Distribution of early developmental stages of jack mackerel in the Southeastern Pacific ocean

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ABSTRACT

Chilean jack mackerel (*Trachurus murphyi*) is a highly migratory pelagic species that inhabits the Southern Pacific Ocean, constituting the most important fishery for Chile. This species exhibits an onshore migration during the summer related to coastal food availability, and an offshore migration towards reproductive oceanic areas (beyond Chilean EEZ) in early spring. During the spawning peaks (November) of 1999-2007, eggs and larvae of jack mackerel were collected from systematic surveys carried out in oceanic waters (75º-92º W) off central Chile, using 5-10 fishing vessels. The eggs abundance shows a decreasing trend for 1999-2007 spawning period, with a strong variability of positive stations (72.7% for 1999 and 26.5% for 2007), and mean densities values ranged from 581.7 ind $10m^{-2}$ (1999) to 39.8 ind 10 m^{-2} (2007) constituting the lowest values of the analyzed series. For larvae, similar results were obtained, with positive stations ranged from 77.0% (2000) to 30.1% (2007), and mean densities values fluctuating between 265.9 ind $10m^{-2}$ (2000) and 65.1 ind $10m^{-2}$ (2007). Our results reveal lower abundance of eggs for 2005-2007, and more variable trend on larval densities for 2003-2007 period.

Spatial distribution of eggs and larvae were modeled by geostatistical techniques, showing that the bulk of jack mackerel spawning occurs in oceanic waters off central Chile, centered between 33-38ºS and from 82º extending to 92°W and beyond. The higher densities of jack mackerel early developmental stages were associated to 16-18ºC isotherm position, moderate winds (4-8 m s^{-1}) and turbulence index (<100 m^3 s^{-3}), and low currents (< 15 cm s^{-1}), suggesting that the spawning process located offshore central Chile could be associate with the southern boundary of the Subtropical Convergence Zone.

* Research was partially supported by the Fondo de Investigación Pesquera (CHILE), and by the Instituto de Investigación Pesquera (CHILE).

INTRODUCTION

Chilean jack mackerel (*Trachurus murphyi* Nichols) is a migrating pelagic species which inhabits the Southern Pacific Ocean, and constitutes the most important fishery for Chile. This species presents a wide distribution, revealing a fairy broad band from Chile to New Zealand and Tasmania (Bailey 1989, Elizarov *et al*. 1993, Gretchina 1998). According to Serra (1991) it is verify a single self-sustained population along the Chilean waters, which includes the oceanic fraction off central-south Chile. Chilean jack mackerel exhibits a strong seasonal migration pattern (Serra 1991, Arcos *et al*. 2001), showing an offshore migration towards the reproductive oceanic habitat in early spring which extends along the Southeastern Pacific (SEP), but mainly in oceanic waters off central Chile from the 82°W to beyond 90°W (Cubillos *et al*. 2008); and an onshore migration during the summer related to coastal food availability. During fall and winter, jack mackerel aggregates in compact schools in coastal and oceanic waters off central Chile, being more available for the Chilean purse-seiner fleet (Arancibia *et al*. 1995). Spawning occurs mainly between October and December, although it can extend from September to February (Grechina *et al*. 1998).

In this contribution, we describe the spatial distribution of eggs and larvae of jack mackerel at the main spawning region located in the oceanic waters off central Chile, for 1999-2007 spawning period (November), and we attempt to examine the relationships between the density of jack mackerel eggs and larvae with the environmental conditions during the spawning season.

DATA AND METHODS

<u>Survey data</u>

The main spawning area of jack mackerel is located in the oceanic waters off central Chile (30ºS-39ºS). This region was studied for 1999-2007 spawning period, through eight cruises conducted during the spawning peak (November) by using 6-10 fishing vessels for determining the jack mackerel eggs/larvae abundance and spatial distribution. All cruises were deployed by using a systematic linear-tracking design, and the sampling design consisted in a regular grid of planktonic stations separated by 20 nm, from 32 to 38ºS in latitude (with a low variability between surveys), and 75 to 92 ºW in longitude reaching the 1100 nm offshore (see Sepúlveda *et al*. 2006 for details). The cruises were carried out in a range of 6-13 days, obtaining a quasi-synoptic view of the distribution and abundance of early developmental stages of jack mackerel in the main spawning region off central Chile (Núñez *et al*. 2004, Sepúlveda *et al*. 2006, Cubillos *et al*. 2008).

At each planktonic station, vertical tows were developed for collecting planktonic jack mackerel eggs and larvae, by means of 0.6 m diameter, 0.303 mm mesh size WP-2 nets. Geostatistical techniques were used to describe the spatial structure of egg distribution and to estimate egg density and precision. Both spherical and exponential model were fitted for 1999-2007 cruises according to the weighted least-square minimization criterion. Satellite information of SST, wind, geostrophical currents were used for stablish the association between jack mackerel eggs/larvae and environmental conditions in the spawning area off central Chile (30 -

40ºS, 75 - 92ºW). To explore the possible non-linear association between eggs and the environment, data were analyzed by using the Generalized Additive Model technique (Hastie & Tibshirani 1990).

RESULT AND DISCUSSION

Reproductive aspects

The reproductive biology of jack mackerel in the Southeastern Pacific (SEP) has been widely studied and summarized by several authors (Kaiser 1973, Serra 1983, Alexeeva 1985, Andrianov 1987, Evseenko 1987, Serra 1991, Gretchina *et al*. 1998). This species is considered as a partial spawner, showing an asynchronic and continuous oocytes maturation. According to Gretchina *et al*. (1998) the oocytes maturity begin at June-July for SEP northern region evidencing an extended spawning between August-September; while for SEP southern region a huge and intense spawning was observed between October-December on oceanic waters off central Chile, revealing a low interannual fluctuation related to environmental variability.

Jack mackerel is fully mature at 3-4 years, and females released 3-6 batches of eggs during the spawning season (Alexeeva 1986, Gretchina *et al*. 1998), although it is also showed that 7-19 batches of eggs can occur in the annual spawning peak off central Chile (Sepúlveda *et al*. 2006). The reproductive strategy of jack mackerel is to disperse over a large area, not forming compact schools or commercial aggregations in contrast to fall and winter when jack mackerel aggregates in compact schools in coastal waters off central Chile (Arcos *et al*. 2001, Cubillos *et al*., 2008). For 1999-2007 spawning period, Sepúlveda *et al*. (2006) carried out a randomly sampling from fishing sets in order to determining the reproductive condition of the jack mackerel population in oceanic waters off central Chile (see **Table 1**), showing a variable trend in the spawning fraction (S) ranged between 7 and 19 % of the female population, an important increase in the mean weight of mature females and the batch fecundity (F) for 2003-2006, and a stable trend in the sex ratio (R) parameter. Several authors had shown temporal and spatial differences in the size at first maturity of jack mackerel (Kaiser 1973, Serra 1983, Andrianov 1985, 1990, Dioses *et al*. 1989, Oyarzún *et al*. 1998, Gretchina *et al*. 1998), evidencing a broad range of variation between 21.6 cm FL (Alegría *et al*. 1995) and 39 cm FL (Andrianov 1985).

Table 1. Reproductive parameters of jack mackerel in the spawning area off central Chile, during the 1999-2006 spawning period. Mean weight of mature females (W), Spawning fraction (S), Batch fecundity (F), Sex ratio (R). (a): is an average of years 2000-2001. No available data set.

Spawning period	W	F	S	R
	(g)	(eggs/female))	(day^{-1})	(g)
Nov 1999	191,8	26610a	0,126a	0,433a
Nov. 2000	211	26069	0,148	0,472
Nov. 2001	223,7	27150	0,104	0,393
Nov. 2003	394,7	39846	0,09	0,48
Nov. 2004	412,1	39957	0,194	0,475
Nov. 2005	364,7	40463	0,142	0,466
Nov. 2006	532,4	48213	0,07	0,49

Spawning area and spatial distribution of eggs/larvae

According to Gretchina *et al*. (1998) jack mackerel spawn in the South Pacific ocean extending along the coastal zone of Perú y northern Chile to 200-400 nm offshore, and from the coastal zone of central Chile (35º-40ºS) until to 170ºW. Nevertheless, it is recognized the region located in oceanic waters off central Chile, from 32ºS to 39ºS and extending beyond 92ºW westward, as a main jack mackerel spawning area in the SEP (Serra 1991, Núñez *et al*. 2004, Sepúlveda *et al*. 2006, Cubillos *et al*., 2008). In this spawning region, the results for 1999-2007 surveys indicate a high variability in the sampled area (between 253995 and 403938 km^2), and it is also show a decreasing trend in the spawning area from 307400 km^2 in Nov 2004 to 106755 km^2 in Nov 2007. Likewise, it had been suggested an association between the austral boundary of jack mackerel eggs distribution and the 16ºC isotherm spatial position (Elizarov *et al*. 1993, Núñez *et al*. 2004, Sepúlveda *et al*. 2007, Cubillos *et al*. 2008), which is consistent with the association observed between the jack mackerel spawning and the Subtropical Convergence Zone, extends from the coasts of central Chile to SW Pacific (Evseenko 1987, Elizarov *et al*. 1993).

For 1999-2007 spawning period, **Table 2** shows the abundance indexes of jack mackerel eggs and larvae in the oceanic spawning area off central Chile. It is reveals a high incidence of eggs positive stations for 1999-2004 (>60%) revealing that the bulk of jack mackerel spawning occurs in oceanic waters off central Chile, centered between 80-90°W in longitude, and 32-39°S in latitude; nevertheless, it is also observed a strong decrement trend in the series, reaching the lowest value

(26.5% egg positive stations) in the last year (November 2007). The mean density of jack mackerel eggs for both total and positive stations, also exhibits a decreasing trend from 2005 to 2007, showing the lowest densities in November 2007 (39.8 and 150.2 eggs 10^{-2}, respectively). For larvae, the abundance indexes indicate a low percentage of positive stations in the last two years (2006 and 2007), and a similar mean densities for the 2004-2007 cruises varying between 128.4 and 185.8 larvae $10m^{-2}$ were observed.

Table 2. Abundance indexes for jack mackerel eggs and larvae in the spawning region off central Chile (1999-2007 spawning season). D= total density, Var(D)= variance of total density, SE(D)= standard error of total density, Dpos= density for positive stations; Var(Dpos)= variance for positive stations, SE(Dpos)= standard error; Dmin= minimum density, Dmax = maximum density, FS= Finney-Sichel estimate; Var(FS)= variance of Finney-Sichel estimate, Pielou index= aggregation index, IP= patchness index.

Parameters	1999	2000	2001	2003	2004	2005	2006	2007
Jack Mackerel eggs								
Stations	751	880	661	694	910	784	791	445
Posit. Sts.	546	660	478	419	658	326	308	118
% Posit. Sts.	72,7	75,0	72,3	60,4	72,3	41,6	38,9	26,5
D	561,7	444,2	640,2	132,0	373,5	98,4	111,3	39,8
Var(D)	3618,6	413,9	1781,8	97,6	763,0	87,9	183,0	31,7
EE(D)	60,2	20,3	42,2	9,9	27,6	9,4	13,5	5,6
Dpos	772,6	592,2	885,8	218,7	516,6	236,7	285,8	150,2
Var(Dpos)	6550,4	603,1	2956,0	222,6	1347,5	408,7	1046,8	311,8
EE(Dpos)	80,9	24,6	54,4	14,9	36,7	20,2	32,4	17,7
Dmin	35,4	35,4	35,4	35,4	35,4	35,4	35,4	35,4
Dmax	26844,1	5199,1	11353,0	2900,2	14465,4	4420,9	4633,2	1167,1
FS	543,5	492,3	707,7	124,4	386,2	94,4	95,1	37,1
Var(FS)	1736,0	847,2	3065,8	71,4	689,1	63,3	89,5	21,5
Pielou Index	4629,3	672,2	1591,8	426,4	1716,4	562,8	1128,1	245,1
PI	6,991	2,133	2,796	2,945	4,321	3,373	4,944	2,625

Parameters	1999	2000	2001	2003	2004	2005	2006	2007
Jack Mackerel larvae								
Stations		363	880	660	694	910	784	791
Posit. Sts.		207	678	503	270	483	367	205
% Posit. Sts.		57,0	77,0	76,2	38,9	53,1	46,8	25,9
D		152,0	265,9	242,5	49,9	97,6	87,0	37,0
Var(D)		134,7	149,4	164,1	19,2	43,9	45,1	16,1
EE(D)		11,6	12,2	12,8	4,4	6,6	6,7	4,0
Dpos		266,5	345,2	318,2	128,4	183,9	185,8	142,7
Var(Dpos)		415,0	211,3	234,7	89,8	122,9	155,9	166,5
EE(Dpos)		20,4	14,6	15,3	9,5	11,1	12,5	12,9
Dmin		35,4	35,4	35,4	35,4	35,4	35,4	35,4
Dmax		2157,4	3395,3	2864,8	1379,3	1697,7	2122,1	1379,3
FS		156,0	278,4	254,4	47,0	148,1	82,9	34,4
Var(FS)		232,4	233,6	265,9	12,9	82,8	35,9	11,5
Pielou Index		322,4	415,1	371,1	188,8	322,7	308,0	239,2
PI		2,206	2,200	2,163	2,463	2,749	2,652	2,670

The spatial distribution of jack mackerel eggs during the 1999-2007 spawning period off central Chile is presented in **Figure 1**. This figure shows a similar distribution pattern for the November of 1999, 2000, 2001 and 2004 characterized by an strong east-west gradient in eggs density, where higher values (>1.5 $*10^4$ eggs 10 m^{-2}) were distributed from 82-84ºW until to the western boundary of study area (91-92ºW), and between 33-36ºS in latitude, evidencing that the bulk of jack mackerel spawning occurs 400-500 nm offshore. This results are agree with the spatial analysis of eggs distribution for 1998-2001 spawning period (Núñez *et al*. 2004, Cubillos *et al*. 2004, Cubillos *et al*. 2008), and the Russian surveys developed in oceanic waters of Southeastern and Central Pacific ocean (Evseenko & Gorbunova 1984, Dejnik & Nevinskiy 1987, Evseenko 1987, Gretchina *et al*. 1992, Elizarov *et al*. 1993). By contrary, during the last three years (2005-2007) very low densities were observed in the study area, and the zonal/meridional gradients in eggs densities were not so clear. For larval densities, results show a similar distribution pattern described for eggs, characterized by a clear east-west gradient, high values confined in the western part of the study area (between 82 to 92ºW), and between 32-36ºS in latitude, mainly in the 1991-2001 spawning period, and low larval densities in 2003-2007, maintaining a similar spatial distribution pattern.

The vertical distribution of eggs and larvae for 2004-2005 spawning time, showed that a high percentage of eggs (>85%) and larvae (>70%) were associated to the mix layer depth (MLD= 50-80 m depth). This results were consistent the vertical distribution reported for oceanic waters off Peru and northern Chile (Evseenko *et al*. 1984, Evseenko & Karavaev 1986), for the oceanic region off central Chile (Serra *et al*. 1994, Sepúlveda et al. 2007), and agree with results of Guillén & Calienes (1981) who suggest an explanation for the extended distribution of jack mackerel eggs and larvae off Peruvian coasts associated to the Ekman transport of surface layer. This results confirm that the bulk of the jack mackerel spawning in the SEP occurs in the surface layer (< 50 m depth) above the thermocline.

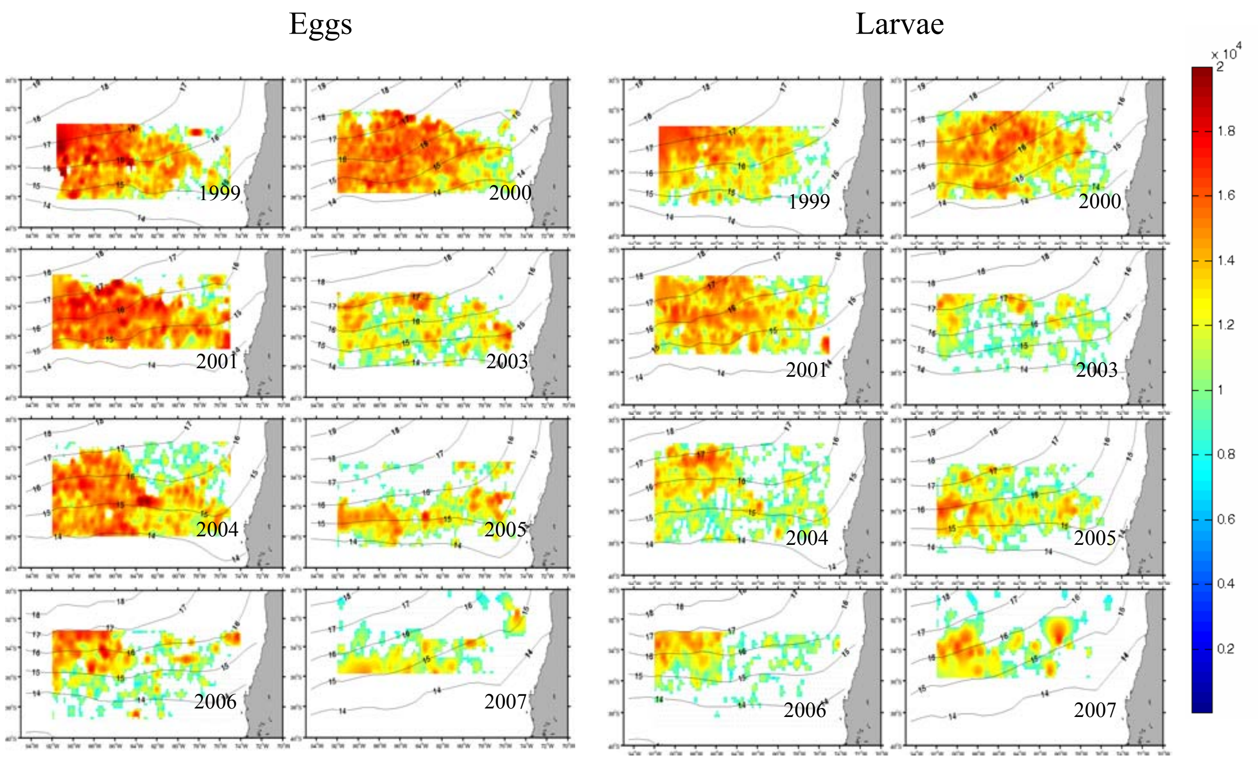


Figure 1: Spatial distribution of jack mackerel eggs and larvae density (ind.10 m^{-2}) for 1999-2007 spawning period (November) as a result of the spatially stochastic process by kriging. Lines indicate isotherms in the study area.

Eggs/larvae – environment associations

The relationships between the oceanic spawning of jack mackerel in the SEP and environmental conditions, as well as the mechanisms controlling their spatial-temporal variability have not been clearly established. It has been suggested that spawning is confined to the Subtropical Convergence Zone (northern 40ºS), characterized by small food, warm waters and low variability in plankton biomass (Evseenko 1987); as well as, that the spawning region located between 30-40ºS and from the Chilean EEZ to beyond 95ºW exhibit a low spatial variability and is related with highly productive divergences and meanders (Zhigalova & Rudomiotkina 1991).

The analysis of the spatial distribution of jack mackerel eggs/larvae and environment conditions (SST, surface wind, turbulence, geostrophic currents) in the spawning region off central Chile for the 1999-2007 spawning season, show that the most important densities were found in oceanic waters (westward than 84 ºW) characterized by warmer waters (15-18 ºC), low/moderate values of wind speed (2-6 m s^{-1}), as well as low turbulence (< 150 $m^3 s^{-3}$), and low current speed (< 15 cm s^{-1}). **Figure 2** presents an example of the jack mackerel's larvae spatial distribution for November 2004 and the environmental conditions within the spawning region off central Chile, showing an important association between the most important larval concentration and 15-17 ºC TSM range, low values of wind speed and turbulence, and a good spatial coupling between higher larval densities and eddies and meanders, recognized as a recurrent mesoscale structures in the SEP (Hormazábal *et al*. 2004).

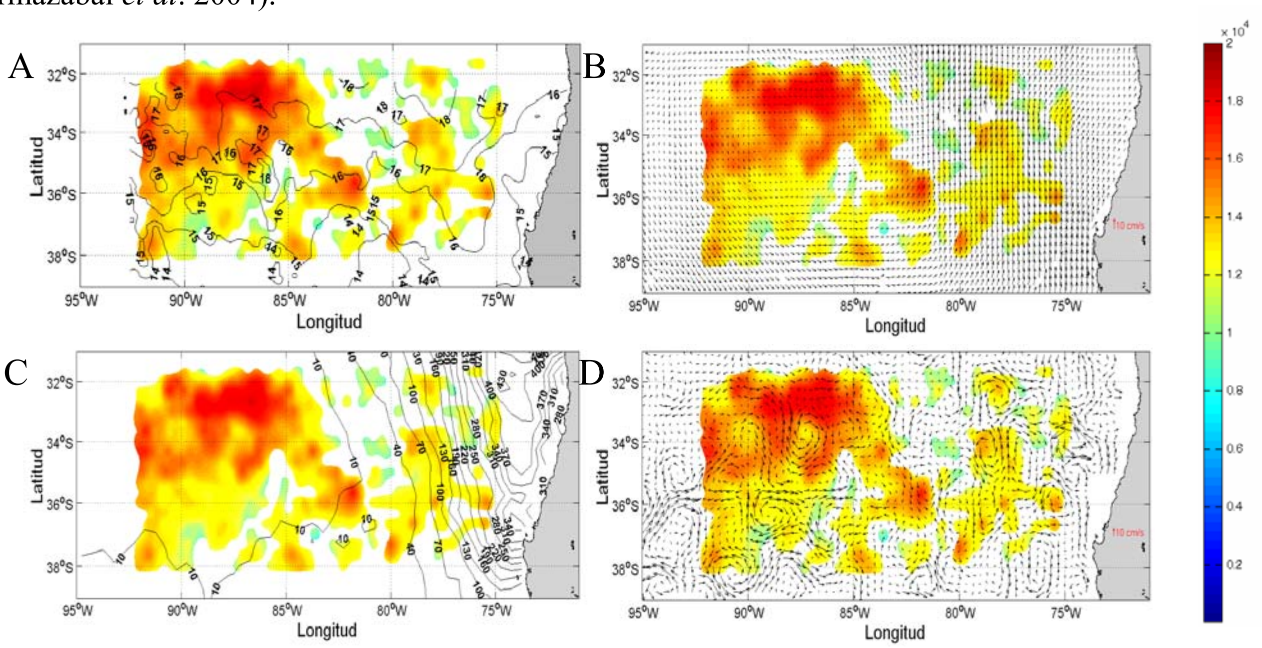
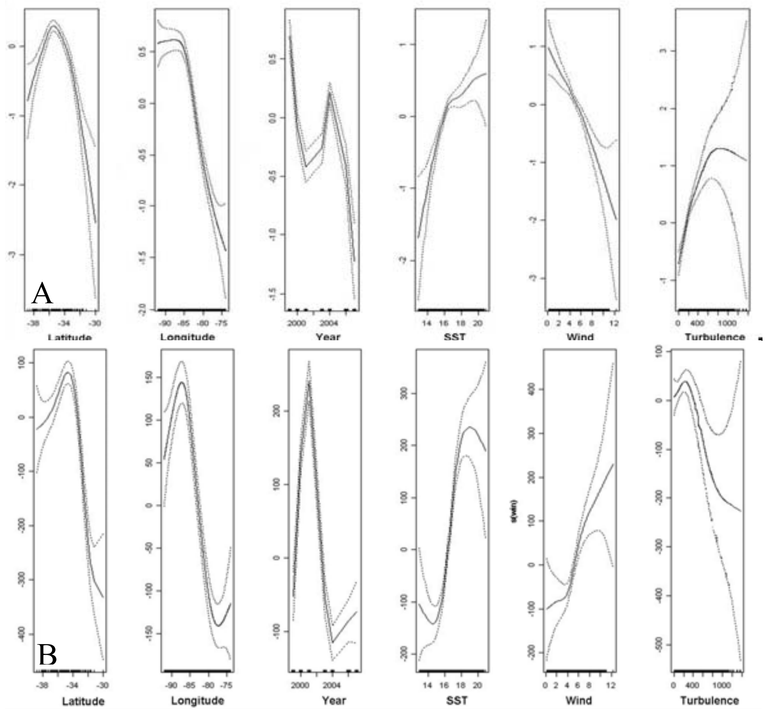


Figure 2: Spatial distribution of jack mackerel larvae (ind.10 m^{-2}) for November 2004 in the oceanic waters off central Chile. (A) sea surface temperature (ºC), (B) surface wind field (m s^{-1}), (C) turbulence index ($m^3 s^{-3}$), and (D) geostrophic current field (cm s^{-1}).

In addition, the GAM's analysis evidenced a dome-shaped relationship between egg density and latitude with maximal spawning at 35ºS considering the 1999-2007 pooled data. Besides, these high eggs concentrations were associated with SST higher than 16ºC, wind speeds lower than 6 knots and low/moderate values of turbulence. According to GAM, the continuous increases in egg density with longitude indicate that the spawning zone extends beyond de western limit considered in our study, verifying that the offshore boundary of spawning has been clearly unsolved. For jack mackerel larvae, it is shown a high density nucleus registered at 34ºS and at 85ºW, associated with SST centered in 18-19ºC, wind speeds higher than 6 knots and low turbulence values (<200 m^3s^{-3}). For 1999-2007 time series, two egg densities peaks were registered, the main in 1999 and a secondary at 2004 evidencing a lower abundance in the last years. The larval densities showed one peak in 2001 followed by a strong decline to the 2004, and an increase in larval densities in the last three years.



		d.f.	Parameters	F- value	p - value
Eggs	s (Latitude S)	1	3	38.656	>0.001
	s (Longitude W)	1	3	24.729	>0.001
	s (Year)	1	3	64.029	>0.001
	s (SST)	1	3	6.616	>0.001
	s (Wind)	1	3	0.933	0.4238
	s (Turbulence)	1	3	4.613	>0.001
Larvae	s (Latitude S)	1	3.4	52.648	>0.001
	s (Longitude W)	1	3	24.456	>0.001
	s (Year)	1	3	105.988	>0.001
	s (SST)	1	3	22.59	>0.001
	s (Wind)	1	3	4.381	0.004
	s (Turbulence)	1	3	3.985	0.007

Figure 3: GAM plots explaining the jack mackerel eggs (A) and larvae (B) density for pooled data considering the 1999-2007 spawning period. Solid lines indicate the fitted model and dashed lines are 95% confidence.

The physical-biological spatial coupling for jack mackerel eggs/larvae reported here, are consistent to other studies showing a significant association ($p<0.05$) between eggs density and both SST and wind speed, revealing a preferential range of temperature (14.9 – 18.5 ºC) and wind magnitude (4.4 – 8.6 m s^{-1}) using a cumulative frequency distributions analysis (Perry & Smith 1984) for 1998-2001 spawning time (Núñez *et al*. 2004). Likewise, our results are also coherent with the high egg densities - warmer waters association in the oceanic spawning area off Chile determined by using the habitat selection by SST analysis (van der Lingen 1999), and a nonlinear dome-shape relationship between eggs and both latitude and SST (Núñez *et al*. 2004, Cubillos *et al*. 2008), suggesting that spawning is confined within 35º to 37°S, and 16-19 °C SST. Also, in the spawning area off central Chile, it was observed a spatially consistency between higher egg density with warmer waters and low magnitudes of wind as a result of the spatial distribution of EOF modes, suggesting a possible bio-physical coupling between these variables, and a good spatial association between larvae and mesoscale eddies, showing that 25 to 50% of jack mackerel larval density were associated to mesoscale eddies (Núñez *et al*. 2006).

The range of SST associated to high densities of jack mackerel eggs/larvae and the position of the 15 – 16 °C isotherms, has been suggested to be useful as a southern limit of high egg concentration of jack mackerel (Evseenko 1987; Elizarov *et al*. 1993). These SST spatial changes could also be related to oceanic upwelling due to mesoscale eddies and shear vortices, constitute zones either upwelling or downwelling. In this way, jack mackerel larvae could be favored from patterns of alternating zones of divergence and convergence occurring in the oceanic spawning habitat, such as it is revealed from satellite altimeter data (Hormazábal *et al*. 2004, Núñez *et al*. 2004, Sepúlveda *et al*. 2006). Thus, according to changes in SST, the spawning habitat could be related to inter-annual dominance in cyclonic or anticyclonic eddies, and here linked to the observed changes in recruitment (Cubillos *et al*. 2002).

REFERENCES

Alegría, V., J. Oliva, H. Robotham, H. Miranda, G. Böhm, L. Caballero, D. Boré, U. Parker, V. Baros, S. Peña, G. Claramunt, G. Herrera, C. Padilla, P. Pizarro, M. Medina, H. Arancibia, M. Araya, L. Cubillos, R. Gili, D. Garland, H. Hidalgo & M. Oliva. 1995. Estudio biológico pesquero sobre el recurso jurel en la zona norte (Regiones I y II). Informes Técnicos FIP-IT/93-17, 221 p. (www.fip.cl).

Alexeeva, E.I. 1986. Característica comparativa de la madurez y desove de jureles del género Trachurus de los océanos Atlántico y Pacífico. En: Ciclos de vida, distribución y migración de peces comerciales de los océanos Atlántico y Pacífico. Informe AtlatNIRO, Kaliningrado:47-59.

Andrianov, D.P. 1985. Study on the reproduction of Peruvian scad, *Trachurus murphyi* (Carangidae), of the Peruvian shelf. Journal of Ichthyology, 25: 32-40.

Andrianov, D.P. 1990. Maduración, formación de fecundidad y carácter de desove de de principales peces comerciales del Pacífico Suroriental. Tesis doctora. VNIRO, Moscú. 2999 págs.

Arancibia, H., L. Cubillos, A. Grechina, D. Arcos & L. Vilugrón 1995. The fishery of horse mackerel (Trachurus symmetricus murphyi) in the south Pacific Ocean, with notes on the fishery off central-southern Chile. Scientia Marina 59(3/4), 589-596.

Arcos, D.F., L. Cubillos & S. Núñez. 2001. The jack mackerel fishery and El Niño 1997-1998 effects off Chile. Progress and Oceanography, 49:597-617.

Bailey, K., 1989. Description and surface distribution of juvenile Peruvian jack mackerel, Trachurus murphyi, Nichols from the Subtropical Convergence Zone of Central South Pacific. Fishery Bulletin, U.S. 87,273-278.

Cubillos, L., S. Núñez & D. Arcos. 2002. Relating Chilean jack mackerel recruitment to sea surface temperature (SST): looking for spatial spawning pattern and SST indexes. WG Product 4. Report of the Second meeting of the SPACC/IOC study group on "Use of environmental indices in the management of pelagic fish populations". 9-11 November 2002, Paris, France. GLOBEC Special Contribution Nº6. GLOBEC Report Series. 156 p.

Cubillos, L., S. Núñez, J. Páramo & A. Sepúlveda. 2004. The oceanic spawning of Chilean jack mackerel: daily egg production, spawning biomass and habitat conditions. Contribution to the SPACC meeting: Small pelagic fish spawning habitat dynamics and the daily egg production method. Concepción (Chile), January 14-16, 2004.

Cubillos, L.A., J. Páramo, P. Ruíz, S. Núñez & A. Sepúlveda. 2008. The spatial structure in the oceanic spawning of jack mackerel (Trachurus murphyi) off central Chile (1998-2001). Fisheries Research 90:261-270.

Dejnik, T.V. & M.M. Nevinskiy. 1987. Distribución y abundancia de huevos y larvas. En: Recopilaciçon: Biologçia y Pesca del Jurel Peruano. Moscú. VNIRO, 35-44.

Dioses, T., V.H. Alarcón, M.E. Nakama & A. Echevarría. 1989. Desarrollo ovocitario, fecundidad parcial y distribución vertical de los cardúmenes en desove de jurel Trachurus murphyi (N.). Memorias Simposio Internacional de Recursos Vivos y las Pesquerías en el Pacífico Sudeste. Viña del Mar, 9-13 de Mayo de 1988. CPPS. Revista Pacífico Sur Nº especial:287-294.

Elizarov, A.A., A.S. Grechina, B.N. Kotenev & A.N. Kuzetsov. 1993. Peruvian jack mackerel, Trachurus symmetricus murphyi, in the open waters of the South Pacific. Journal of Ichtyology, 33(3), 86-104.

Evseenko, S.A., S.M. Karavaev & M.M. Nevinskiy. 1984. Antecedentes sobre la reproducción del jurel peruano en el Pacífico Sur. En: Estudios Pesqueros en las Áreas Abiertas del Océano Mundial. Informe interno del Instituto VNIRO, Moscú. Pp: 123-135.

Evseenko, S.A. & .N. Gorbunova. 1984. Ictioplancton de la Cordillera de Nazca y de la parte Este de la zona subantártica frontal. Moscú. Nauta:303-314.

Evseenko, S.A. & S.M. Karavaev. 1986. Ictioplancton de aguas peruanas en el período El Niño 1972. Trabajos del Instituto de Oceanología de la Academia de Ciencias de URSS, Nº116:126-151.

Evseenko, S.A., 1987. On the reproduction of the Peruvian jack mackerel, Trachurus symmetricus murphyi (Nichols), in the southern part of the Pacific Ocean. Voprosy Ikhtiologii 27(2), 264-273.

Grechina, A.S., S. Núñez & D. Arcos. 1998a. Biología reproductiva del jurel (Trachurus symmetricus murphyi) en el Pacífico sur. In: Arcos, D. (ed.) Biología y ecología del jurel en aguas chilenas, Instituto de Investigación Pesquera, Talcahuano, Chile, p. 77-99.

Grechina, A.S., S. Núñez & D. Arcos. 1998b. El desove del recurso jurel Trachurus symmetricus murphyi (Nichols) en el océano Pacífico sur. In: Arcos, D. (ed.) Biología y ecología del jurel en aguas chilenas, Instituto de Investigación Pesquera, Talcahuano, Chile, p. 117-140.

Guillén, O. & R. Calienes. 1981. Biological productivity and El Niño. In: Resource Management and Environmental Uncertainty: Lessons for coastal upwelling fisheries. (M.H. Glatz & J.D. Thompson, Eds.) Wiley Interscience, New York, 255.282 p.

Hastie, T. & R. Tibshirani. 1990. Generalizad Additive Models. Chapman and Hall. London. England.

Hormazábal, S., G. Shaffer & O. Leth. 2004. The coastal transition zone of Chile. Journal of Geophysical Research, Volumen 109, C01021, doi:10.1029/2003JCC001956.

Kaiser, C.E. 1973. Gonadal maduration and fecundity of horse mackerel Trachurus murphyi (Nichols) off the coast of Chile. Trans. Am. Fish. Soc., 102(1):101-108.

Núñez, S., J. Letelier, D. Donoso, A. Sepúlveda & D. Arcos. 2004. Relating spatial distribution of Chilean jack mackerel and environmental factors in the oceanic waters off Chile. Pan Ocean Remote Sensing Conference-2004. Remote Sensing of Oceans, Coasts and the Atmosphere: Developments and Applications. Gayana, Vol. 68(2):444-449.

Núñez, S., S. Hormazábal, F. Gómez, J. Letelier & A. Sepúlveda. Some evidences of physical-biological coupling between jack mackerel larvae and mesoscale structures off central Chile. Internacional Conference. The Humboldt Current System. Climate. Ocean dynamics, ecosystem processes and fisheries. Nov 27th – Dec. 1st, 2006. Lima Perú.

Oyarzún, C., J. Chong & M. Malagueño. 1998. Fenología reproductiva en el jurel Trachurus symmetricus (Ayres 1855) (Perciformes, Carangidae) en el área de Talcahuano, Chile: 1982-1984. In: Arcos, D. (ed.) Biología y ecología del jurel en aguas chilenas, Instituto de Investigación Pesquera, Talcahuano, Chile, p. 67-75.

Perry, R. & S. Smith. 1994. Identifying habitat asocciations of marine fishes using survey data: An application to the Northwest Atlantic. Canadian Journal of Fisheries and Aquatic Sciences, 51:589-602.

Sepúlveda A., P. Ruiz, S. Núñez, R. Alarcón, J. Chong, R. Bahamonde, J. Córdova, H. Rebolledo, M Aguayo, L. Bustos. 2007. "Condición biológica del jurel en alta mar, año 2006". PreInforme Final FIP 2006-05, Fondo de Investigación Pesquera, Instituto de Investigación Pesquera – Instituto de Fomento Pesquero 267 pp.

Serra, R. 1983. Changes in abundance of pelagic resources along the Chilean coast. FAO Fish. Rep., Vol.2. Nº291:255-284.

Serra, J.R., 1991. Important life history aspects of the Chilean jack mackerel, Trachurus symmetricus murphyi. Investigación Pesquera (Chile) 36, 67-83.

Van der Lingen, C.D., L. Hutchings, D. Merkle, J.J. Van der Westhuizen & J. Nelson. 1999. Comparative spawning habitats of anchovy (Engraulis capensis) and sardine (Sardinops sagax) in the Southern Benguela upwelling. In: Kruse, G.H., N. Bez, A. Booth, M.W. Dorn, S. Hills, R.N. Lipcius, D. Pelletier, C. Roy, S.J. Smith & D. Witherlls (eds). Ecosystem spatial processes and management of marine populations. Lowel Wakefield Dish. Symp. Ser. 17: 185-209.

Zhigalova, R.A. & G.P. Rudomiotkina. 1991. On the effects of interanual hydrological variability on the Peruvian horse mackerel eggs and larvae distribution in the South Pacific ocean. In: Fishery-Ecological Researchin the South Pacific Ocean. Kaliningrad. AtlantNIRO, 61-69.