			Constancia o Frecuencia %	Dominancia numérica %
				Número de larvas	Totales	Positivas		
<i>Trachurus murphyi</i>	1981	247(3)E1CA	25	588	16	24	67,6	0,7
	1983	277(3)E3CP	0	0	0	0	0,0	0,0
	1984	286(3)E4CP	3	63	1	21	6,1	0,3
	1985	299(3)E5CP	2	101	1	51	2,4	0,0
	1986	305(3)E6CP	2	61	1	31	2,4	0,0
	1987	310(3)E7CP	8	372	5	47	9,8	0,4
	1988	318(3)E8CP	21	2449	25	117	21,4	1,3
	1989	326(3)E9CP	6	438	4	73	6,1	0,1
	1990	334(3)E0CP	0	0	0	0	0,0	0,0
	1991	338(3)E1AM	2	112	1	56	2,0	0,2
	1992	354(3)E2CP	34	3290	24	97	24,6	1,8
	1993	362(3)E3CP	37	4540	38	123	31,1	1,4
	1994	370(3)E4CP	10	507	4	51	8,4	0,1
	1995	383(3)E5CP	2	67	1	34	1,7	0,0
	1996	394(3)E6CP	1	34	1	34	2,9	0,1
	1997	404(3)E7CP	0	0	0	0	0,0	0,0
	1998	415(3)E8CP	0	0	0	0	0,0	0,0
	1999	425(3)E9CP	3	124	2	41	6,0	0,2
	2000	436(3)E0CP	0	0	0	0	0,0	0,0
	2001	447(3)E1CP	0	0	0	0	0,0	0,0
	2002	456(3)E2CP	1	36	1	36	1,7	0,0
	2003	464(3)E3CP	0	0	0	0	0,0	0,0
	2004	471(3)E4CP	5	269	5	54	9,3	0,3
	2005	477(3)E5CPAM	0	0	0	0	0,0	0,0
	2006	487(3)E6AM	3	276	5	92	5,6	0,2
	2007	502(3)E7AM	1	38	1	38	1,6	0,0

JACK MACKEREL EGGS / LARVAE OFF NORTHERN REGION OF CHILE

- Highest densities in winter and spring.
- 26 winter surveys covered 1,871 stations, 318 were positive for eggs (17%) and 166 for larvae (8.9%).
- Average densities per total stations fluctuated between 3 - 349 eggs/10m² and between 1 – 38 larvae/10m².
- In this period, the jack mackerel eggs and larvae are concentrated mainly between 20° and 24° S and in the more oceanic sector of the study area.

ENVIRONMENTAL CONDITIONS IN THE SPAWNING AREA OFF CENTRAL CHILE



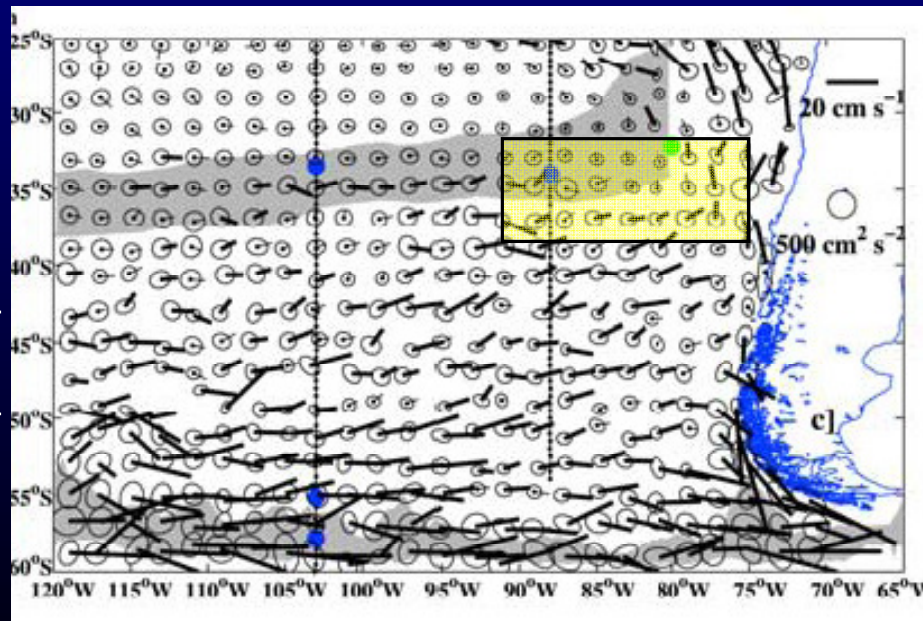


It has been suggested that spawning is confined to the Subtropical Convergence Zone (northern 40°S) (Evseenko 1987).

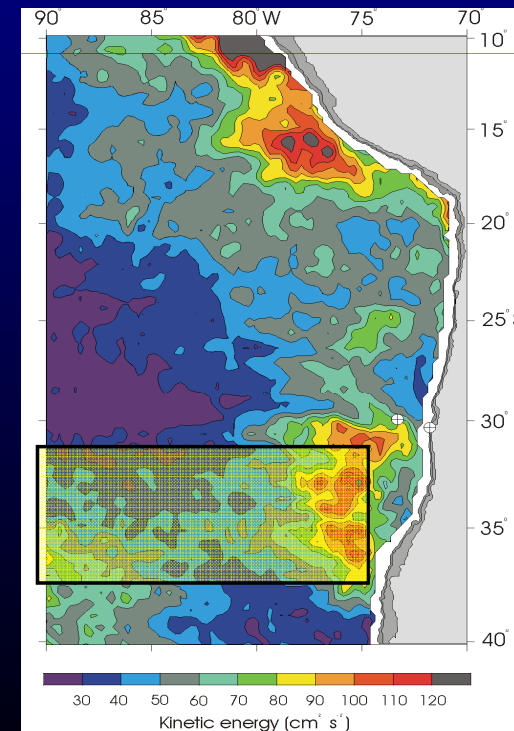
STF separates the warmer/saline subtropical waters from colder and less saline subAntarctic waters.

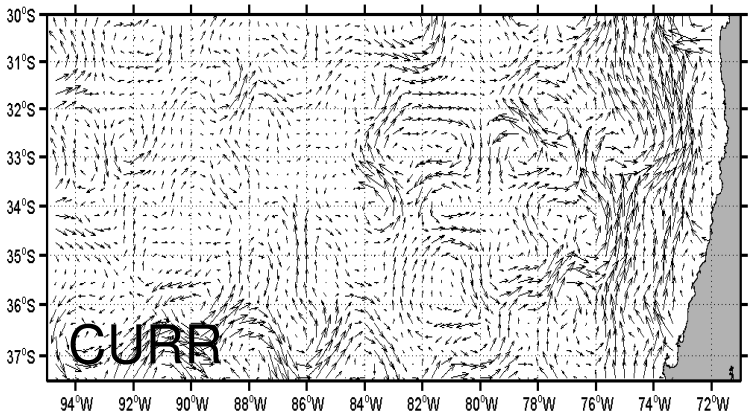
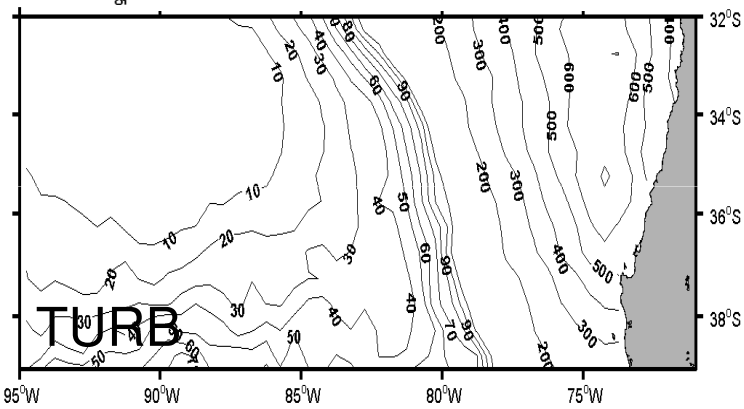
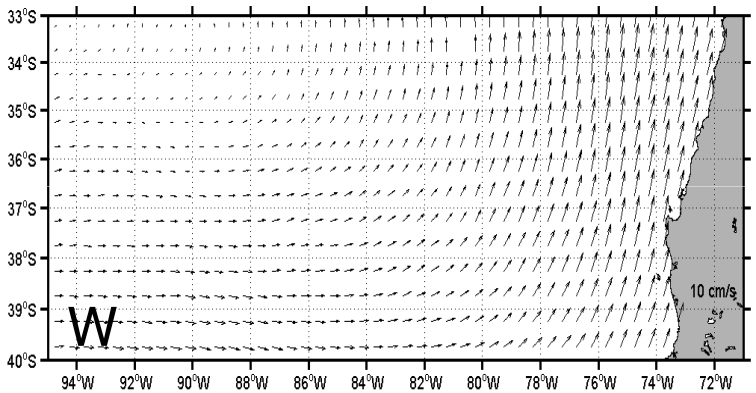
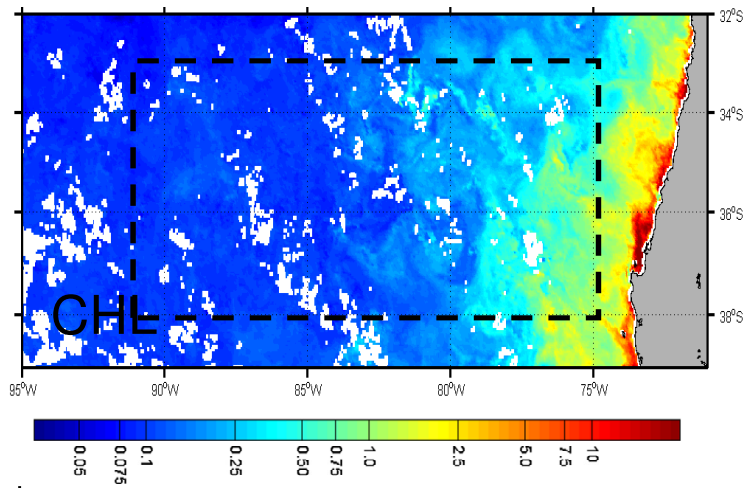
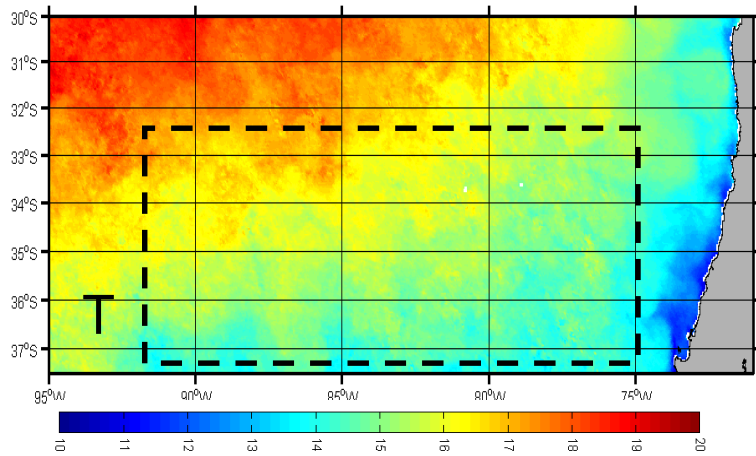
Spawning region shows a low variability associated to mesoscale structures.

STF
WWD



(From Cheagneau & Pizarro, 2005)

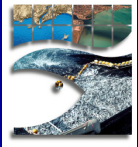




ENVIRONMENTAL
CONDITIONS IN THE
SPAWNING PERIOD
OFF CENTRAL CHILE

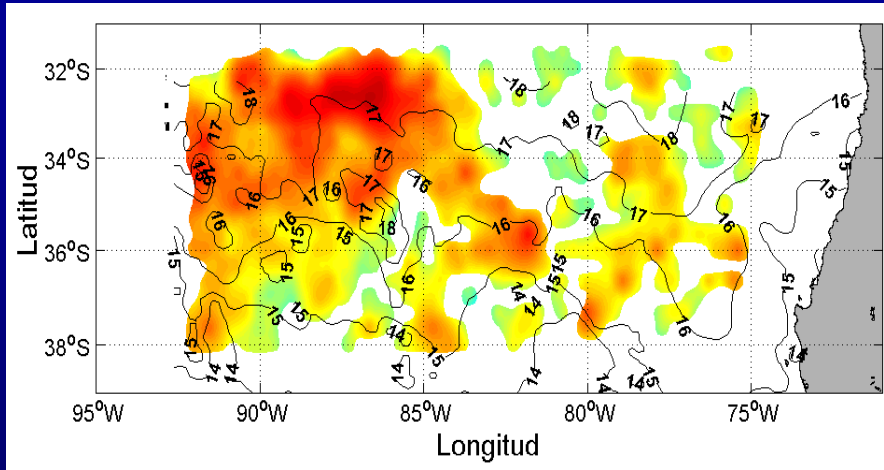


EVIDENCES OF PHYSICAL-
BIOLOGICAL COUPLING

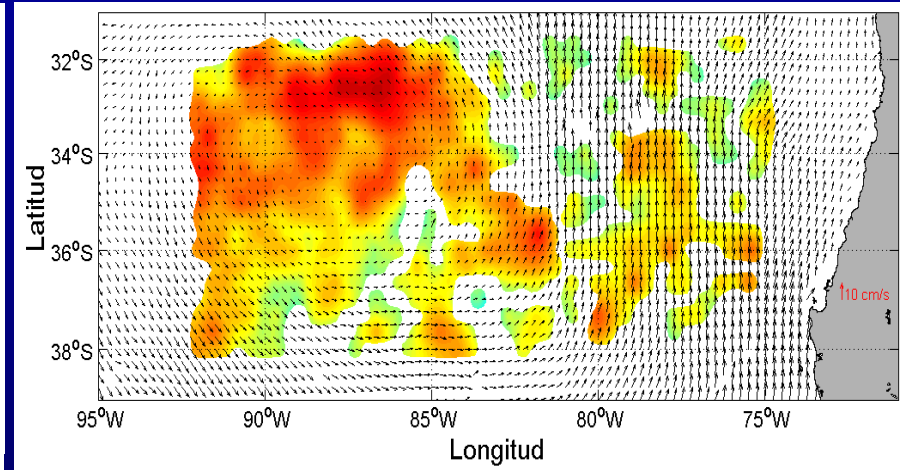


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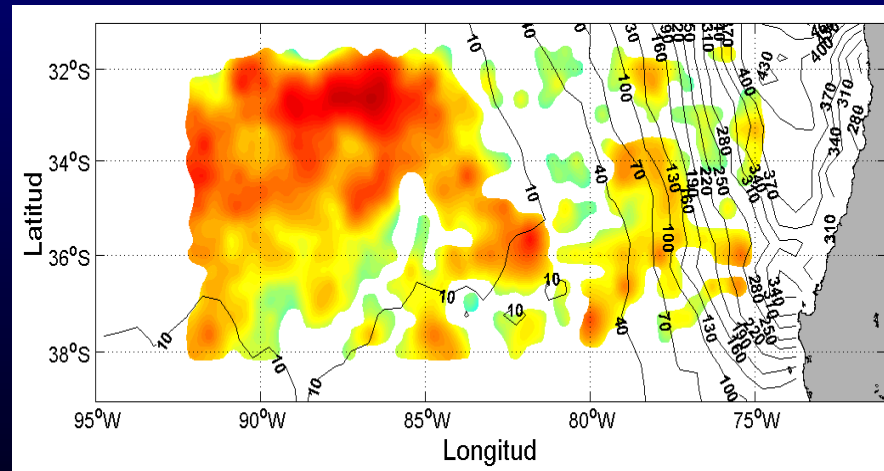
SPATIAL DISTRIBUTION OF LARVAE AND THE OCEANIC SPAWNING ENVIRONMENT. EXAMPLE FOR NOV. 2004



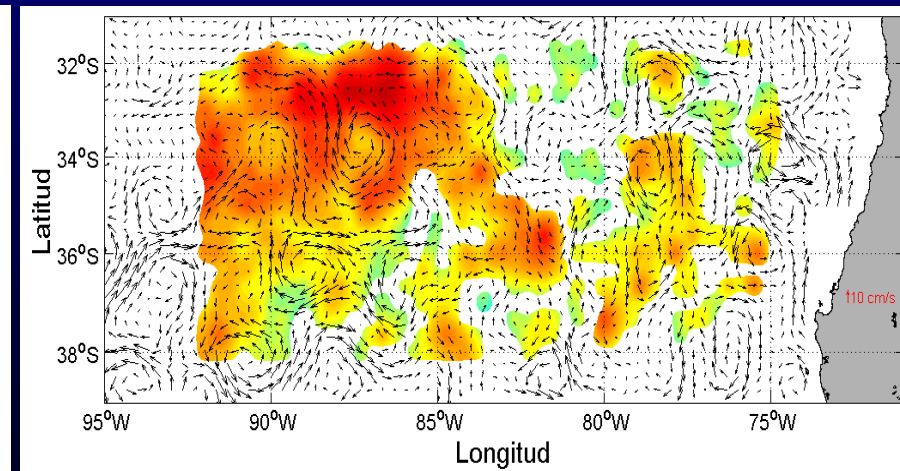
LARVAE & SST



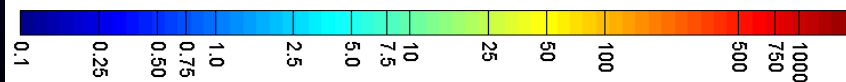
LARVAE & WIND



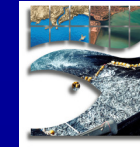
LARVAE & TURBULENCE INDEX



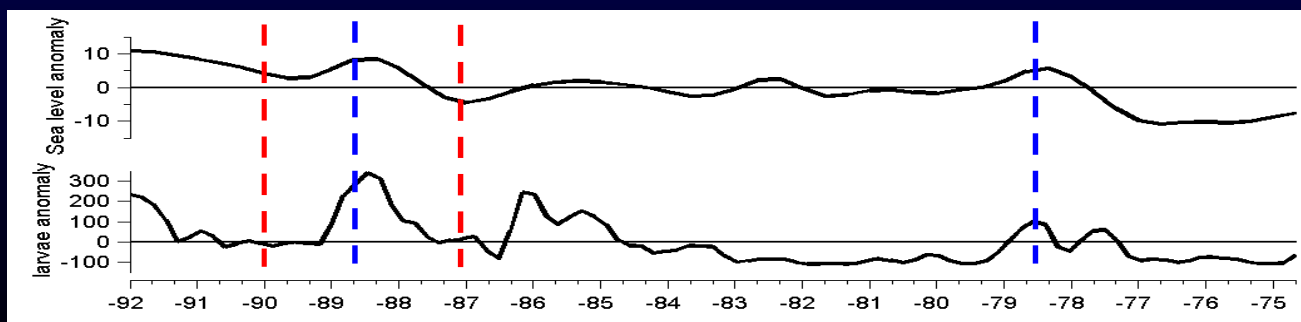
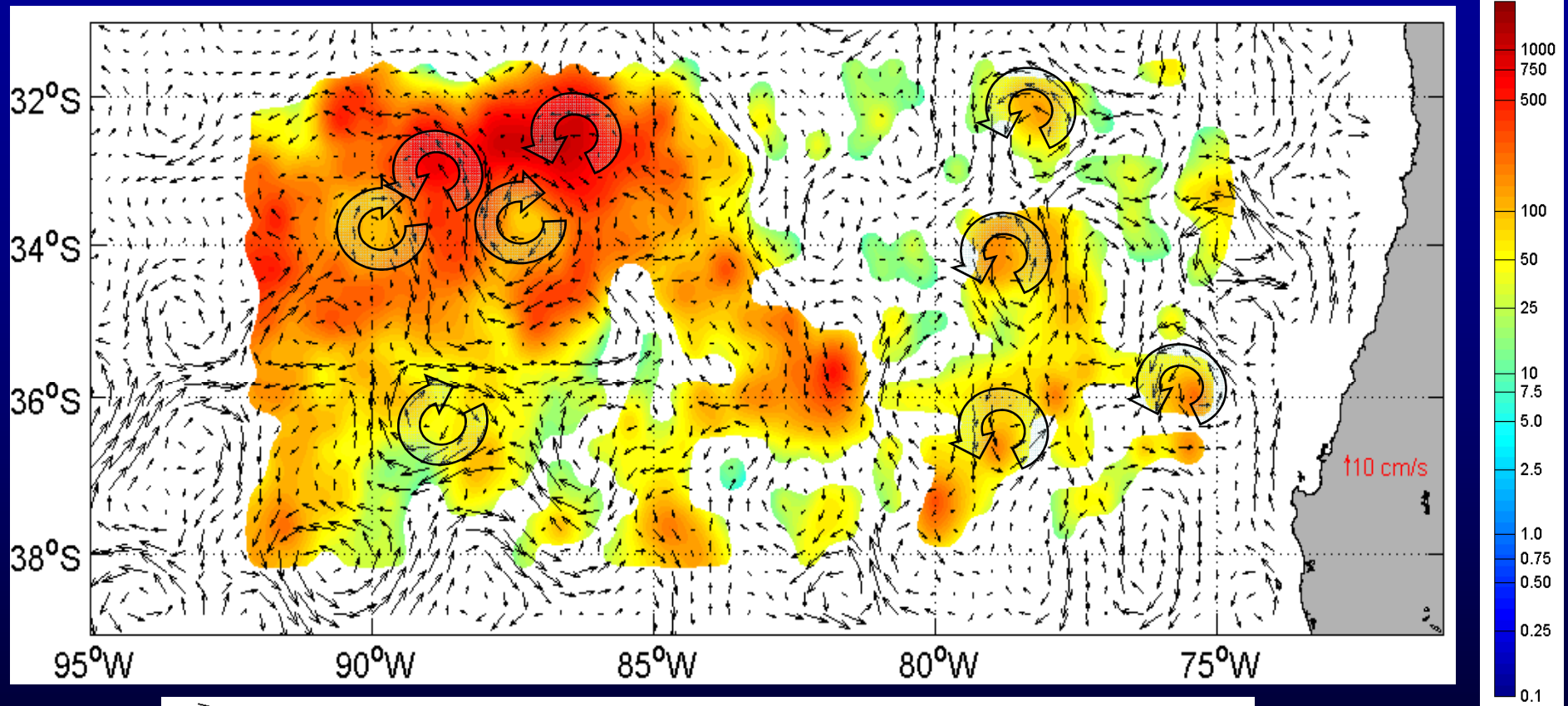
LARVAE & CURRENTS



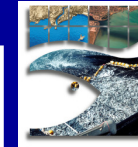
JACK MACKEREL LARVAE & MESOSCALE EDDIES



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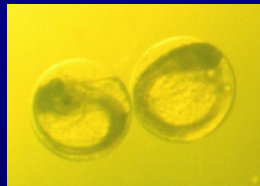


Example for
33.5-34.5°S
band



ENVIRONMENTAL RANGES FOR EGGS/LARVAE DENSITY OF CHILEAN JACK MACKEREL IN THE SPAWNING AREA OFF CENTRAL CHILE

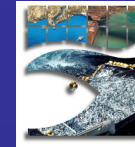
Example for Nov 2006



SST		TURBULENCE		WIND		SST GRADIENTS	
Range	%	Range	%	Range	%	Range	%
12, 1-13, 0	0, 04	0-50	81, 84	0, 0-1, 5	32, 42	0-0, 035	24, 87
13, 1-14, 0	4, 42	51-100	1, 61	1, 6-2, 5	35, 64	0, 036-0, 07	27, 04
14, 1-15, 0	9, 44	101-200	5, 22	2, 6-3, 5	8, 60	0, 071-0, 105	14, 66
15, 1-16, 0	43, 79	201-300	2, 53	3, 6-4, 5	4, 42	0, 106-0, 140	18, 36
16, 1-17, 0	29, 57	301-400	0, 32	4, 6-6, 0	5, 22	0, 141-0, 175	6, 99
17, 1-18, 0	2, 65	401-700	7, 35	6, 1-9, 0	9, 60	0, 176-0, 22	2, 53

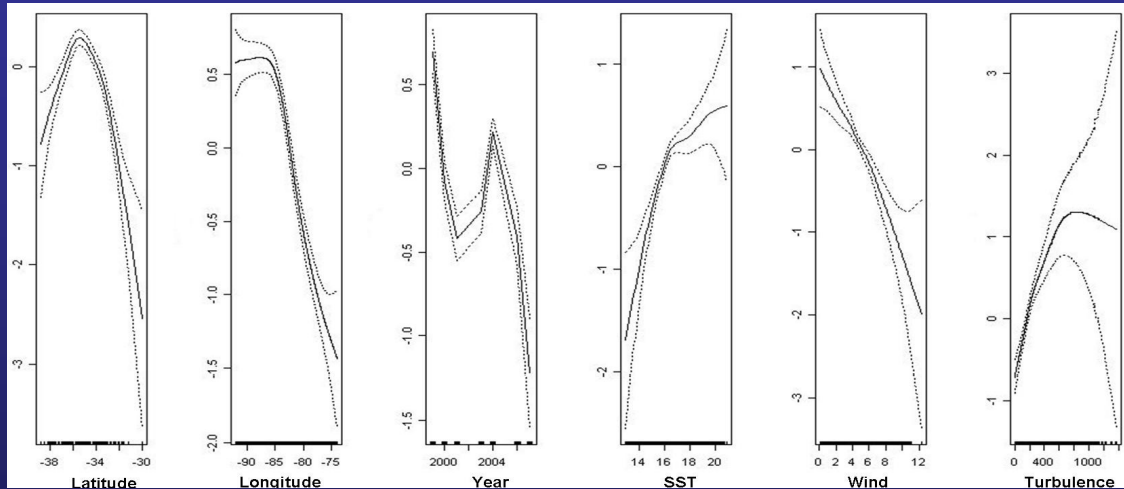
SST		TURBULENCE		WIND		SST GRADIENTS	
Range	%	Range	%	Range	%	Range	%
12, 1-13, 0	0, 0	0-50	87, 18	0, 0-1, 5	52, 36	0-0, 035	22, 01
13, 1-14, 0	0, 48	51-100	1, 21	1, 6-2, 5	24, 43	0, 036-0, 07	28, 54
14, 1-15, 0	6, 29	101-200	2, 90	2, 6-3, 5	5, 44	0, 071-0, 105	26, 72
15, 1-16, 0	42, 81	201-300	2, 18	3, 6-4, 5	1, 09	0, 106-0, 140	11, 0
16, 1-17, 0	43, 29	301-400	1, 69	4, 6-6, 0	3, 02	0, 141-0, 175	7, 26
17, 1-18, 0	2, 90	401-700	3, 63	6, 1-9, 0	7, 13	0, 176-0, 22	3, 39

GAM ANALYSIS



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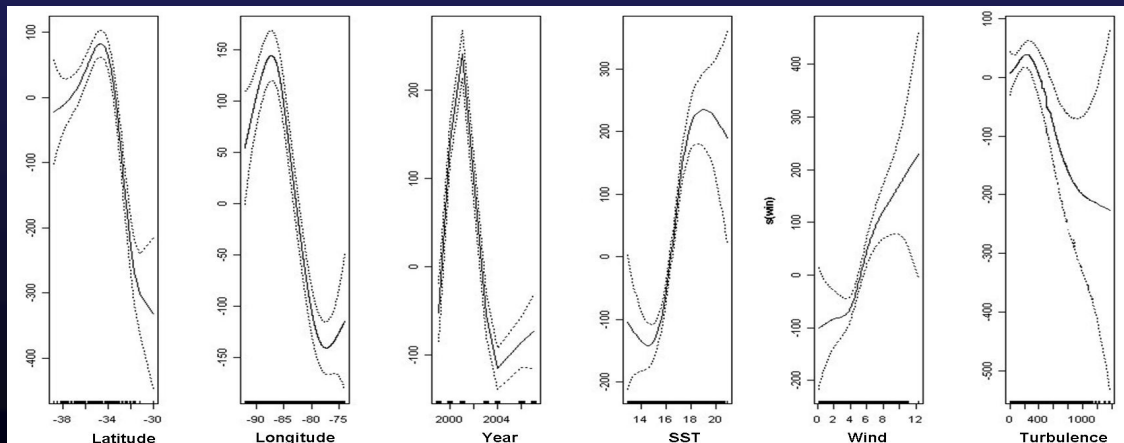
Eggs



GAM plots for jack mackerel eggs and larvae considers 1999-2007 pooled data.

Dome-shaped relationship between eggs density and latitude reveal a max density at 35°S . Results show that the spawning zone extends beyond the western limit considered in this study.

Larvae



High eggs concentrations were associated to SST higher than 16°C , wind speeds lower than 6 knots and low values of turbulence. Time series shows two peaks of egg densities in 1999 and 2004 evidencing a lower abundance in the last years.

For jack mackerel larvae, it is shown high densities at 34°S and 85°W , associated with warmer waters ($18-19^{\circ}\text{C}$), wind speeds between 4-6 knots and low turbulence values.

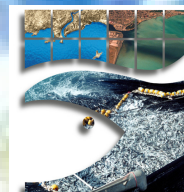
CONCLUSIONS



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- 1.- The high incidence of positive stations ($>70\%$), reveals that the bulk of jack mackerel spawning occurs in oceanic waters off central Chile, between $33 - 38^{\circ}\text{S}$, and westward 82°W . Several nucleus of high density of eggs/larvae were found farther offshore than 84°W extending beyond 90°W . Abundance of eggs and larvae revealed an important east-west gradient, and interannual variability.
- 2.- Higher eggs/larvae density were associated to warmer waters ($16-19^{\circ}\text{C}$), moderate winds ($4-8\text{ m s}^{-1}$), low currents ($< 15\text{ cm s}^{-1}$) and turbulence, as well as SST gradients ($< 0.3^{\circ}\text{C } 10\text{ km}^{-1}$).
- 3.- Statistical analysis reveals a significant relationship ($p<0.05$) between eggs/larvae density and both SST and wind magnitude. Other analysis as habitat-species association, and spatial EOF coupling eggs and environmental data (not shown here), confirm the statistical analysis and suggest a bio-physical coupling among these variables in the jack mackerel spawning area.
- 4.- The spawning area located in the oceanic waters off central Chile ($33-40^{\circ}\text{S}$) constitutes an important region for spawning of Chilean jack mackerel in the Southeastern Pacific.

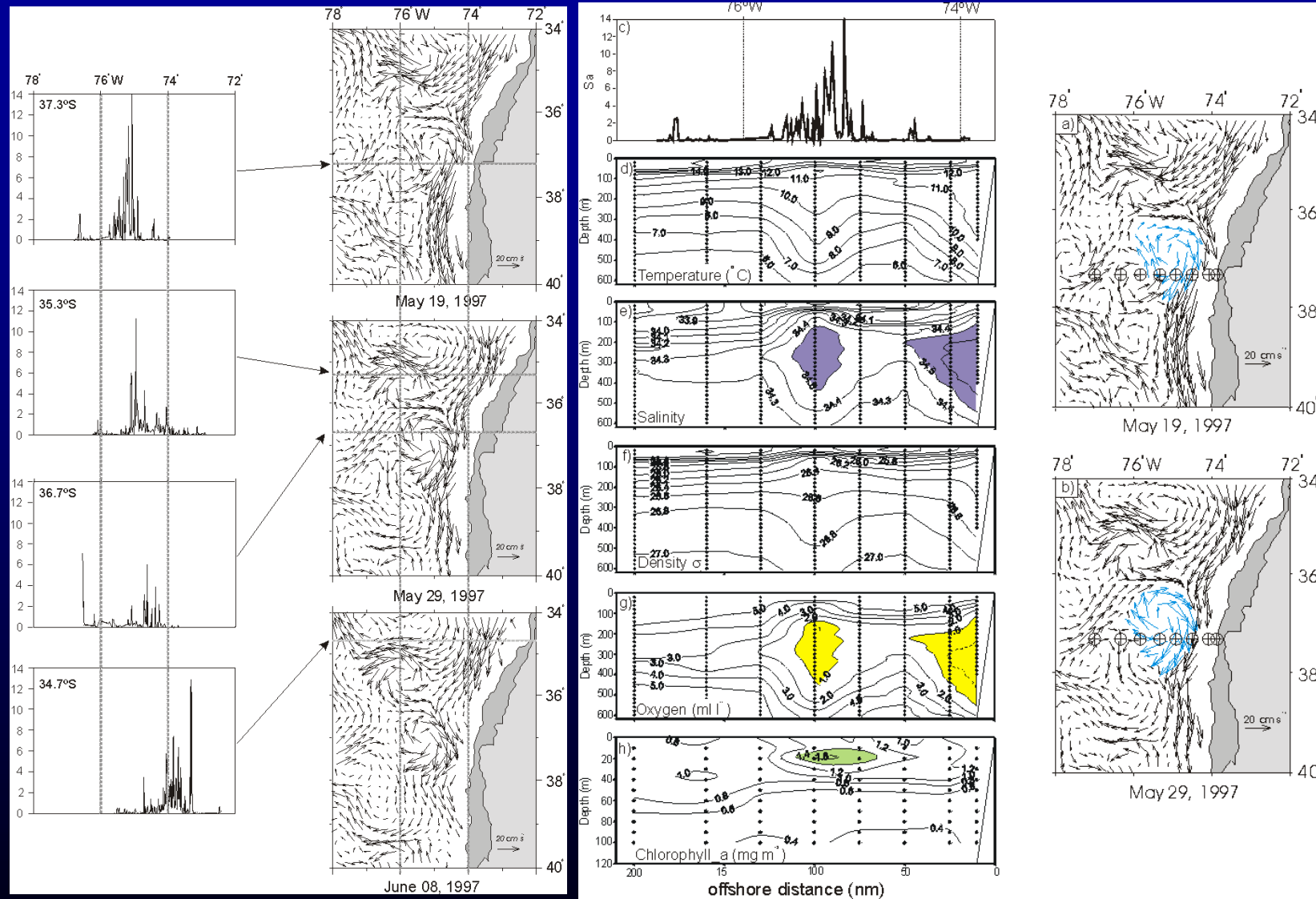
THANK YOU ...



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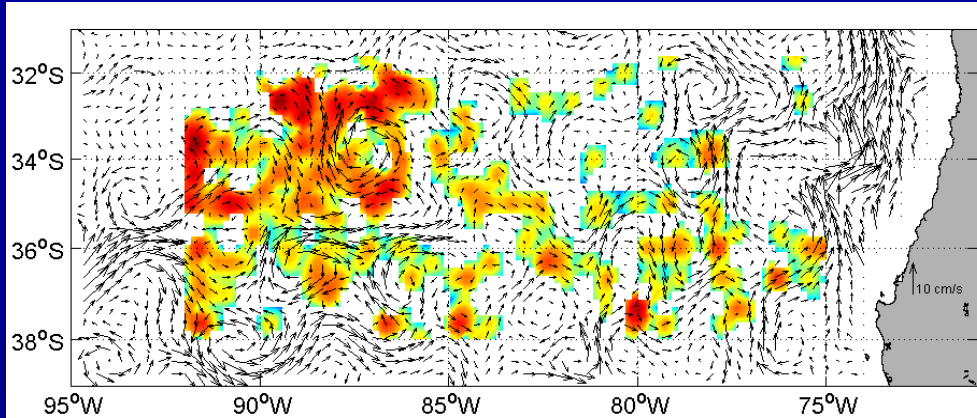
CORRIENTES Y BIOMASA ACÚSTICA DE JUREL

La biomasa acústica incrementa en los bordes de los remolinos ciclónicos y en corrientes de meandro fuertes.

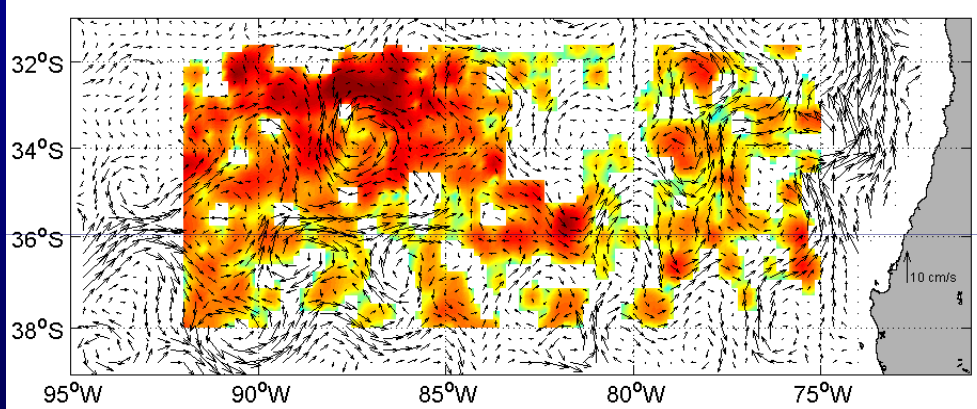


Tomado de S. Hormazábal, S. Núñez, D. Arcos, F. Gómez & G. Yuras. In press (Fish. Oceanogr.)

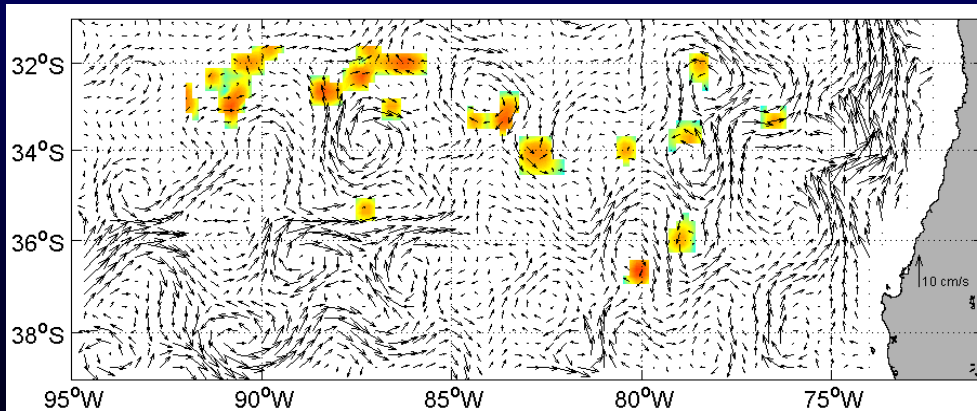
SPATIAL DISTRIBUTION OF LARVAL STAGES (Example for Nov. 2004)



Vitelogenic larvae



Pre-flexion larvae



Post-flexion larvae

