Seasonal distribution and abundance of jack mackeral (*Trachurus murphyi*) eggs and larvae off northern Chile 1981-2007

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Abstract

We herein summarize the results of 85 seasonal surveys for eggs and larvae carried out by the IFOP between 1981 and 2007 within the EEZ, from the northern limit with Peru to the port of Antofagasta (24° S). These results indicate that egg and larva density peak in winter-spring, with a greater concentration towards the southern zone of the study area. Annually, a clear tendency for egg density to decrease stands out. The signal for larva density is more erratic due to their capacity to avoid the sampling net.

1. Introduction

Jack mackeral is a partial spawner and, as such, eggs and larvae can be found throughout its distribution area along the coast of South America. Nonetheless, two important spawning zones have been reported off Peru (Santander and Flores, 1983) and Chile. The latter, between 35º and 42º S, is a larger area with higher densities and extends into the open sea beyond the EEZ (Evseenko ***et al***., 1982; Galactionov and Reshetnikova, 1983; Evseenko and Gorbunova, 1984; Gorbunova ***et al***., 1985; amongst others).

The present document summarizes the results of seasonal surveys carried out by Chile between 1981 and 2007 in order to monitor the density and distribution of jack mackeral eggs and larvae off northern Chile in the EEZ from the northern limit with Peru to 24° S.

2. Materials and Methods

Between 1981 and 2007, the Instituto de Fomento Pesquero (IFOP) developed seasonal surveys aimed at evaluating the bio-oceanographic conditions and the abundance, distribution, and spatial coverage of eggs and larvae from commercially important fish, including jack mackeral ichthyoplankton. The study area corresponded to the EEZ between the northern limit with Peru (Arica) and 24° S (Antofagasta).

Basic information on jack mackerel eggs and larvae for northern Chile comes from the analysis of 5,399 zooplanktonic samples taken during a total of 85 bio-oceanographic and acoustic-bio-oceanographic surveys that covered the four seasons of the year between 1981 and 2007. The *in situ* surveys were done on board the B/C "Carlos Porter" (1981-2004) and the B/C "Abate Molina" (2004-2007) and, in terms of longitude, stretched from one to 100 nautical miles (nm) from the coast. Depending on the year, between 9 and 14 transects were performed perpendicular to the coast, equidistant one from the other, between 20 and 80 nm.

Planktonic fishing was done using vertical hauls with a cylindrical-conical net model WP-2 (UNESCO, 1968; Sameoto et al., 2000). This monofilament synthetic mesh (300 µm openings) had an opening of 0.25 m^2 is 261 cm long. The samples collected were obtained from maximum depths of 100 m and with speeds for lowering and raising the net of 0.8 m/s and 0.6 m/s, respectively. The volume of water filtered was measured by a TSK flow meter installed in the mouth of the net.

The samples obtained were preserved with a formalin solution in sea water at 5%, and buffered with borax. Sample processing in the laboratory on land was done in four stages:

- Extraction of all the early fish stages (eggs, larvae) from each of the samples collected,
- Taxonomic identification of jack mackerel eggs and larvae,
- Quantification of target species eggs and larvae, and
- Enumeration and grouping of the remaining ichthyoplankton as "other species".

Sample analysis was done with Nikon and Zeiss stereoscopes (8x and 40x magnification). Taxonomic determinations of the target species were aided by descriptions of embryonic development and other published studies such as Santander and Castillo (1972), Balbontín and Pérez (1980), Boltovskoy (1981), Orellana and Balbontín (1983), Santander ***et al.*** (1984), and Olivar and Fortuño (1991), amongst others.

For relative density, the measurement of the number of eggs and larvae considered a standard unit of area of 10 m^2:

$$C = 10 \frac{d}{w} c$$

where:

C : Number of eggs or larvae per unit of area (10 m^2)

d : Maximum haul depth (m)

$$d = L_o \cos \theta$$

L_o : Length of cable (m)

$\cos \theta$: Cosine of the angle recorded prior to the retrieval of the net

w : Volume of water filtered (m^3)

$$w = Q \cdot t$$

Q : Volume of water filtered per unit of time (m^3/sec)

t : Time of trawling (sec)

$$Q = V \cdot A$$

A : Area of the mouth of the net (m^2)

V : Towing speed of the net expressed in m/sec, obtained based on an adjustment of the calibration curve of the flow meter:

$$V = a \cdot N + b \, .$$

N : Number of revolutions per second

a and b : Constants

3. Results / Discussion

The results of the surveys for eggs and larvae carried out by IFOP show a marked seasonal variation and clear tendency for an annual reduction in the indices (**Figure 1**). Lower average densities are associated with autumn, during which 18 research surveys covered a total of 1,028 sampling stations; 14 of these were positive for jack mackerel eggs (1.4%) and four for larvae (0.39%). Eggs were found during four autumn surveys and larvae during two. Average total densities were very low per station, fluctuating between 4 and 22 eggs/10m^2 and between 1 and 6 larvae/10m^2 (**Table 1**).

The average densities and frequency of positive stations increased in summer, when 21 research surveys were carried out between 1982 and 2007, with a total of 1,281 sampling stations. Of these, 110 were positive for eggs (8.6%) and 36 for larvae (2.8%). Unlike autumn, the number of surveys that were positive for eggs (n = 15) and larvae (n = 13) increased in summer. Average densities per total stations also increased, fluctuating between 1 and 59 eggs/10m^2 and between 1 and 30 larvae /10m^2 (**Table 2**).

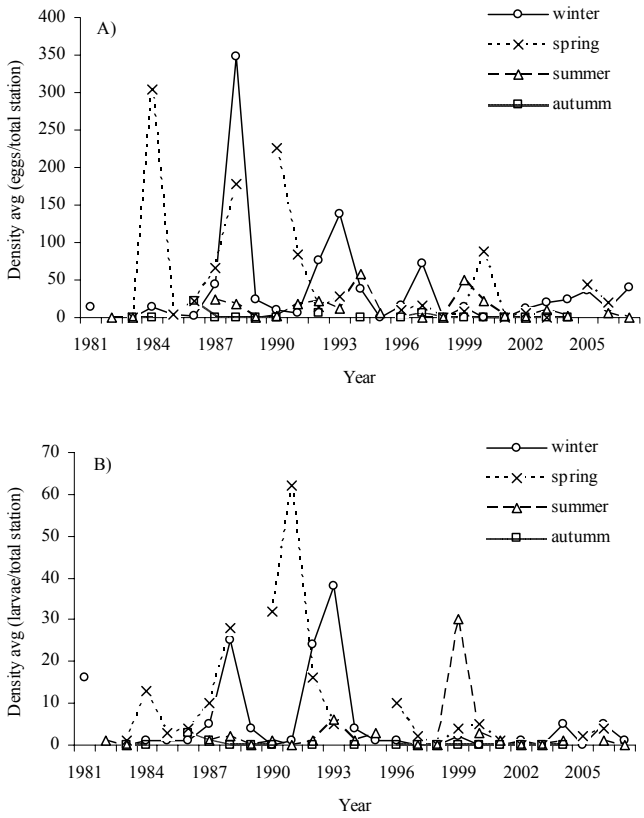

Figure 1. Seasonal abundance of jack mackeral, ***Trachurus murphyi***, eggs (a) and larvae (b) (1981-2007).

Records of both development phases make in autumn and summer showed more coastal egg laying and low average densities, especially in autumn. Thus, egg and larva densities were highest in winter and spring, particularly winter (**Figures 2 and 3)**. The 26 winter surveys covered a total of 1,871 stations, of which 318 were positive for eggs (17%) and 166 for larvae (8.9%). The average densities per total stations fluctuated between 3 and 349 eggs/10m^2 and between 1 and 38 larvae/10m^2. Although this range was similar to that reported for the spring, the frequencies and numerical dominance were higher (**Tables 3 and 4**). 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 (**Figure 3**). The most recent surveys done in this decade (2003-2007) have shown a very low presence of jack mackerel eggs and larvae off northern Chile, which differs significantly from the records of the 1980s and the first half of the 1990s. Egg and larva densities were scarce towards the limit with Peru.

In spring, information was compiled from 20 research surveys for a total of 1,219 stations. Of these, 208 were positive for the presence of jack mackerel eggs (17.1%) and 135 for larvae (11.1%). In most cases, average jack mackerel egg and larva densities were lower than those reported in winter, but maintained important frequencies and numerical dominances. In this region,

other authors (Palma *et al.,* 1994) have analyzed the seasonal variation of the abundance of jack mackerel larvae, detecting greater abundances of larval stages in spring (December 1990) between 5 and 30 nm from the coast, a situation that coincides with the intrusion of warm waters to the southeast and northeast, the location of the 19-21 °C isotherms, and information provided by the IFOP. On the other hand, Loeb & Rojas (1988) analyzed the interannual variability of the ichthyoplanktonic abundance off northern Chile between 1964 and 1983, reporting low abundances of jack mackerel larval stages as compared to purely coastal species in winter (July-September).

These results revealed important spatial and inter-annual changes in the jack mackerel egg and larva density off northern Chile. On the one hand, this confirmed the clear seasonal pattern of reproductive activity for this resource, which peaks in winter-spring and, on the other hand, showed that the main area of reproductive activity in this sector is located towards the south of the study area and projecting seaward. Density and spatial coverage were found to be lower in the winter periods as of 1995. In spring, the most important spawning in terms of spatial frequency and numerical density was detected until the beginning of the 1990s; after 1996, the abundance and spatial frequency levels of both phases was reduced to minimum values.

Larvae, unlike eggs, presented a lower frequency and abundance index due to diverse factors such as greater evasion of the sampling nets (WP-2 nets) and increased dispersal due to feeding and advective processes, to name a few. Estimates of the average larval abundance per positive stations were, in general, quite a bit lower than those for eggs, which had greater abundance levels in the springs of 1987, 1990, 2000, 2005, and 2006 and in the winters of 1980, 1992, 1997, and 2003. With this, we ratify that winter is the most successful period in terms of spatial presence and numerical importance of the jack mackeral eggs, followed by spring.

Table 1. Average density, consistency, and numerical dominance of *Trachurus murphyi* eggs and larvae, autumn surveys (1983-2004).

HUEVOS

ESPECIE	Año	Crucero	Número de estaciones positivas	Número de huevos	Densidad promedio por estaciones		Constancia o Frecuencia %	Dominancia numérica %
					Totales	Positivas		
Trachurus murphyi	1983	274(2)83CP	0	0	0	0	0,0	0,0
	1984	285(2)84CP	0	0	0	0	0,0	0,0
	1985							
	1986	304(2)86CP	5	1816	22	363	6,0	1,3
	1987	309(2)87CP	0	0	0	0	0,0	0,0
	1988	315(2)88CP	0	0	0	0	0,0	0,0
	1989	324(2)89CP	0	0	0	0	0,0	0,0
	1990	333(2)90CP	0	0	0	0	0,0	0,0
	1991							
	1992	346(2)92CP	6	363	6	61	10,7	1,2
	1993							
	1994	368(2)94AM	0	0	0	0	0,0	0,0
	1995							
	1996	390(2)96CP	1	153	4	153	2,9	0,2
	1997	401(2)97CP	2	215	6	108	5,7	1,2
	1998	413(2)98CP	0	0	0	0	0,0	0,0
	1999	422(2)99CP	0	0	0	0	0,0	0,0
	2000	431(2)00CP	0	0	0	0	0,0	0,0
	2001	442(2)01CP	0	0	0	0	0,0	0,0
	2002	452(2)02CP	0	0	0	0	0,0	0,0
	2003	461(2)03AM	0	0	0	0	0,0	0,0
	2004	469(2)04CP	0	0	0	0	0,0	0,0

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ESPECIE	Año	Crucero	Número de estaciones positivas	Número de larvas	Densidad promedio por estaciones		Constancia o Frecuencia %	Dominancia numérica %
					Totales	Positivas		
Trachurus murphyi	1983	274(2)83CP	0	0	0	0	0,0	0,0
	1984	285(2)84CP	0	0	0	0	0,0	0,0
	1985							
	1986	304(2)86CP	3	240	6	80	7,1	1,2
	1987	309(2)87CP	1	32	1	32	1,0	0,1
	1988	315(2)88CP	0	0	0	0	0,0	0,0
	1989	324(2)89CP	0	0	0	0	0,0	0,0
	1990	333(2)90CP	0	0	0	0	0,0	0,0
	1991							
	1992	346(2)92CP	0	0	0	0	0,0	0,0
	1993							
	1994	368(2)94AM	0	0	0	0	0,0	0,0
	1995							
	1996	390(2)96CP	0	0	0	0	0,0	0,0
	1997	401(2)97CP	0	0	0	0	0,0	0,0
	1998	413(2)98CP	0	0	0	0	0,0	0,0
	1999	422(2)99CP	0	0	0	0	0,0	0,0
	2000	431(2)00CP	0	0	0	0	0,0	0,0
	2001	442(2)01CP	0	0	0	0	0,0	0,0
	2002	452(2)02CP	0	0	0	0	0,0	0,0
	2003	461(2)03AM	0	0	0	0	0,0	0,0
	2004	469(2)04CP	0	0	0	0	0,0	0,0

Table 2. Average density, consistency, and numerical dominance of *Trachurus murphyi* eggs and larvae, summer surveys (1982-2007).

E S P E C I E	Año	Crucero	Número de estaciones positivas	Número de huevos	Densidad promedio por estaciones Totales	Positivas	Constancia o Frecuencia %	Dominancia numérica %
Trachurus murphyi	1982	251(1)82IT	0	0	0	0	0,0	0,0
	1983	270(1)83IT	0	0	0	0	0,0	0,0
	1984							
	1985							
	1986							
	1987	308(1)87CP	10	2202	24	220	10,9	3,0
	1988	313(1)88CP	7	1761	18	252	7,1	0,6
	1989	323(1)89CP	0	0	0	0	0,0	0,0
	1990	330(1)90CP	2	333	3	167	2,0	0,2
	1991	336(1)91CP	10	1849	19	185	10,2	1,0
	1992	343(1)92CP	9	1213	22	135	16,1	0,6
	1993	EPERVA	18	1326	13	74	17,6	10,9
	1994	365(1)94CP	15	4149	59	277	21,4	2,4
	1995	EPERVA	7	522	6	75	8,6	4,3
	1996							
	1997	398(1)97CP	0	0	0	0	0,0	0,0
	1998	410(1)98CP	0	0	0	0	0,0	0,0
	1999	420(1)99AM	8	2468	50	309	16,3	2,4
	2000	430(1)00CP	7	1055	22	151	14,9	0,5
	2001	441(1)01CP	3	153	3	51	6,4	0,2
	2002	451(1)02CP	2	68	1	34	4,3	0,0
	2003	460(1)03AM	3	561	11	187	6,0	0,1
	2004	467(1)04CP	2	137	3	69	3,8	0,1
	2005							
	2006	481(1)06CP	7	364	7	52	13,0	0,1
	2007	493(1)07AM	0	0	0	0	0,0	0,0

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E S P E C I E	Año	Crucero	Número de estaciones positivas	Número de larvas	Densidad promedio por estaciones Totales	Positivas	Constancia o Frecuencia %	Dominancia numérica %
Trachurus murphyi	1982	251(1)82IT	5	57	1	11	11,9	0,1
	1983	270(1)83IT	0	0	0	0	0,0	0,0
	1984							
	1985							
	1986							
	1987	308(1)87CP	3	126	1	42	3,3	0,3
	1988	313(1)88CP	5	193	2	39	5,1	0,1
	1989	323(1)89CP	0	0	0	0	0,0	0,0
	1990	330(1)90CP	2	61	1	31	2,0	0,0
	1991	336(1)91CP	0	0	0	0	0,0	0,0
	1992	343(1)92CP	2	65	1	33	3,6	0,1
	1993	EPERVA	1	652	6	652	1,0	5,4
	1994	365(1)94CP	3	68	1	23	4,3	0,1
	1995	EPERVA	4	228	3	57	4,9	1,4
	1996							
	1997	398(1)97CP	0	0	0	0	0,0	0,0
	1998	410(1)98CP	0	0	0	0	0,0	0,0
	1999	420(1)99AM	6	1457	30	243	12,2	1,5
	2000	430(1)00CP	2	126	3	63	4,3	0,1
	2001	441(1)01CP	1	40	1	40	2,1	0,1
	2002	451(1)02CP	0	0	0	0	0,0	0,0
	2003	460(1)03AM	0	0	0	0	0,0	0,0
	2004	467(1)04CP	1	46	1	46	1,9	0,1
	2005							
	2006	481(1)06CP	1	46	1	46	1,9	0,1
	2007	493(1)07AM	0	0	0	0	0,0	0,0

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

ESPECIE	Año	Crucero	Número de estaciones positivas	Densidad promedio por estaciones Número de huevos	Totales	Positivas	Constancia o Frecuencia %	Dominancia numérica %
Trachurus murphyi	1981	247(3)81CA	11	504	14	46	29,7	0,5
	1983	277(3)83CP	0	0	0	0	0,0	0,0
	1984	288(3)84CP	4	682	14	171	8,2	1,7
	1985	299(3)85CP	2	295	4	148	2,4	0,0
	1986	305(3)86CP	1	239	3	239	1,2	0,0
	1987	310(3)87CP	25	3607	44	144	30,5	2,6
	1988	318(3)88CP	44	34230	349	778	44,9	7,1
	1989	326(3)89CP	16	2378	24	149	16,3	0,4
	1990	334(3)90CP	9	933	10	104	9,2	0,3
	1991	338(3)91AM	7	653	7	93	7,1	0,3
	1992	354(3)92CP	57	10444	76	183	41,3	3,0
	1993	362(3)93CP	51	16379	138	321	42,9	5,9
	1994	370(3)94CP	28	4566	38	163	23,5	0,6
	1995	383(3)95CP	0	0	0	0	0,0	0,0
	1996	394(3)96CP	4	575	17	144	11,8	1,0
	1997	404(3)97CP	5	2452	72	490	14,7	1,6
	1998	416(3)98CP	0	0	0	0	0,0	0,0
	1999	425(3)99CP	6	714	14	119	12,0	0,7
	2000	436(3)00CP	0	0	0	0	0,0	0,0
	2001	447(3)01CP	0	0	0	0	0,0	0,0
	2002	456(3)02CP	10	693	12	69	16,9	0,1
	2003	464(3)03CP	3	1110	21	370	5,7	0,2
	2004	471(3)04CP	9	1333	25	148	16,7	0,2
	2005	477(3)05CPAM	9	2009	37	223	16,7	0,4
	2006	487(3)06AM	5	668	12	134	9,3	0,3
	2007	502(3)07AM	12	2599	41	217	19,0	0,8

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ESPECIE	Año	Crucero	Número de estaciones positivas	Densidad promedio por estaciones Número de larvas	Totales	Positivas	Constancia o Frecuencia %	Dominancia numérica %
Trachurus murphyi	1981	247(3)81CA	25	588	16	24	67,6	0,7
	1983	277(3)83CP	0	0	0	0	0,0	0,0
	1984	288(3)84CP	3	63	1	21	6,1	0,3
	1985	299(3)85CP	2	101	1	51	2,4	0,0
	1986	305(3)86CP	2	61	1	31	2,4	0,0
	1987	310(3)87CP	8	372	5	47	9,8	0,4
	1988	318(3)88CP	21	2449	25	117	21,4	1,3
	1989	326(3)89CP	6	438	4	73	6,1	0,1
	1990	334(3)90CP	0	0	0	0	0,0	0,0
	1991	338(3)91AM	2	112	1	56	2,0	0,2
	1992	354(3)92CP	34	3290	24	97	24,6	1,8
	1993	362(3)93CP	37	4540	38	123	31,1	1,4
	1994	370(3)94CP	10	507	4	51	8,4	0,1
	1995	383(3)95CP	2	67	1	34	1,7	0,0
	1996	394(3)96CP	1	34	1	34	2,9	0,1
	1997	404(3)97CP	0	0	0	0	0,0	0,0
	1998	416(3)98CP	0	0	0	0	0,0	0,0
	1999	425(3)99CP	3	124	2	41	6,0	0,2
	2000	436(3)00CP	0	0	0	0	0,0	0,0
	2001	447(3)01CP	0	0	0	0	0,0	0,0
	2002	456(3)02CP	1	36	1	36	1,7	0,0
	2003	464(3)03CP	0	0	0	0	0	0
	2004	471(3)04CP	5	269	5	54	9,3	0,3
	2005	477(3)05CPAM	0	0	0	0	0,0	0,0
	2006	487(3)06AM	3	276	5	92	5,6	0,2
	2007	502(3)07AM	1	38	1	38	1,6	0,0

Table 4. Average density, consistency, and numerical dominance of *Trachurus murphyi* eggs and larvae, spring surveys (1983-2006).

ESPECIE	Año	Crucero	Número de estaciones positivas	Número de huevos	Densidad promedio por estaciones		Constancia o Frecuencia %	Dominancia numérica %
					Totales	Positivas		
Trachurus murphyi	1983	280(4)83IT	0	0	0	0	0,0	0,0
	1984	290(4)84CP	22	8216	304	373	47,8	34,4
	1985	301(4)85CP	4	336	4	84	4,8	0,2
	1986	306(4)86CP	10	1810	22	181	12,0	2,1
	1987	312(4)87CP	8	5649	67	706	9,5	3,3
	1988	320(4)88CP	45	17459	178	388	45,9	6,6
	1989							
	1990	335(4)90CP	39	21978	227	564	40,2	14,2
	1991	341(4)91CP	30	9488	85	316	26,8	4,7
	1992	358(4)92CP	9	762	14	85	16,7	0,8
	1993	364(4)93AM	14	1928	28	138	20,0	1,3
	1994							
	1995							
	1996	396(4)96AM	4	372	11	93	11,4	0,2
	1997	408(4)97CP	9	602	17	67	25,7	0,4
	1998	419(4)98AM	0	0	0	0	0,0	0,0
	1999	427(4)99CP	1	331	7,9	331	2,4	0,5
	2000	438(4)00CP	4	4192	89,2	1048	8,5	0,9
	2001	449(4)01CP	1	38	0,8	38	2,1	0,0
	2002	457(4)02AM	4	342	6,84	86	8	0,2
	2003	465(4)03CP	0	0	0	0	0,0	0,0
	2004							
	2005	478(4)05CP	3	2390	44,26	797	5,6	1,0
	2006	489(4)06AM	1	1152	21,33	1152	1,9	0,2

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ESPECIE	Año	Crucero	Número de estaciones positivas	Número de larvas	Densidad promedio por estaciones		Constancia o Frecuencia %	Dominancia numérica %
					Totales	Positivas		
Trachurus murphyi	1983	280(4)83IT	1	23	1	23	3,7	0,2
	1984	290(4)84CP	13	612	13	47	28,3	7,8
	1985	301(4)85CP	3	254	3	85	3,6	0,3
	1986	306(4)86CP	7	292	4	42	8,4	0,5
	1987	312(4)87CP	8	876	10	110	9,5	1,4
	1988	320(4)88CP	28	2778	28	99	28,6	2,8
	1989							
	1990	335(4)90CP	17	3099	32	182	17,5	6,5
	1991	341(4)91CP	16	6911	62	432	14,3	10,4
	1992	358(4)92CP	11	848	16	77	20,4	0,9
	1993	364(4)93AM	8	346	5	43	11,4	0,8
	1994							
	1995							
	1996	396(4)96AM	8	343	10	43	22,9	0,7
	1997	408(4)97CP	2	76	2	38	5,7	0,1
	1998	419(4)98AM	0	0	0	0	0,0	0,0
	1999	427(4)99CP	4	145	3,5	36	9,5	0,2
	2000	438(4)00CP	2	225	4,8	113	4,3	0,9
	2001	449(4)01CP	1	40	0,9	40	2,1	0,1
	2002	457(4)02AM	0	0	0	0	0	0
	2003	465(4)03CP	0	0	0	0	0	0
	2004							
	2005	478(4)05CP	2	83	1,5	42	3,7	0,1
	2006	489(4)06AM	4	223	4,1	56	7,4	0,3

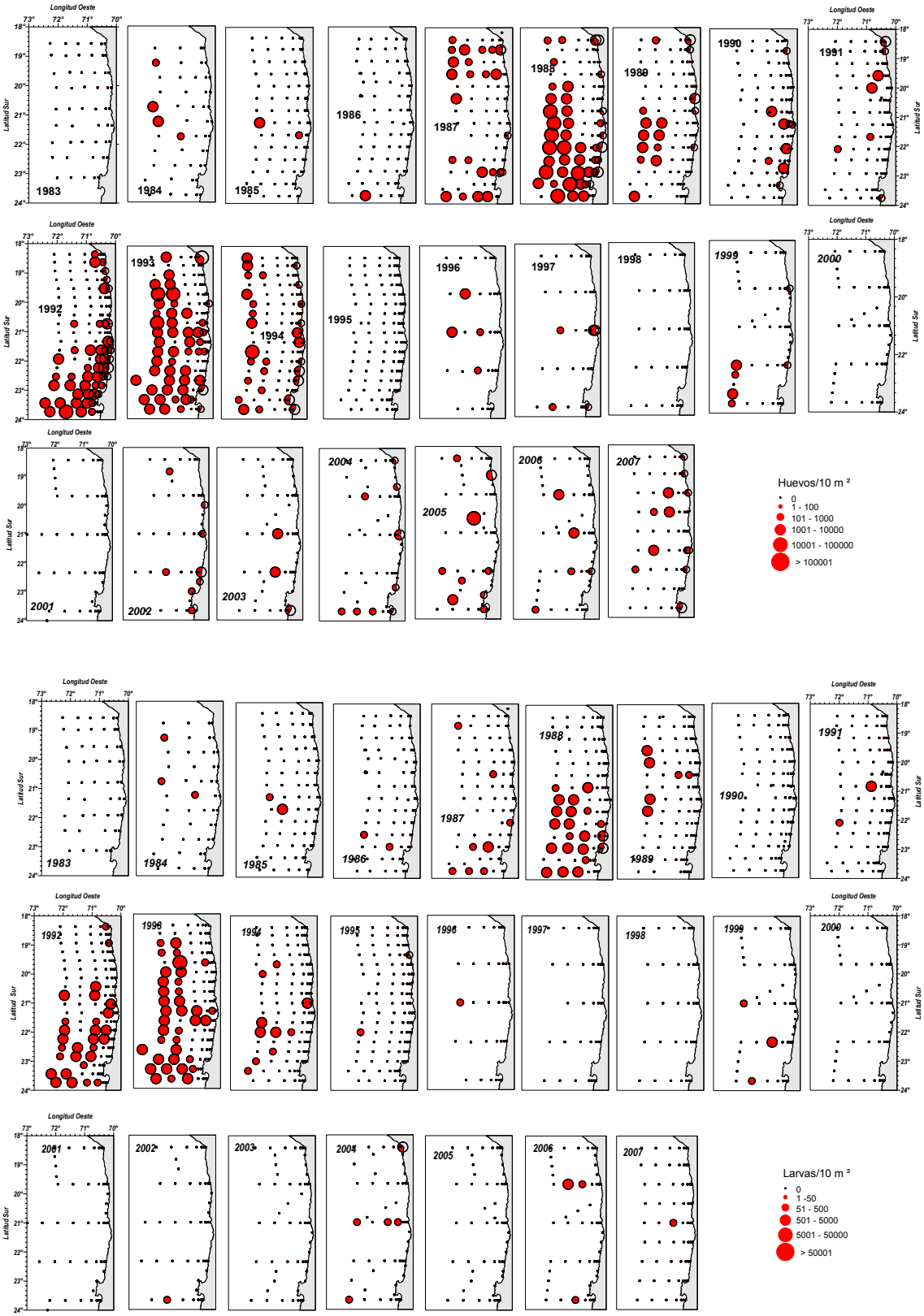

Figure 2. Distribution and abundance of jack mackeral, *Trachurus murphyi*, eggs and larvae, winter surveys (1983-2007).

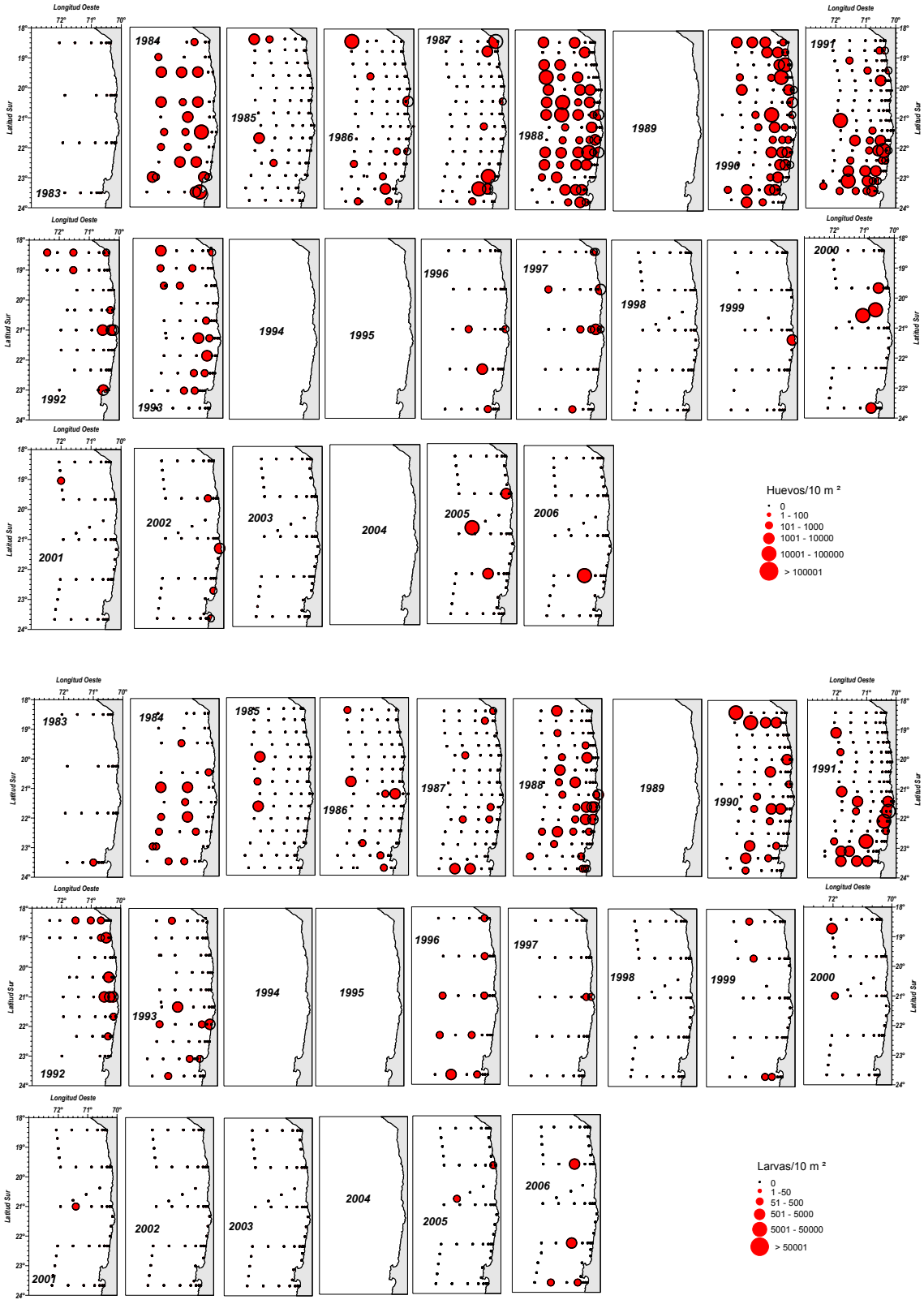

Figure 3. Distribution and abundance of jack mackeral, *Trachurus murphyi*, eggs and larvae, spring surveys (1983-2006).

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