

## Temporal fluctuations of nearshore ichthyoplankton off Valparaíso, central Chile, during the ENSO cycle 1997-2000

Fluctuaciones temporales del ictioplancton costero frente a Valparaíso, Chile central, durante el ciclo ENOS 1997-2000

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**Resumen.** Entre enero de 1997 y diciembre de 2000 se tomaron datos diarios de temperatura superficial del mar (TSM), altura del nivel del mar y transporte de Ekman, junto con muestreos quincenales y mensuales de ictioplancton en una estación costera ubicada en la bahía Valparaíso. Las muestras se recolectaron mediante lances verticales desde 50 m de profundidad hasta la superficie con una red cónica. De un total de 103 muestras, 71 tuvieron presencia de ictioplancton; se separó un total de 10.646 huevos y 1.189 larvas de peces, correspondiendo a 6 y 20 taxa, respectivamente. Las especies dominantes en los huevos fueron *Engraulis ringens* (35,5%), *Merluccius gayi* (32,7%) y *Sardinops sagax* (23,3%). En las larvas dominaron *M. gayi* (53,5%), *S. sagax* (16,1%), *E. ringens* (13,7%), *Hygophum bruuni* (3,0%) y *Prolatilus jugularis* (2,9%). Taxa específicos de huevos y larvas mostraron fluctuaciones en su abundancia a escala estacional y de acuerdo a las fases cálida y fría de El Niño-Oscilación del Sur (ENOS), similar a las observadas en las variables físicas. Aunque se encontraron fuertes diferencias en la abundancia de huevos durante el periodo, sólo los de *M. gayi* mostraron un incremento significativo durante La Niña. En el ciclo ENOS 1997-2000, la altura del nivel del mar y el transporte de Ekman mostraron fuertes diferencias entre las fases del ENOS, pero la diversidad total de la comunidad ictioplanctónica no fue afectada. No se detectaron diferencias significativas en los índices de diversidad, tanto en el índice de Shannon como en el de Simpson. Sin embargo, los análisis multivariados demostraron que las asociaciones de larvas estuvieron separadas significativamente de acuerdo a las fases cálida y fría del ENOS. Por lo tanto, la composición del ictioplancton fue afectada significativamente por el ciclo ENOS en la zona costera de Valparaíso entre 1997 y 2000.

Palabras clave: larvas de peces, estacionalidad, *Engraulis ringens*, *Sardinops sagax*

**Abstract.** Between January 1997 and December 2000 daily data of sea surface temperature, sea level height and Ekman transport were taken, together with biweekly and monthly sampling of ichthyoplankton in a coastal station located in Valparaíso Bay. Samples were collected through vertical tows from 50 m depth to surface with a conical net. From a total of 103 zooplankton samples, 71 samples had positive presence of ichthyoplankton; a total of 10,646 eggs and 1,189 larval fish were separated, corresponding to 6 and 20 taxa, respectively. Eggs specific composition was dominated by *Engraulis ringens* (35.5%), *Merluccius gayi* (32.7%) and *Sardinops sagax* (23.3%). For larvae, dominant species were *M. gayi* (53.5%), *S. sagax* (16.1%), *E. ringens* (13.7%), *Hygophum bruuni* (3.0%) and *Prolatilus jugularis* (2.9%). Specific taxa of both eggs and larvae showed fluctuations of their abundance at seasonal scale and according to the warm and cold phases of El Niño-Southern Oscillation (ENSO), similar to those observed in the physical time series data. Despite the strong differences in egg abundance in the period, only *M. gayi* eggs showed a significant increase during La Niña phase. In the ENSO 1997-2000 cycle, sea level height and Ekman transport showed strong differences between ENSO phases, but the whole diversity of the larval fish community was not affected. No significant differences in the diversity indices were detected, for Shannon index or for Simpson index. However, multivariate analyses showed that larval assemblages were significantly stratified according to the warm and cold phase of ENSO. Therefore, composition of ichthyoplankton was significantly affected by the ENSO cycle in the coastal area of Valparaíso between 1997 and 2000.

Key words: larval fish, seasonality, *Engraulis ringens*, *Sardinops sagax*

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## Introduction

Physical processes at an interannual scale control environmental variability and together with seasonality of meteorology/oceanography and reproductive behaviour of fish determine the fluctuations in abundance and composition of early life stages of marine fish (Sánchez-Velasco *et al.* 2000, 2004, Franco-Gordo *et al.* 2004, Landaeta *et al.* 2008).

One of the most important processes at the interannual scale is the El Niño-Southern Oscillation (ENSO). During these events changes occur in sea-surface temperature, vertical thermal structure of the ocean (particularly in coastal regions), and coastal and upwelling currents. These changes may delay phytoplankton blooms, modify the abundance and distribution of invertebrates, affect species composition and abundance of macrozooplankton and fishes, and reduce fish catch (Funes-Rodríguez *et al.* 2006, Rojas-Méndez & Robinson 2008).

In the Humboldt current ecosystem, the warm phase of ENSO (El Niño) deepens the thermocline, oxycline and nutricline, triggering variations in chlorophyll-*a* concentration (González *et al.* 2000, Ulloa *et al.* 2001), community structure of copepods (Hidalgo & Escribano 2001), and the abundance of several larval fish taxa (Rodríguez-Graña & Castro 2003). Increases in immigrant marine fish species have also been observed during El Niño, with a correlation between thermal anomaly and number of species (Kong *et al.* 1985, Kong & Bolados 1987, Sielfeld *et al.* 2002). Some key species such as the copepod *Calanus chilensis* exhibit greater abundances, higher growth rates and a significant reduction in adult body size, allowing them to cope with strong environmental perturbations such as the 1997-1998 El Niño event, the strongest on record (Ulloa *et al.* 2001).

On the other hand, the cold phase of ENSO (La Niña) is characterized by unusually cold ocean temperatures in the central and Eastern Pacific driven by stronger trade winds. Among other biological effects, La Niña affects the composition and abundance of seabird assemblages (Ribic *et al.* 1992), triggers an increase in the size of the female copepod *C. chilensis* (Escribano & Hidalgo 2000), and negatively affects settlement of the black snail *Tegula atra* in southern Chile (Moreno 2004).

Most research into the biological impact of ENSO events has been restricted to the northern zone of Chile, and there is little knowledge about the bio-physical coupling of early life stages of marine fishes in the coastal area of central Chile (Hernández-Miranda & Ojeda 2006). The main goal of this investigation was to establish the

temporal variability of ichthyoplankton (eggs and larval fish) in a coastal station located at Valparaíso Bay during the warm and cold phases of the ENSO cycle 1997-2000, and to determine the effect of ENSO on the composition and abundance of early life stages of fish.

## Material and methods

### Physical data

Sea surface temperature (SST) data from January 1997 to December 2000 were taken daily at the monitoring coastal station of Valparaíso port from the Servicio Hidrográfico y Oceanográfico de la Armada de Chile (SHOA). Trends were extracted from the time series, and monthly averages were calculated. Daily information on sea level height at Valparaíso port was obtained from the Sea Level Center of Hawaii University<sup>1</sup>; and monthly averages were calculated. Wind data were extracted from a global regular grid of scatterometer ERS 2 satellite images (mean wind fields), distributed by CERSAT (Centre ERS d'Archivage et de Traitement) of IFREMER (French Research Institute for Exploitation of the Sea)<sup>2</sup>. Ekman transport was estimated from a time series with a spatial resolution of 0.5° and a temporal monthly resolution (data centered on 33.5°S and 72.5°W).

### Field work

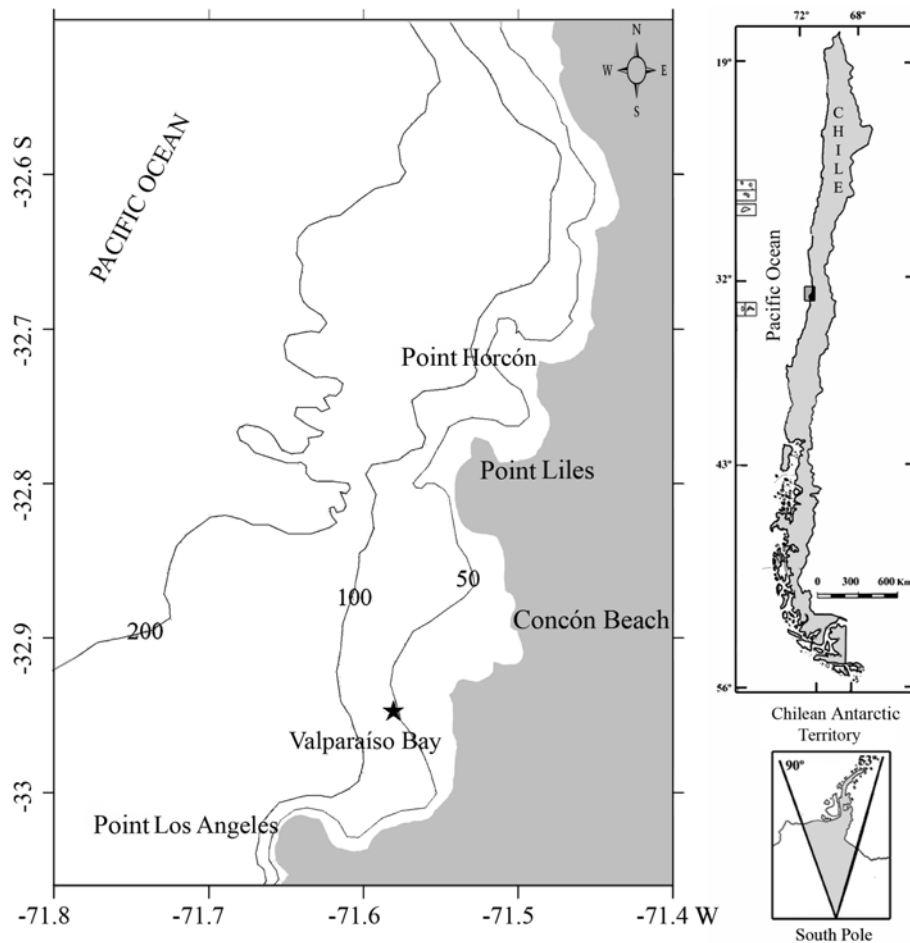
Between January 1997 and December 2000 biweekly and monthly sampling of ichthyoplankton was carried out in a coastal station located at 2 km off Montemar, Valparaíso Bay, central Chile (32°57'S, 71°33'W, Fig. 1) over an a motorboat. Samples were collected using vertical tows from 50 m depth to the surface with a conical net (66-cm diameter, 330 µm mesh size) equipped with a TSK flowmeter to estimate filtered volumes of sea water. On recovery, the net was washed and the contents fixed with sodium borate buffered 5% formalin.

### Laboratory work and data analyses

All eggs and larval fish were separated, counted and identified to the lowest taxonomic level according to Fischer (1958, 1959), Balbontín & Garretón (1977), Balbontín & Pérez (1979, 1980), Pérez (1979, 1981), Orellana & Balbontín (1983), Olivar & Fortuño (1991), Zuñiga & Acuña (1992), and Landaeta *et al.* (2006). Larval fish were categorised according to adult habitat (epipelagic, mesopelagic, demersal and subtidal/intertidal) and the egg and larval densities were standardised to individuals per 10 m<sup>2</sup> following Smith & Richardson (1977).

<sup>1</sup><http://uhslc.soest.hawaii.edu/>

<sup>2</sup><http://www.ifremer.fr/cersat/en/data/data.htm>



**Figure 1**

**Study area, Valparaíso Bay, central Chile. A star indicates the sampling location, and bathymetry is presented in meters**

Área de estudio, bahía de Valparaíso, Chile central. La estación de muestreo se indica con una estrella y la batimetría es presentada en metros

The Shannon-Wiener diversity index ( $H'$ ) and Simpson diversity index ( $1 - \lambda$ ) were used as measures of heterogeneity in the larval community. These indices express the number of species and uniformity in abundance of individuals of different species. A large number of species increases diversity (richness), but the same is true when abundance among them is uniform (evenness). These measures were applied to the standardised abundance during each sampling month. Pielou analysis of dominance ( $J'$ ) was obtained by calculating maximum diversity of the Shannon-Wiener ( $H'_{max}$ ). This index makes it possible to determine if, within a group of species, there exist a greater number of individuals in a reduced number of species. These indices and the abundance of selected taxa of eggs and larvae

were then compared between the warm and cold phase of the ENSO during 1997-2000 by using the Mann-Whitney U test, because assumptions of normality were not achieved (Shapiro-Wilks W tests for all variables:  $P < 0.05$ ).

Larval fish assemblages were classified with a hierarchical cluster analysis using a Bray-Curtis dissimilarity matrix, which was calculated among species using standardised larval abundances of species with dominance  $> 0.5\%$ . Dominance corresponds to the sum of standardized values of fish larvae (individuals per 10 m<sup>2</sup>) of all samples taken during the studied period. The cut percentage of the cluster was determined calculating the average value of the dissimilarity matrix. To study the variability of larval fish assemblages during the ENSO

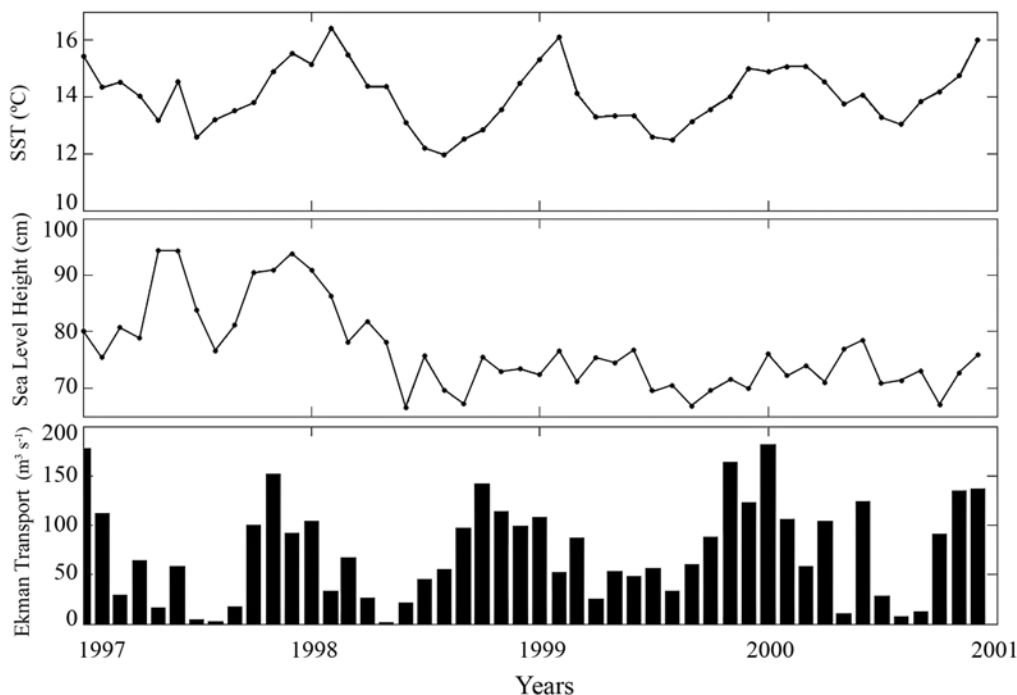
cycle, standardised larval density was  $\log(x+1)$  transformed to enhance the contribution of less abundant taxa and a Bray-Curtis similarity matrix was generated from these data. Similarities between assemblages were graphically represented by non-metric multidimensional scaling (MDS, Cox & Cox 2000) ordination. The degree of correspondence between the distances among points implied by MDS map and the matrix input was measured by a stress function. A one-way analysis of similarities (ANOSIM), which is analogous to univariate analysis of variance, was used to determine if assemblage groupings in the MDS ordination were significantly different from each other (Clarke 1993). Pairwise ANOSIM comparisons were made between groups, by using 10,000 permutations.

## Results

Monthly time series of physical data showed seasonal and ENSO patterns (Fig. 2). For the SST and Ekman

transport a seasonal pattern was noticeable. SST during austral winter 1997 was higher ( $14.3^{\circ}\text{C}$ ) than winter 1998 ( $12^{\circ}\text{C}$ ). Also, SST during summer 1998 and 1999 were higher than summer of 2000 (Fig. 2). High values of Ekman transport were evident during early spring and low values during early autumn. At inter-annual time scales, differences between winter and summer SST during El Niño (from January 1997 to May 1998) were lower than during La Niña (from September 1998 to December 2000), sea level height was also higher during the warm phase of ENSO (up to 95 cm) than the cold phase ( $< 80$  cm). Ekman transport was lower and highly seasonal during El Niño off the Valparaíso area compared with the La Niña period. The increase of Ekman transport during autumn-winter 1999 ( $\sim 50 \text{ m}^3 \text{ s}^{-1}$ ) was associated with an input of cold, dense water ( $\sim 13^{\circ}\text{C}$ ) that reduced the sea level height during the period.

From a total of 103 zooplankton samples, 71 samples included ichthyoplankton during the study period (1997



**Figure 2**

**Time series of monthly-averaged daily data of sea surface temperature (SST,  $^{\circ}\text{C}$ ), sea level height (cm), and Ekman transport ( $\text{m}^3 \text{ s}^{-1}$ ) off Valparaíso Bay, central Chile, between January 1997 and December 2000**

Series de tiempo de datos diarios promediados mensualmente de temperatura superficial del mar (SST,  $^{\circ}\text{C}$ ), altura del nivel del mar (cm), y transporte de Ekman ( $\text{m}^3 \text{ s}^{-1}$ ) frente a la bahía de Valparaíso, Chile central, entre enero de 1997 y diciembre de 2000

**Table 1**

**Composition and abundance of fish eggs in a coastal station during the warm and cold phase of ENSO 1997-2000. Egg density expressed as individuals per 10 m<sup>2</sup>.**

**SD = one standard deviation**

Composición y abundancia de huevos de peces en una estación costera durante la fase cálida y fría del ENOS 1997-2000. Densidad de huevos expresada como individuos por 10 m<sup>2</sup>.

SD = una desviación estándar

	El Niño 1997-1998			La Niña 1999-2000		
	Mean	SD	Median	Mean	SD	Median
<i>Engraulis ringens</i>	707.03	1065.00	296.57	2396.67	5964.41	170.80
<i>Sardinops sagax</i>	510.52	728.90	106.06	4248.43	11050.11	434.96
<i>Merluccius gayi</i>	411.81	451.27	247.47	2049.60	2908.25	843.57
<i>Paralichthys</i> spp.	411.41	512.73	250.09	322.73	407.58	151.52
<i>Hippoglossina macrops</i>	56.54	51.37	36.57	50.05	37.67	44.45
<i>Scomberesox saurus</i>	39.14	-	39.14	18.76	-	18.76

**Table 2**

**Composition and abundance of larval fish in a coastal station during the warm and cold phase of ENSO 1997-2000. Larval density expressed as individuals per 10 m<sup>2</sup>.**

**SD = one standard deviation**

Composición y abundancia de larvas de peces en una estación costera durante la fase cálida y fría del ENOS 1997-2000. Densidad larval expresada como individuos por 10 m<sup>2</sup>.

SD = una desviación estándar

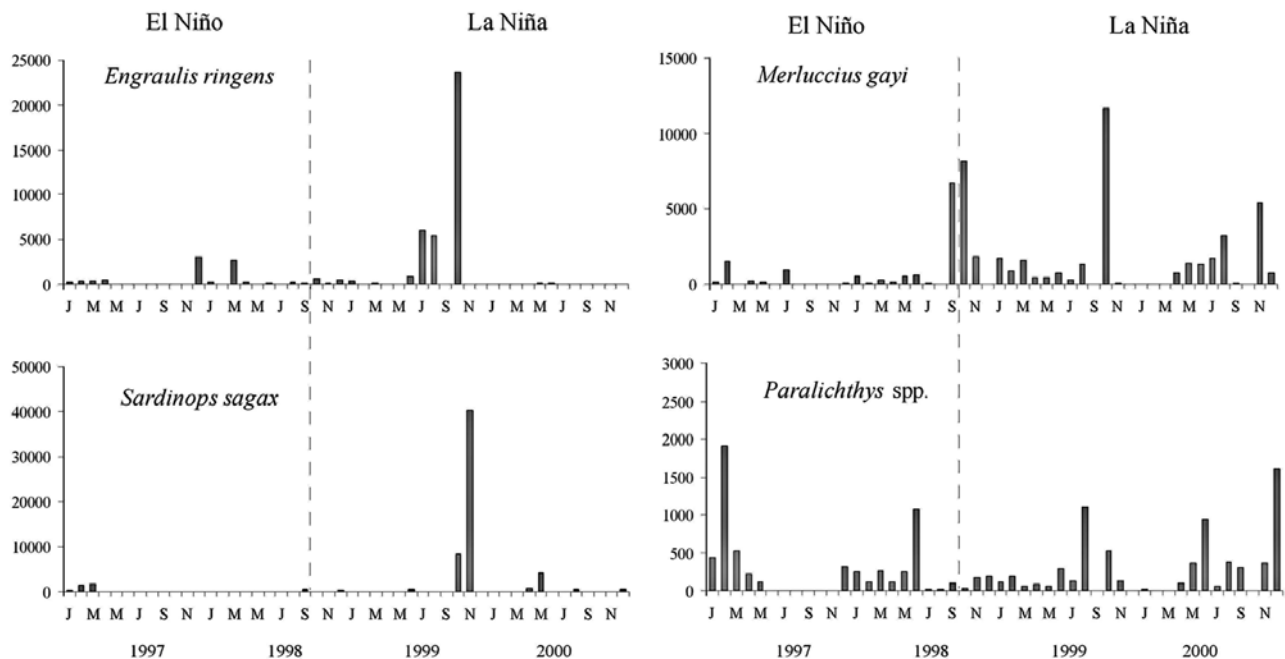
	El Niño 1997-1998			La Niña 1999-2000		
	Mean	SD	Median	Mean	SD	Median
<b>Epipelagic</b>						
<i>Engraulis ringens</i>	131.08	135.70	65.05	539.83	537.64	581.41
<i>Sardinops sagax</i>	253.96	252.02	177.94	69.27	35.49	80.07
<i>Ethmidium maculatum</i>	36.22	14.09	36.22	-	-	-
<i>Normanichthys crockeri</i>	-	-	-	47.45	-	47.45
<b>Oceanic</b>						
<i>Diogenichthys atlanticus</i>	38.49	18.52	42.24	24.90	8.88	19.77
<i>Diogenichthys laternatus</i>	-	-	-	24.97	-	24.97
<i>Hygophum bruuni</i>	30.72	18.18	26.15	48.91	37.39	32.72
<i>Nannobranchium</i> sp.	51.32	-	51.32	27.90	21.56	27.90
<i>Protomyctophum chilensis</i>	26.89	-	26.89	18.76	-	18.76
<i>Triphoturus oculus</i>	28.72	-	28.72	-	-	-
<i>Seriotelella</i> sp.	147.83	154.90	147.83	90.80	5.80	90.80
<b>Demersal</b>						
<i>Merluccius gayi</i>	425.16	660.97	157.57	291.47	414.06	82.52
<i>Sebastes capensis</i>	100.54	116.32	100.54	23.73	-	23.73
<i>Genypterus</i> sp.	86.17	-	86.17	22.93	5.91	22.93
<i>Hippoglossina macrops</i>	47.01	14.76	47.01	23.75	3.04	24.33
<b>Subtidal-Intertidal</b>						
<i>Helcogrammoides chilensis</i>	18.17	-	18.17	26.13	4.99	26.13
<i>Hypsoblennius sordidus</i>	26.89	-	26.89	30.06	11.42	24.97
<i>Prolatilus jugularis</i>	191.49	-	191.49	71.18	-	71.18
<i>Paralichthys</i> sp.	64.73	39.29	57.66	-	-	-
<i>Scartichthys</i> sp.	64.24	47.52	64.24	21.64	6.86	21.09
Unidentified taxa	29.20	9.60	33.00	65.68	43.42	57.28

to 2000); a total of 10,646 eggs and 1,189 larval fish were collected, corresponding to 6 and 20 taxa respectively (Tables 1 and 2). For the entire period, eggs were dominated by 'anchoveta' *Engraulis ringens* (35.5%), hake *Merluccius gayi* (32.72%) and sardine *Sardinops sagax* (23.29%). For larvae, dominant species were *M. gayi* (53.48%), *S. sagax* (16.09%), *E. ringens* (13.70%), myctophid *Hygophum bruuni* (3.04%) and sandperch *Prolatilus jugularis* (2.96%). Specific taxa of both eggs and larvae showed fluctuations of their standardised abundance at both seasonal and ENSO scale. During El Niño 1997-1998, eggs were more abundant during the austral summer and autumn (Fig. 3). At the beginning of the cold phase of ENSO, there was an abrupt increase in the abundance of *M. gayi* eggs. A peak of *E. ringens* eggs occurred during winter 1999, and spring 1999, with the highest densities of *E. ringens*, *S. sagax* and *M. gayi* eggs collected (Fig. 3). In contrast, the density of *Paralichthys* spp. eggs varied seasonally, with higher peaks during mid summer, early autumn, and early spring. Despite the strong difference in egg abundance during the period, only *M. gayi* eggs showed a significant

increase during the La Niña phase (Mann-Whiney U test,  $U = 160$ ,  $P = 0.025$ ).

For the most dominant larval fish, two temporal patterns were evident (Fig. 4). The species group, including *S. sagax* and *Paralichthys* spp., showed a density peak during later summer 1997, and then a reduced abundance during the rest of the study period. Other taxa, like *E. ringens*, *H. bruuni* and *Hypsoblennius sordidus*, showed reduced abundance or were almost absent during El Niño, but during La Niña increased two to three times in late austral winter and early spring 1999 (Fig. 4). Larvae of *M. gayi* showed a decreasing trend in density throughout the studied period. However, none of the taxa showed significant differences in their densities (Mann-Whiney U test,  $P > 0.1$ ).

Overall density of larval fish community was not affected by the ENSO 1997-2000 cycle. No significant differences in dominance or diversity indices were detected (Shannon index,  $U = 130.5$ ,  $P = 0.677$ ; Simpson index,  $U = 137$ ,  $P = 0.848$ ; and Pielou index,  $U = 137$ ,  $P = 0.356$ ) (Table 3).



**Figure 3**

**Temporal series of fish eggs abundance (individuals per 10 m<sup>2</sup>) captured at a coastal station between January 1997 and December 2000 off Valparaíso**

Serie temporal de abundancia de huevos de peces (individuos por 10 m<sup>2</sup>) capturados en una estación costera entre enero de 1997 y diciembre de 2000 frente a Valparaíso

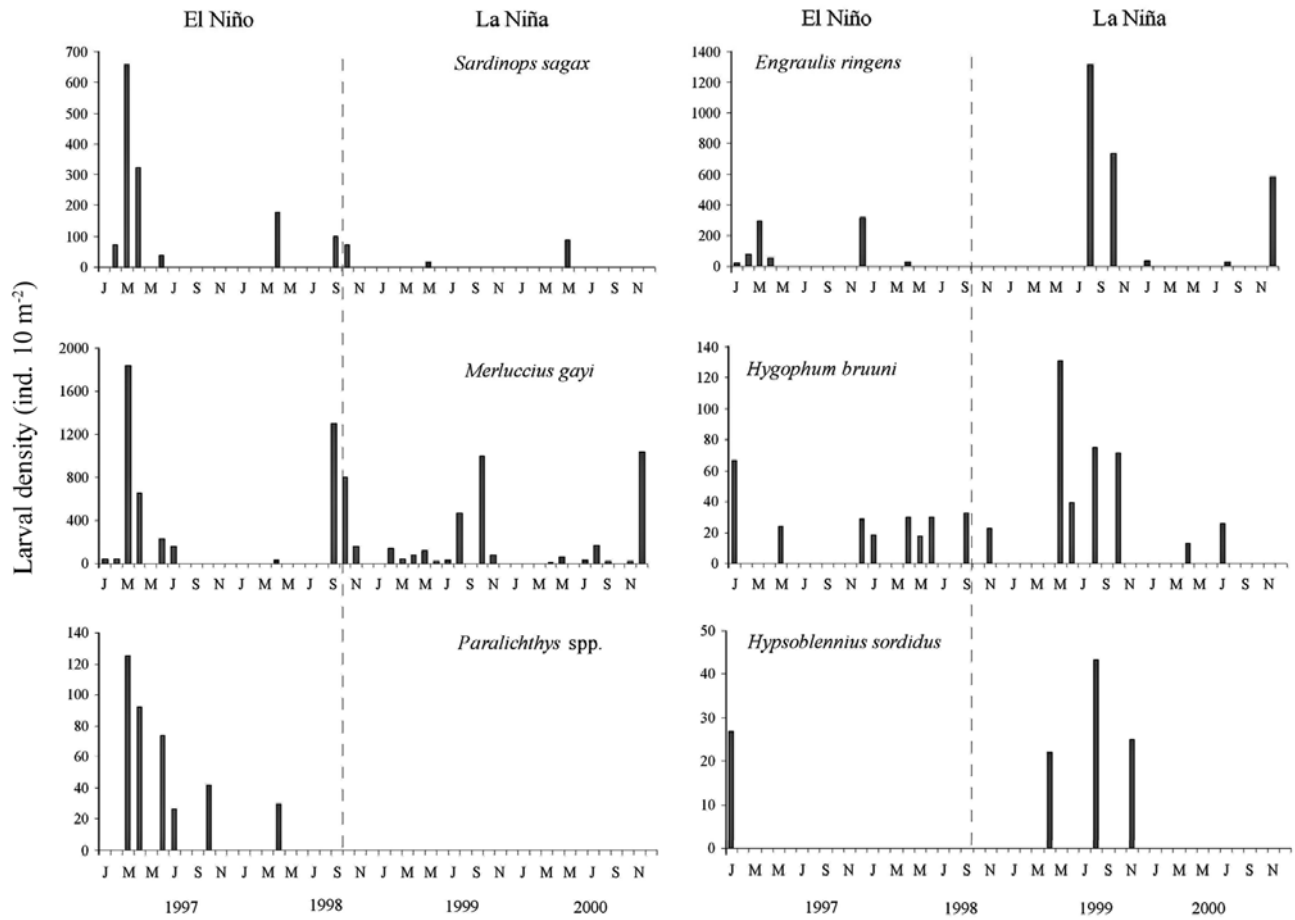


Figure 4

Temporal series of specific taxa of larval fish abundance (individuals per 10 m<sup>2</sup>) captured at a coastal station between 1997 and 2000 off Valparaíso

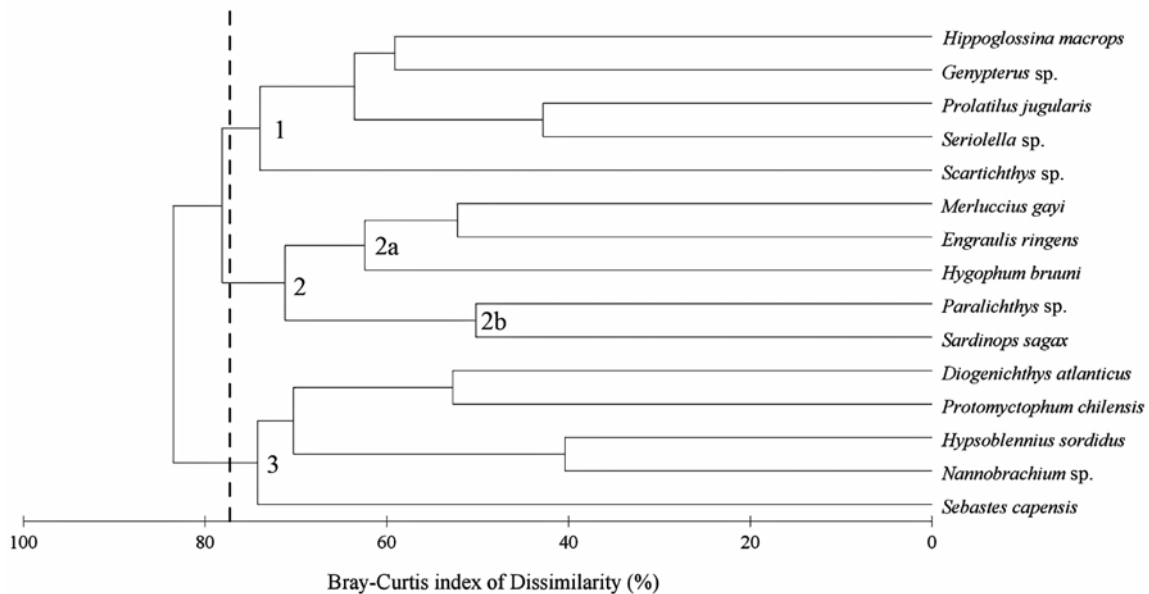
Serie temporal de taxa específicos de abundancia de larvas de peces (individuos por 10 m<sup>2</sup>) capturadas en una estación costera entre enero de 1997 y diciembre de 2000 frente a Valparaíso

Table 3

Synopsis of the indices of larval community during both phases of ENSO 1997-2000 off Valparaíso. SD = one standard deviation

Sinopsis de los índices de comunidad larval durante ambas fases del ENSO 1997-2000 frente a Valparaíso. SD = una desviación estándar

	El Niño 1997-1998		La Niña 1999-2000	
	Mean	SD	Mean	SD
Shannon-Wiener diversity index	1.034	0.541	0.874	0.282
Simpson diversity index	0.527	0.212	0.523	0.129
Pielou dominance index	0.735	0.216	0.810	0.177



**Figure 5**

**Cluster analysis of dominant larval fish species during the 1997-2000 ENSO cycle. Numbers correspond to the identified ichthyoplanktonic assemblages**

Análisis de dendrogramas de larvas de peces más abundantes durante el ciclo ENOS 1997-2000. Los números indican las asociaciones ictioplanctónicas identificadas

Over the entire time series, three larval assemblages were defined at a 77% dissimilarity level (Fig. 5): bigeye flounder *Hippoglossina macrops*, *Genypterus* sp., *Prolatilus jugularis*, warehou *Seriolella* sp. and *Scartichthys* sp. composed a demersal-intertidal assemblage. Abundance of these species increased during the ENSO warm phase. The second larval assemblage included the dominant taxa: a first subgroup which was more abundant during La Niña (*Merluccius gayi*, *Engraulis ringens* and *Hygophum bruuni*) and a second subgroup that appeared mostly during El Niño phase (*Paralichthys* sp. and *Sardinops sagax*). The third larval assemblage comprised mesopelagic and subtidal species, including *Diogenichthys atlanticus*, *Protomyctophum chilensis*, *Nannobranchium* sp., blennioid *Hypsoblennius sordidus* and rockfish *Sebastes capensis*. Larvae of *Ethmidium maculatum*, *Diogenichthys laternatus*, *Triphoturus oculus*, *Normanichthys crockeri* and *Helcogrammoides chilensis* were not included in the cluster analysis due to their low relative abundance. The

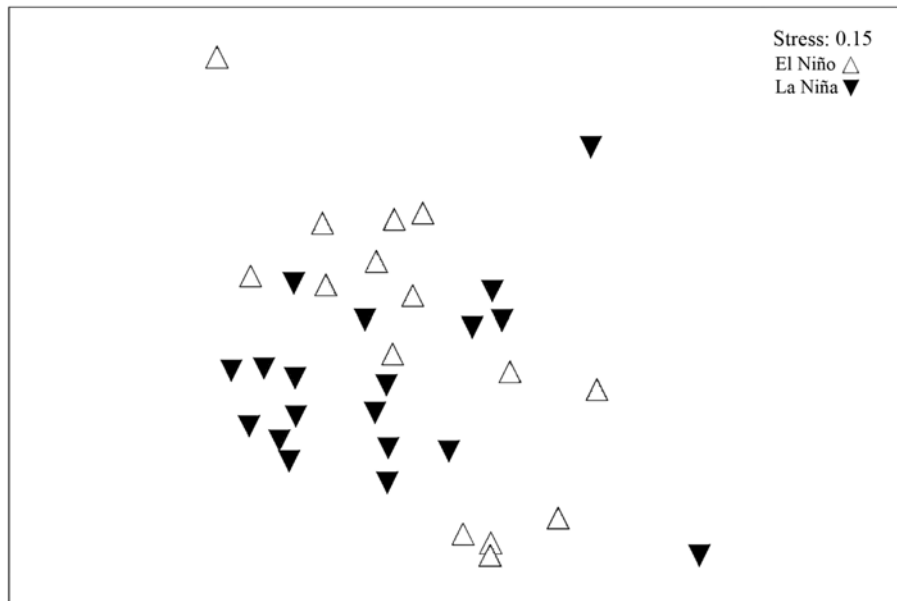
structure of larval fish throughout the sampled period showed some grade of overlapping according to the warm and cold phase of ENSO in the MDS plot (Fig. 6); however, ANOSIM revealed this difference was significant (global  $R = 0.197$ ,  $P < 0.01$ ).

## Discussion

Analysis of the ichthyoplankton eggs and larvae time series showed two temporal patterns, one associated with seasonal abundances, and another related to the variability of larval fish assemblages during the warm and cold phase of the ENSO cycle.

Changes in the composition and abundance of fish eggs and larval fish have been observed in the Humboldt Current ecosystem during transitional periods (late summer and winter). For instance, Hernández-Miranda *et al.* (2003) showed increases in the fish egg abundance during September 1999 (late winter-early spring) and March 2000 (late summer-early autumn) in coastal areas off Las Cruces, central Chile. Also, they found seasonal





**Figure 6**

**Non-metric multi-dimensional scaling ordination plot of log-transformed abundance data. Stress value is given in the top right corner of the plot. ( $\Delta$ ) – El Niño samples and ( $\blacktriangledown$ ) – La Niña samples**

Gráfico de ordenación de datos de abundancia log-transformados utilizando escalamiento no métrico multidimensional. El valor de estrés está dado en la esquina derecha del gráfico. ( $\Delta$ ) – muestras de El Niño y ( $\blacktriangledown$ ) – muestras de La Niña

variability in the abundance of epipelagic and mesopelagic larval fish in the same area. Similar changes in larval fish assemblages have been observed at seasonal scales in nearshore zones off Perú (14°S) (Vélez *et al.* 2005), Valparaíso (33°S) (Balbontín & Bravo 1999), Talcahuano (37°S) (Landaeta *et al.* 2008) and southern Chile (41-46°S) (Landaeta & Castro 2006b, Bustos *et al.* 2008).

The seasonality of the abundance of both eggs and larval fish during transitional seasons are mainly linked to reproductive behavior of adult population and the phase of their life cycle, which in turn is often associated with oceanographic and meteorological features. During transitional periods, the south eastern Pacific subtropical anticyclone moves, producing high wind variability associated with frontal disturbances and coastal lows (Rutllant *et al.* 2004). The high variability in wind speed and direction may reduce the offshore advection of the surface Ekman layer, increasing the residence time of surface planktonic organisms near headlands in coastal

areas (Palma *et al.* 2006), where feeding success and growth of early life stages of fishes are high (Hernández-Miranda *et al.* 2003, Landaeta & Castro 2006a). However, these seasonal trends can be affected by physical processes occurring at larger temporal scales, such as interannual signals like El Niño and La Niña events.

The ENSO cycle 1997-2000 was characterized by an increase of 4-5°C SST during El Niño and a decrease of 2 to 3°C during La Niña, together with variations in the chlorophyll-*a* concentration in coastal areas of central Chile (Bello & Maturana 2004, Hernández-Miranda & Ojeda 2006). Off Valparaíso, a decrease of wind intensity triggered a reduction in the offshore Ekman transport during El Niño, which in turn reduced the upwelling of colder waters to the coastal area, increased sea level height, and elevated SST. The presence of warmer waters in coastal areas off Valparaíso may have been caused not only by entrance of warm waters from the north, but also by local warming of coastal water parcels due to the decreased upwelling activity. In contrast, during La Niña

there was an increase of surface offshore Ekman transport throughout 1999 and 2000, which increased the upwelling of colder and denser waters, reduced sea level height, and lowered SST during the austral summer of 2000.

This strong event not only affected abundance, composition and reproductive output of epipelagic, oceanic, and demersal fish (Table 2, Funes-Rodríguez *et al.* 2006), but also affected somatic growth and mortality rates of intertidal fishes (Hernández-Miranda & Ojeda 2006). Other components of the plankton were also affected. For instance, Hidalgo & Escribano (2001) observed an increase in the number of the dominant herbivorous copepods, *Calanus chilensis*, during El Niño in northern Chile. They did not find significant differences in the diversity of pelagic copepods between El Niño and non-El Niño periods, probably because the contribution of expatriate species compensated for the decrease in abundance of some resident species. A similar explanation may be given for the lack of differences in the larval community diversity and dominance indices calculated between El Niño and La Niña phases in the Valparaíso zone. For instance, larval flounder *Paralichthys* spp. were found only during El Niño months, but mote sculpin *Normanichthys crockeri* larvae were only collected during La Niña period.

In this time series, among larval fish with epipelagic adults, larvae of sardine *S. sagax* showed higher densities during the beginning of 1997 in the warm phase of ENSO. In contrast, larval anchoveta *E. ringens* were collected in higher abundance during La Niña. However, observation in the north Pacific showed the opposite trend (Sánchez-Velasco *et al.* 2000; Franco-Gordo *et al.* 2004) during the same ENSO event. While larval sardine *S. caeruleus* were almost absent during the warm phase, when SST increased by 4°C, *Engraulis mordax* larvae were recorded in high abundance (>100 larvae per 10 m<sup>2</sup>). After the event, larval *S. caeruleus* increased in abundance. More information is needed to understand and interpret such differences in occurrence patterns of those two epipelagic larvae.

Mesopelagic larvae such as *Vinciguerria lucetia* and *Benthoosema panamense* and carangid larvae (*Caranx* sp. and *Auxis* sp.), also showed a significant increase in their abundance during ENSO 1997-98 along the central Pacific coast of Mexico and Australia. According to Franco-Gordo *et al.* (2004) and Sampey *et al.* (2004), a tropicalization of the species composition during the El Niño event occurred in tropical and subtropical areas. In the coastal area off Valparaíso Bay, excepting for *H. bruuni*, most mesopelagic larvae were more abundant during the El Niño than La Niña, and some species were

replaced between phases (*e.g.* *Triphoturus oculus* was collected only during El Niño, but *Diogenichthys laternatus* was collected only during La Niña). The alteration in the composition of larval mesopelagic taxa has also been detected off Baja California during ENSO events. Recently, Funes-Rodríguez *et al.* (2006) suggested that tropical species such as *Diplophos proximus*, *Diaphus pacificus* and *Benthoosema panamense* larvae were indicative of the El Niño 1982-1984 event in the California Current; this assemblage was replaced by mesopelagic larval fishes of temperate affinity (*i.e.* *Symbolophorus*, *Melamphaes*, *Bathylagus*, *Protomyctophum crockeri*) during the normal period, from mid 1984 to mid 1987.

Throughout our study, larval hake was the dominant taxon. The Valparaíso area has been identified as one of the most important spawning areas of *Merluccius gayi* in Chile (Bernal *et al.* 1997, Balbontín & Bravo 1999, Vargas & Castro 2001). Although spawning of the Chilean hake may occur offshore in the vicinity of the shelf-break (Vargas & Castro 2001), during certain periods adult hake reproduce near the coast (< 8 km from shore, Bernal *et al.* 1997, Landaeta & Castro 2006a). Our data also showed that highest larval densities of *M. gayi* were collected at the onset and the end of the El Niño phase, but during La Niña, larval hake appeared more frequently in the samples; the highest value of larval abundance obtained during this cold period occurred when Ekman transport was low. Bernal *et al.* (1997) showed that larval hake were most abundant associated to cold waters and moderate upwelling indices off Valparaíso area; a similar trend has also been detected for larval *Merluccius productus* off Baja California between 1951 and 2001 (Funes-Rodríguez *et al.* 2009). The presence of colder surface waters in coastal areas, either as a result of upwelling events and/or by La Niña may affect the abundance of this key species through a still unknown bio-physical coupling.

In sum, the information presented here shows that the physical processes associated with large-scale event like El Niño and La Niña may exert an influence on the composition and abundance of larval fish in coastal areas of central Chile, affecting the seasonal trends of reproduction and spawning of marine fishes.

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