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ARTICLE

Seasonal dynamics of zooplankton in a northern Chile bay exposed to upwelling conditions

Dinámicas estacionales del zooplancton en una bahía de la zona norte de Chile expuesta a condiciones de surgencias

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Resumen.- Debido al creciente uso del borde costero con fines industriales, particularmente aquellas actividades que utilizan cantidades importantes de agua de mar, es fundamental entender la composición de la fauna planctónica junto con reconocer su variabilidad espacial y temporal en función de variables hidrográficas relevantes. Totoralillo Norte (~30°S) es un bahía localizada dentro de un área comúnmente afectada por eventos de surgencia, así como una zona que se proyecta relevante para el desarrollo industrial. Aquí se realizaron muestreos estacionales (varios días en cada estación) durante 2013 y 2014 donde se pudo reconocer una comunidad zooplanctónica abundante con una buena representación de los principales taxa, conformada por al menos 166 especies. Los copépodos dominaron en términos numéricos el holoplancton (91,7%), mientras que el meroplancton estuvo compuesto principalmente por estadios larvales de cirripedios, moluscos, decápodos, briozoos y peces. A pesar de ser una zona de la costa normalmente afectada por eventos de surgencia, la abundancia del zooplancton fue elevada durante todo el año, incluso durante períodos dominados por vientos débiles y condiciones de hundimiento. Estudios como este ayudan a develar patrones ecológicos relevantes así como procesos que los afectan; información vital y que debe ser considerada al momento de evaluar impactos ambientales.

Palabras clave: Bahía, surgencia, holoplancton, meroplancton, diversidad del zooplancton

Abstract.- Due to the ever-increasing use of the coastline for industrial purposes, particularly by those activities that take up great amounts of sea water, it is fundamental to understand the composition of the planktonic fauna and its natural spatial and temporal variability in relation to hydrographic variables, in order to understand the potential impact of such undertakings. Totoralillo Norte (~30°S) is an embayment located within a well-known area of recurring upwelling events, as well as a zone with projection for industrial development. Here we performed seasonal surveys (several days sampling within each season) during 2013 and 2014 recognizing an abundant zooplanktonic community with a good representation of the main taxa comprised by at least 166 species. In terms of numbers, copepods dominated the holoplankton (91.7%), whereas meroplankton was mainly composed of larval stages of barnacles, mollusks, decapods, bryozoans and fish. In spite this being a coastal zone normally affected by upwelling events, zooplankton abundance was high throughout the year, even during periods dominated by weak winds and downwelling conditions. Studies such as this can help unveil relevant ecological patterns and their related processes; vital information that must be considered during an environmental impact assessments.

Key words: Bay, upwelling, holoplankton, meroplankton, zooplankton diversity

INTRODUCTION

The increasing pressure on coastlines for all sorts of human development imposes the need for a detailed understanding of the ecological patterns of the organisms that inhabit these environments, as well as the processes involved. Many of these organisms either undergo a dispersive larval phase (meroplankton) or live throughout their ontogeny in the water column (holoplankton) near the coast. This diversity in life history strategies poses an additional challenge to the understanding of the characteristics and determinants that affect their distribution and abundance.

The zooplankton community includes larval stages of organisms that become benthic after recruiting, whose population dynamics and community structure is directly determined by a variety of transport mechanisms (Morgan & Fisher 2010). In coastal areas transport mechanisms can intimately be related to: the dynamics of the Ekman layer during upwelling events (*e.g.,* Poulin *et al.* 2002 a, b), the effect of wind over surface layers (*e.g.,* Tapia *et al.* 2004), the presence of upwelling shadows (*e.g.*, Marín *et al.* 2003, Roughan *et al.* 2005), occurrence of internal waves (Pineda 1994, 2000) or vertical migration of organisms (*e.g.*, Marta-Almeida *et al.* 2006, Palma *et al.* 2011). Within this wide array of processes, upwelling events are among the principal determinants of advection or larval positioning, being both frequent and intense, and affecting the coastal dynamics in the north, north-central and south-central areas of Chile (Montecino & Quiroz 2000, Moraga *et al.* 2001, Poulin *et al.* 2002a, Rutllant *et al.* 2004, Montecino *et al.* 2005, Marín *et al.* 2007).

In north-central coastal Chile, the Coquimbo area (~30°S) represents a well-known area of coastal upwelling (Montecino & Quiroz 2000, Moraga *et al*. 2001, Montecino *et al*. 2005), where filaments of sub-superficial waters frequently form due to wind as well as 'jet' type flows that contribute to an increased availability of nutrients in the coastal area (Marín *et al.* 2003a, 2007). In contrast, during periods of calm [from wind intensity] an increase in residence time of dominant currents occurs (Marín *et al.* 2007). These dynamics represent the main physical factors that affect the circulation patterns on the Chilean coastal zones, and that are thus of potential impact to the planktonic communities therein.

Several studies in northern Chilean coastal areas discuss overall aspects of regional oceanography (*e.g*., Escribano *et al.* 2004, Thiel *et al.* 2007), others emphasize the relationship between zooplankton and conditions associated to upwelling episodes (*i.e*., Escribano & Hidalgo 2000, Escribano *et al.* 2001, Giraldo *et al.* 2002). Regardless of these generalized studies, basic and detailed information regarding local circulation patterns, as well as descriptions of planktonic communities in coastal areas (*i.e.*, bays and headlands), are scarce (*i.e.*, Palma *et al.* 2006). Semi-protected embayment systems can display characteristic circulation patterns that have as defining factors the degree of exposure to general oceanographic conditions (Acuña *et al.* 1989, Palma *et al.* 2006, 2009). Fairly recent studies describe the effect that smaller bays and geographic barriers have over local circulation and/or planktonic distribution patterns along the coastline (Mace & Morgan 2006a, b; Palma *et al.* 2006, Vander Woude *et al.* 2006, Henríquez *et al.* 2007, Palma *et al.* 2009, Morgan & Fisher 2010).

Given the above background information and the importance that embayments represent for new investment projects along the coast in general, our primary objective is to provide a seasonal description of the zooplanktonic community present in a semi-protected bay in the north of Chile along with the variability of hydrographic patterns at the same scales. To ensure this, the focus was placed on identifying spatial distribution and abundance patterns of planktonic organisms, as well as their relationships to relevant environmental variables (i.e. water column thermal structure, wind patterns). The underlying hypothesis being that an important part of the observed variance in the zooplanktonic community is related to major hydrographic forcing such as upwelling events. To date there are no comprehensive studies that describe the high diversity of the zooplankton present in smaller embayment systems and the related processes that could affect their spatial and temporal patterns of distribution and abundance. Furthermore, such information may deem relevant when decision regarding the implementation of man-made developmental projects (i.e. desalination plants, thermal power plants) could be guided/improved in order to minimize their environmental impact.

MATERIALS AND METHODS

STUDY AREA AND SAMPLING PROCEDURES

Totoralillo Norte (29°45'S, 71°35'W; 29°49'S-71°35'W) is a semi-exposed embayment located in north-central Chile that was sampled every season in 2013: austral summer (15-20 January), fall (8-14 June), winter (14-19 August) and spring (November 30-December 8) as well as winter 2014 (10-13 July). We sampled several days within each season in order to capture as much of the inherent variability of the zooplankton distribution and abundance patterns. The bay was divided in several distinct zones with several sampling points within each one: 6 sampling transects at the northern bay, 5 sampling transects at the southern bay, 2 sampling transects outside the southern end of the bay, as well as 4 transects approximately 2 nautical miles offshore (Fig. 1). Only during fall and winter 2013 all the points were visited while fewer were considered during the reminding seasons (although the within-bay points were always sampled). In addition to the zooplankton samples, temperature, salinity and dissolved oxygen profiles were recorded by means of a Hydrolab DS-5 CTD, allowing for an accurate water column characterization of each point down to the maximum possible depth at each coastal point and reaching down to 50 m at the outer coastal points.

WIND DATA AND DERIVED VARIABLES

Wind data were obtained from a coastal meteorological station installed in Totoralillo Norte (29°29'30"S-71°19´16"W). Data were recorded every 5 minutes from January 2013 through November 2014. Original data were averaged on an hourly basis to calculate the wind-derived variables. A cumulative

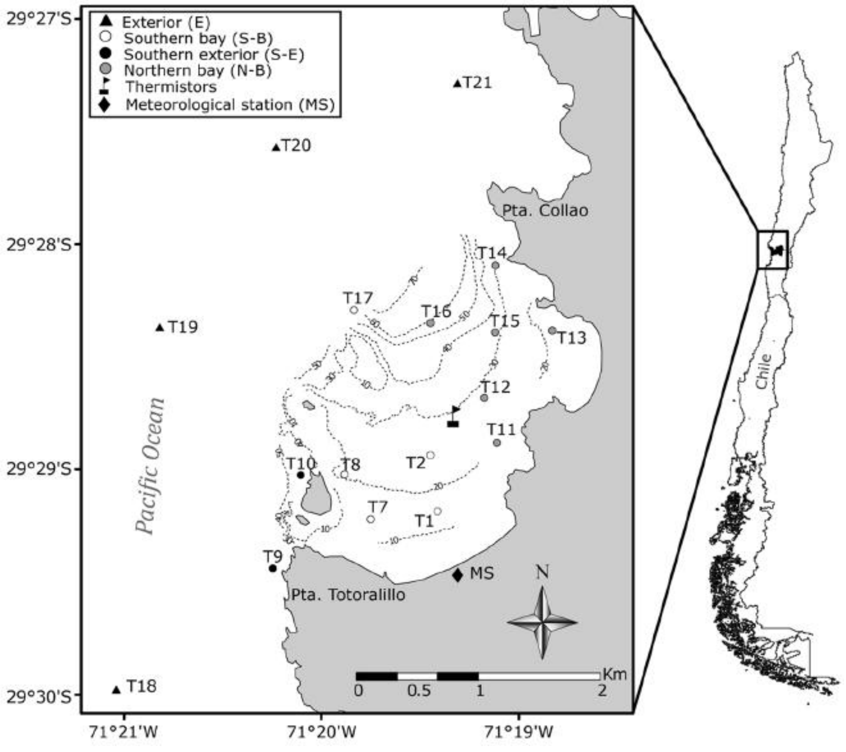

Figure 1. Area and location of the sampling stations indicating the bathymetry (m). Depths from 0 to 60 m / Área y localización de las estaciones de muestreo indicando la batimetría (m). Profundidades de 0 a 60 m

upwelling index was also considered here since it represents the summation of the daily mean upwelling indices that further highlights its potential relevance having local impact (Bograd *et al*. 2009).

The components of the zonal (τ_u) and meridional (τ_v) wind stress were computed as follows:

$$\tau_u = \rho_a C_d u U_{10}\,, \quad \tau_v = \rho_a C_d v U_{10}, \quad (1)$$

where ρ_a is air density (1.2 kg m^{-3}), C_d is a dimensionless drag coefficient, *u* and *v* are the zonal and meridional wind components, respectively, and U_{10} is the magnitude of the wind vector 10 m above sea level.

The drag coefficient was calculated using the formula proposed by Yelland & Taylor (1996), in which the coefficient varies as a function of the wind velocity. The average wind speed was 2.92 m s^{-1}, with an absolute maximum of 11.1 m s^{-1}.

$$C_d = 0.29 + \frac{3.1}{U_{10}} + \frac{7.7}{U^2_{10}} \times 10^{-3}, \text{ for } U_{10} \leq 6\, m\, s^{-1}, \quad (2)$$

Finally, the upwelling index, M_x (m^3 s^{-1}× 100 m), was calculated for the complete time series using the equation (Bakun 1975):

$$M_x = \frac{\tau_v}{\rho_w f}, \quad (3)$$

where τ_v is the meridional wind stress vector, ρ_w is the water density (1025 kg m^{-3}), and *f* is the Coriolis parameter.

TEMPERATURE TIME SERIES

A mooring with a thermistor chain of 5 Hobo Tid bits (Onset Computers) positioned at 4, 11, 16, 19 and 25 m was installed in a central part of the bay at a depth of ~30 m (Fig. 1). Temperature was recorded every 15 min from October 2012 to October 2014, with a resolution of 0.02°C and accuracy of ± 0.21°C.

ZOOPLANKTON ABUNDANCE AND DISTRIBUTION

In each sampling point, zooplankton was collected by means of 3 distinct nets, all of them having the same mesh size (210 µm).The surface layer (0-5 m) was sampled by use of an epineustonic net, towed along a transect of approximately 150 m in length. The subsurface layer (5-10 m) was sampled by use of a bongo net, towed along the same transects. At the end of each transect, a WP-2 net was vertically trawled to capture zooplankton from the bottom layers (>10 m). Each net was equipped with a Hydrobios flowmeter to estimate the volume of water filtered during each tow.

All samples were maintained at constant temperature until preserved in a solution of formaldehyde (10%) 24 h after collection and then transferred to a solution of alcohol for a better handling while identifying and quantifying organisms. Once in the laboratory, plankton samples were identified and quantified following the methodology proposed by Boltovskoy (1981), Olivar & Fortuño (1991) and Palma & Kaiser (1993). All zooplankton specimens were counted and identified using Olympus series SZ stereomicroscopes. Each individual was identified and counted with exception of copepods and sometimes decapod crustacean zoea larvae where a Folsom splitter was used, counting the fraction range of 1/2-1/64, depending upon the abundance of individuals in a single sample. Abundances were standardized to 100 m^{-3}. Abundance of all 3 nets used was added in order to obtain the integrated abundance of zooplankton throughout the water column. Total abundance in the water column was then averaged by the number of days surveyed during each seasonal sampling, thus allowing comparisons between seasons.

Statistical analysis

All datasets were examined for normality using the Kolmorogov-Smirnov test. Abundance datasets were non-normal distributed and therefore non-parametric statistical analyses were applied. We assessed seasonal and upwelling-related changes in the community structure and the abundances by zooplankton group. For community structure analyses, a classical approach from Field *et al*. (1982) and Clarke & Warwick (2001) using PRIMER v6 software (Clarke & Gorley 2006) was used. Prior to the analyses, samples from the stations common to all the sampling times were selected in order to obtain results consistent and statistically comparable. After that, the data were fourth root transformed to normalize the variance while preserving distances among low values (Field *et al*. 1982). To test the hypothesis for differences in the community structure among samples from different time periods (seasons) and upwelling regimes, we applied a similarity analysis (ANOSIM test). ANOSIM is a permutation-based nonparametric test (analogue to a one-way analysis of variance), which performs average ranked values of Bray-Curtis measures of dissimilarity in abundances among and within samples. The R statistic is scaled to lie between -1 and +1, where zero represents the null hypothesis of no differences among a set of samples (Clarke 1993). For abundances of zooplankton groups, statistical differences were assessed with the Kruskal-Wallis test. The descriptive statistical summary presents the median and quartiles (25 and 75%) as central tendency and deviation measures, respectively.

Cumulated Ekman transport was computed as described previously where negative values represent offshore transport or coastal upwelling. Average values were used for each sampling season. Cumulated Ekman transport values were categorized as downwelling (DWN, ≈14,000 $m^2 s^{-1}$), weak upwelling (LUP, ≈ -20,000 $m^2 s^{-1}$), moderate upwelling (MUP, ≈ -40,000 $m^2 s^{-1}$) and strong upwelling (HUP, ≈ -80,000 $m^2 s^{-1}$).

The BEST analysis (in Primer software) was applied in order to select the taxa (zooplankton groups) that best correlate with the Cumulated Ekman transport. The BVSTEP stepwise algorithm was used to search the zooplankton groups (best subset) with >0.95 and <0.001 *P*-values as removal and addition criterions, respectively.

Results

Physical setting characterization

The thermal structure of the water column in Totoralillo Norte presented a clear pattern of higher stratification during the warmer months while during the cooler months there was a higher degree of mixing (Figs. 2a-f). During spring and summer frequent periods of warming and cooling were detected, the highest temperatures were recorded during the summer period (18°C) and spring only presented moderate warming of the water column (~14°C) (Figs. 2b, e). A Fourier analysis of the temperature data collected showed that the fluctuations corresponded mostly to daily cycles, particularly evident from the 4 and 16 m signals (Fig. 2g). The wind stress data exhibited a defined seasonal pattern with periods of high winds (especially zonal) with peaks of intensity during the spring and summer seasons (Figs. 3a, b). Although the upwelling index during these periods was high (Fig. 3c), wind stress averaged during other seasons was not markedly lower. Spectral analysis of the complete wind series recorded at this location revealed prevalence of diurnal and semi-diurnal frequencies (Fig. 3d).

During summer 2013 there was a dominance of winds favorable to the occurrence of upwelling events, and during the sampling period (15-20 January) there were 3 distinguishable upwelling events episodes (Fig. 4a). On the other hand, during fall 2013, winds with weaker characteristics for producing upwelling events alternated with downwelling conditions, albeit during the sampling period (8-14 June) the upwelling index was noticeably at least in 4 opportunities (Fig. 4b). During the winter season of 2013 a scenario similar to the one described for the previous fall was observed, although during August upwelling favorable winds were more dominant, and in at least 3 occasions this occurred during the sampling period (14-19 August, Fig. 4c). During spring, as in summer, there was a predominance of upwelling favorable winds,

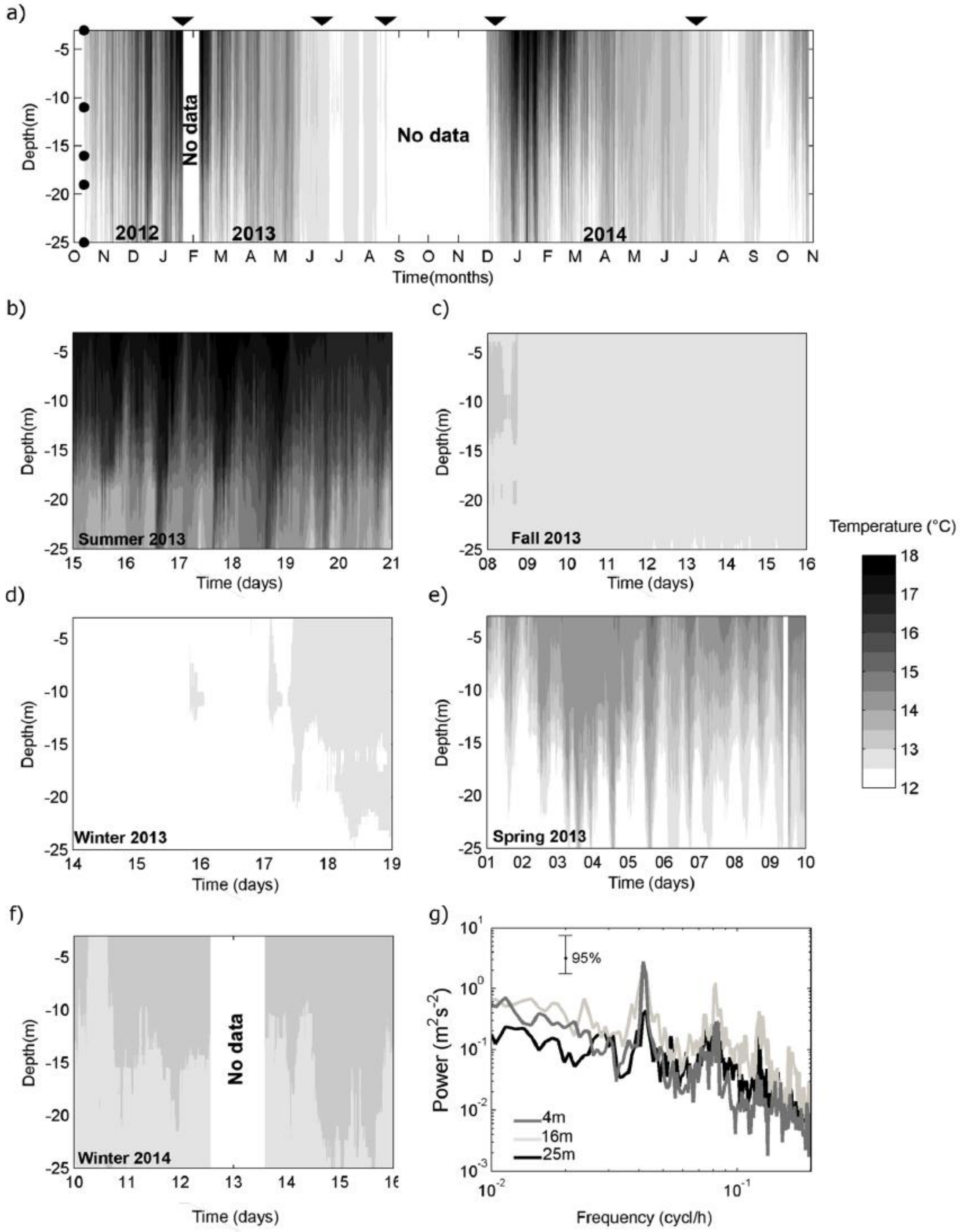

Figure 2. (a) Thermistor chain time series obtained in Totoralillo Norte bay from October 2012 through October 2014. Dots represent the vertical position of the temperature sensors and triangles represent the dates of the different campaigns. (b-f) Daily vertical temperature records obtained during each seasonal campaign. (g) The Fourier spectral analysis to the surface (4 m), middle (16 m) and bottom (25 m) time series / Series de tiempo de la cadena de termistores obtenidos en la bahía Totoralillo Norte desde octubre 2012 a octubre 2014. Los puntos negros representan la posición vertical de los sensores de temperatura y los triángulos representan los datos de las diferentes campañas. (b-f) Registros verticales diarios de la temperatura obtenida durante cada campaña estacional. (g) Series de tiempo del análisis espectral de Fourier en la superficie (4 m), capa media (16 m) y fondo (25 m)

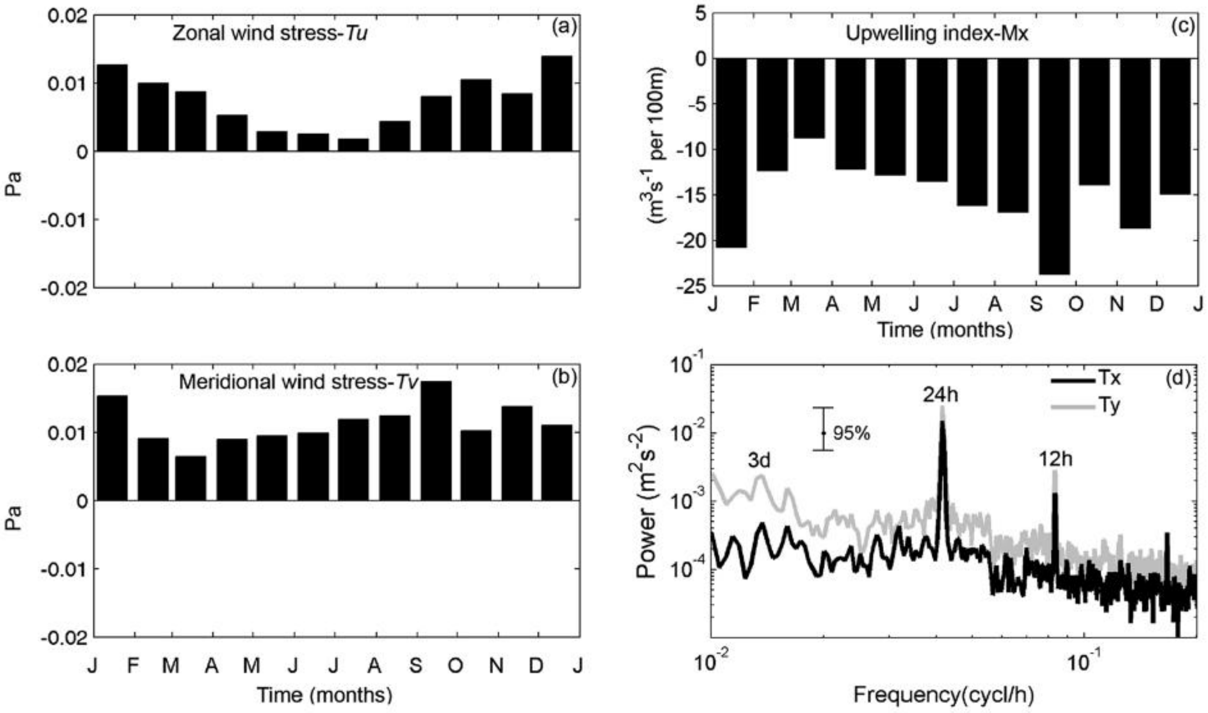

Figure 3. Monthly mean of the (a) zonal and (b) meridional wind stress obtained from the coastal meteorological station in period January 2013 to January 2014. (c) Monthly mean of upwelling index and (d) Fourier spectral analysis to the zonal and meridional wind stress / Promedio mensual de (a) estrés de viento zonal y (b) meridional obtenido de la estación metereológica costera durante Enero 2013 a Enero 2014. (c) Promedio mensual del índice de surgencia y (d) análisis espectral de Fourier del estrés del viento zonal y meridional

however during the sampling period diurnal cycles of strong upwelling (7 such events) alternated with downwelling conditions (Fig. 4d). During winter 2014 downwelling conditions predominated, although 2 consecutive days (12-13 July) of upwelling conditions were registered during the sampling period (Fig. 4e).

The above patterns are further examined and corroborated following the approach proposed by Bograd *et al*. (2009), whereby the cumulative upwelling index allows for a sounder distinction of the upwelling favorable periods with summer, winter 2013 and spring being the clearest ones (Fig. 5).

ZOOPLANKTON COMMUNITY COMPOSITION

From a total of 166 taxa that were encountered, 123 (74.1%) were identified at the species level, 39 (23.5%) at the level of genera and 4 (2.4%) at other lower taxonomic levels, and categorized as follows: 48 holoplankton taxa, 8 meroplankton taxa, 51 copepods (separated from the rest of the holoplankton due to their high abundance), 35 decapods larvae, and 24 taxa of ichthyoplankton (eggs and larvae). Throughout the study period, a total of 55 taxa (33.5% of the total) of the above mentioned were present in every season (Table 1).

ZOOPLANKTON DISTRIBUTION AND ABUNDANCE

The abundance of the principal groups occurring within Totoralillo bay as well as outside its boundaries varied greatly throughout the study period. Summer 2013 registered the lowest overall abundance of zooplankton (< 490000 ind. 100 m^{-3}), while the highest was observed during winter 2014 (< 5950000 ind. 100 m^{-3}) (Fig. 6). Copepods were always the most abundant group over the study period (65.3%) mainly represented by *Acartia tonsa* and *Paracalanus* cf. *indicus*, followed by meroplankton (17.6%), independently from where samples were collected.

These patterns can be graphically appreciated when reviewed as total abundance at each of the sampling points over each of the sampling periods (Fig. 7). Noteworthy is the high abundance of zooplankton within the bay of Totoralillo Norte during winter 2014, although no sampling was conducted outside of the bay during that period. When samples were taken from all points, including those outside the bay, highest abundances were always recorded in the points closest to the coast, regardless of seasonality. From a seasonal perspective, copepods were numerically dominant throughout the study, although exhibited greater abundance during fall and winter periods of each year.

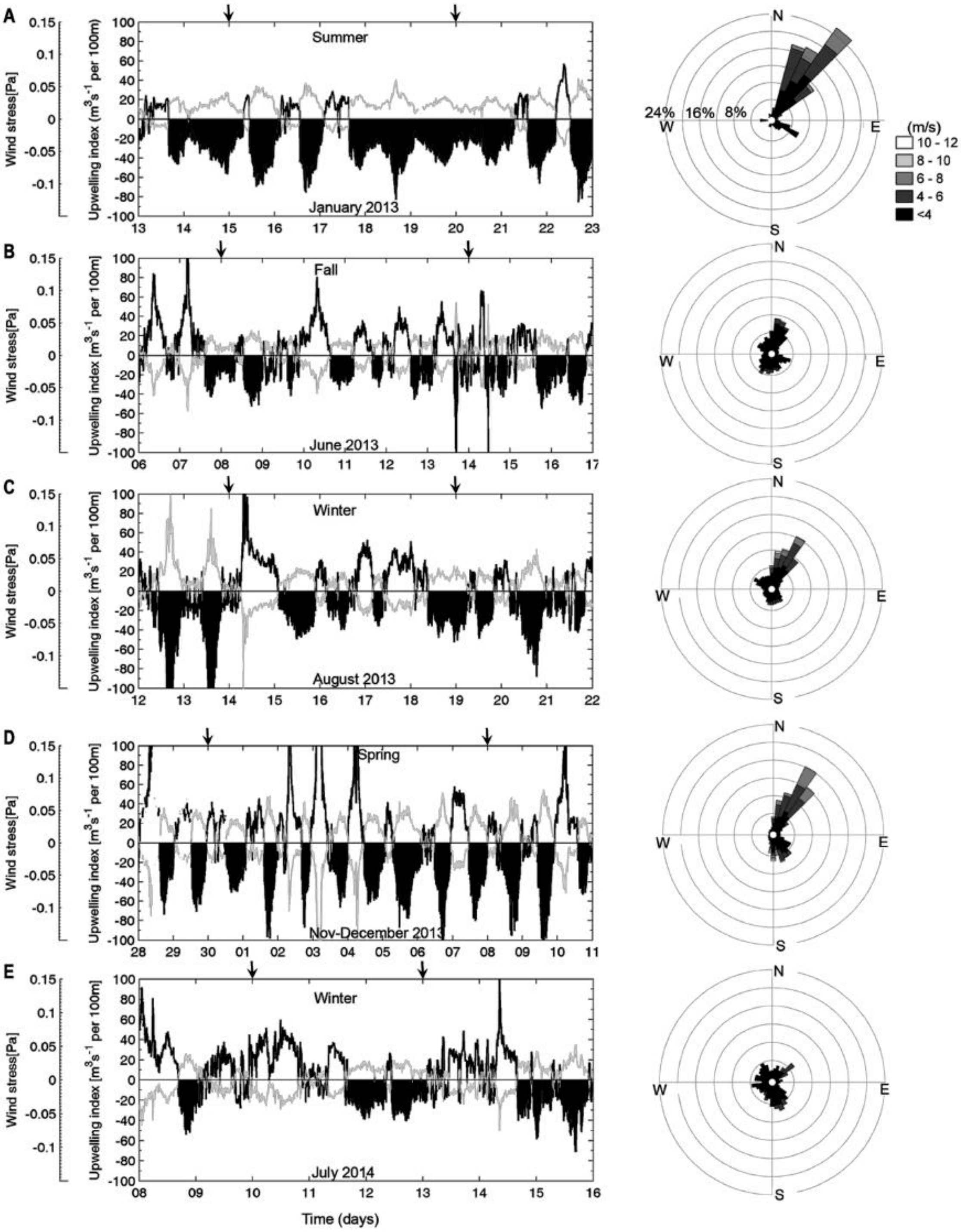

Figure 4. (a-e) Hourly upwelling index (black lines) derived from *in-situ* wind data (grey lines). Arrows indicate the starting and ending dates, respectively, for the sampling period within each season. Right panels depict the average wind direction during the month of the respective surveys / (a-e) Índice de surgencia por hora (líneas negras) derivado de los datos de viento *in-situ* (líneas grises). Las flechas indican los datos iniciales y finales, respectivamente, para el periodo de muestreo dentro de cada estación del año. Paneles a la derecha representan la dirección promedio del viento durante el mes de las mediciones respectivas

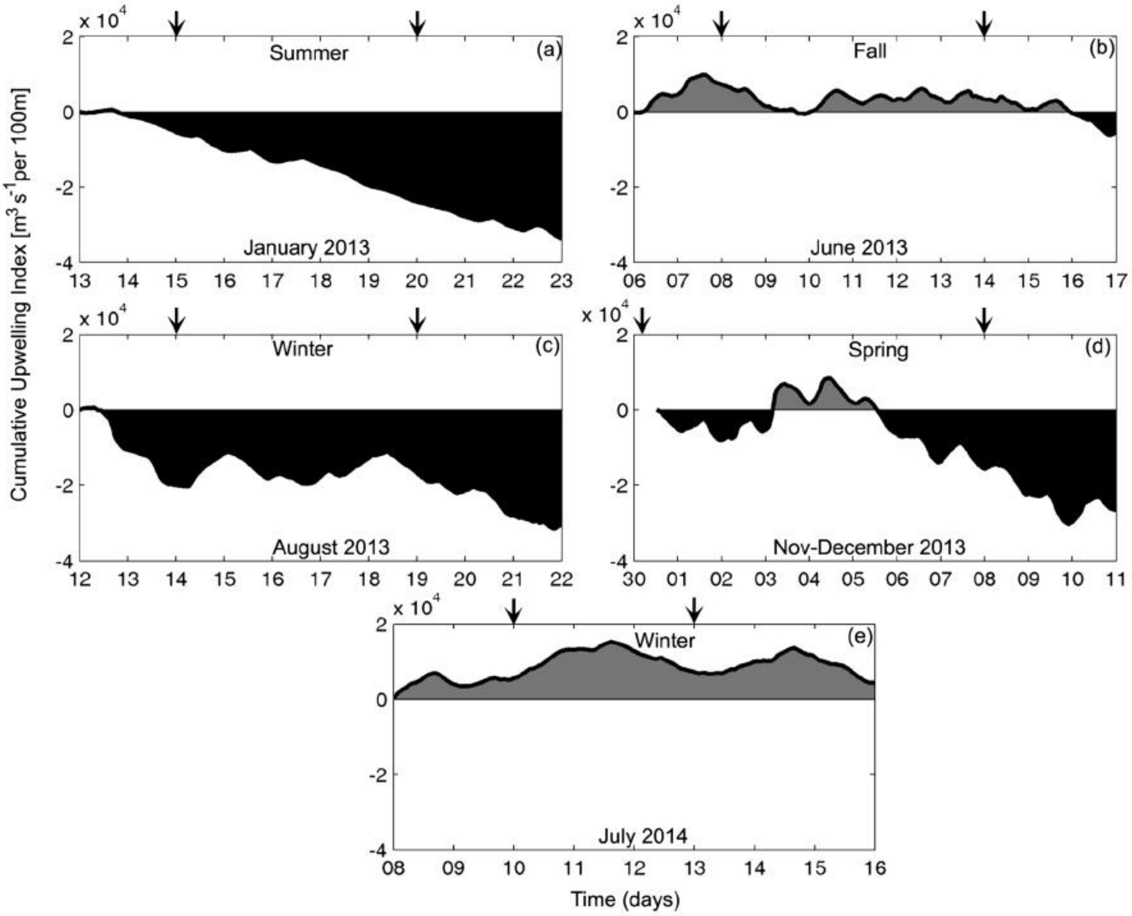

Figure 5. Cumulative upwelling index for the surveyed periods. The sampling period are marked with arrows. Black/grey shaded areas denote favorable upwelling/downwelling conditions / Índice de surgencia acumulado para los períodos analizados. Los períodos de muestreo se marcan con flechas. Áreas negro/gris indican condiciones de surgencia/ hundimiento

The holoplankton, meroplankton and fish eggs did not show marked differences among seasons, although their abundance was higher during the winter 2014. Decapods exhibited a remarkable higher abundance during the winter 2014 season while fish larvae were fairly well represented during all seasons except spring, and fish larvae exhibited some abundance peaks during winter 2013 (Fig. 7).

ZOOPLANKTON COMMUNITY STRUCTURE AND ABUNDANCE DYNAMICS

Numerically the zooplankton was more abundant in samples collected during the winter 2014 than during the remaining seasons. A descriptive statistical summary for zooplankton group abundances is shown in Table 2. Throughout this study zooplankton abundance was highly variable in the study area, ranging from 0 in the case of fish larvae to >1 million of individuals per 100 m^3 in the case of copepods. The latter group accounts for 64% of the overall zooplankton abundance followed by meroplankton which accounted for 22% in abundance. Differences in the community structure between seasons were statistically significant (ANOSIM test, Global R= 0.249, $P < 0.0001$) as well as among different wind regimes (ANOSIM test, Global R= 0.194, $P < 0.0001$) (Table 3).

In relation to the changes observed in the zooplankton abundances, the Kruskal-Wallis test (multiple comparisons) showed statistical differences between seasons and upwelling regimes (Table 4). Strongest statistical differences ($P < 0.00001$) were observed between contrasting seasons (*e.g.*, summer *versus* winter) and a higher influence of moderate and weak upwelling events than strong Ekman transport (Table 4).

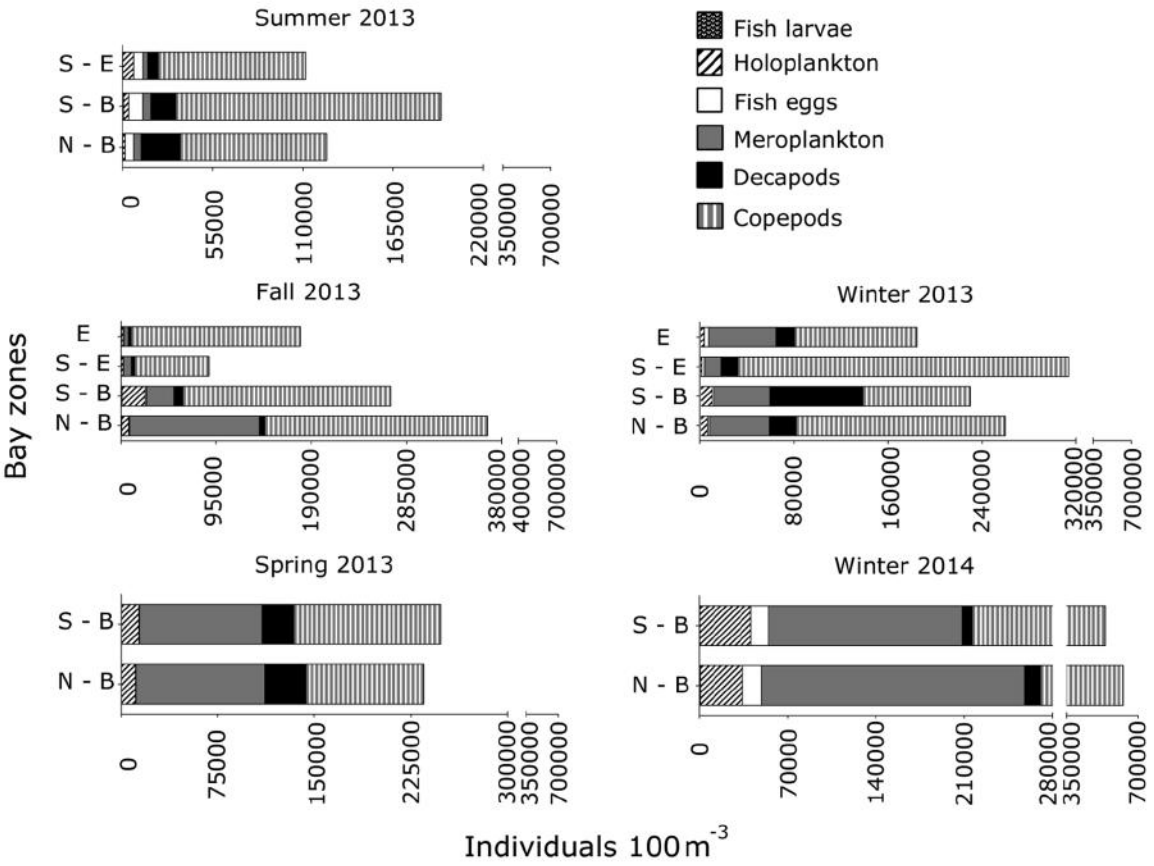

Figure 6 Average abundance (individual 100 m^{-3}) for each zooplankton category from summer 2013 to winter 2014 in Totoralillo Norte Bay. Letters identify position of the different sampling points. E= Exterior, S-E= Southern exterior, S-B= Southern bay, N-B = Northern bay (see Fig. 1 for details) / Abundancia promedio (individuos 100 m^{-3}) para cada categoría de zooplancton desde verano 2013 hasta invierno 2014 en la bahía Totoralillo Norte. Letras identifican la posición de los diferentes puntos de muestreo. E= Exterior, S-E= Exterior sur, S-B= Bahía sur, N-B= Bahía norte (ver Fig. 1 para detalles)

The non-parametric stepwise multiple regression (BEST analysis) indicates that holoplankton, meroplankton, decapods, fish eggs and copepods were the groups that best correlated with the Ekman transport (Global R= 0.99; correlation= 0.990; *P*-value= 0.001), which confirms the influence of coastal upwelling regime on the zooplankton community.

DISCUSSION

The present study not only provides a detailed and exhaustive list of zooplankton species present in the bay of Totoralillo Norte, but also describes its variability at different spatial (bay-scale) and temporal (seasonal) scales. Similar studies exist along the coast of Chile, where detailed patterns of distribution and abundance together with related forcing factors (*i.e.*, wind-driven currents) are provided, although they are generally restricted to a specific group within the zooplanktonic community (*i.e.*, copepods, Escribano & Hidalgo 2000; gelatinous zooplankton, Palma & Apablaza 2004; decapod, meroplankton, Palma *et al*. 2006). Similar such efforts have also been carried out at other latitudes (*i.e.*, California). However, only patterns of distribution and abundance and related processes for single or reduced groups of species were described (i.e. Roughan *et al*. 2005, Mace & Morgan 2006a). Seasonal differences in plankton composition and biomass have been described from a variety of marine environments. In high latitudes like the Barents Sea this is mainly related to water mass circulation and bottom topography (Araskkevich *et al.* 2002) and in a tropical estuarine system in the Persian Gulf the observed changes were mainly related to salinity, chlorophyll a, temperature and pH differences (Farhadian & Pouladi 2014). Other examples of changes in plankton composition and abundance along coastal settings

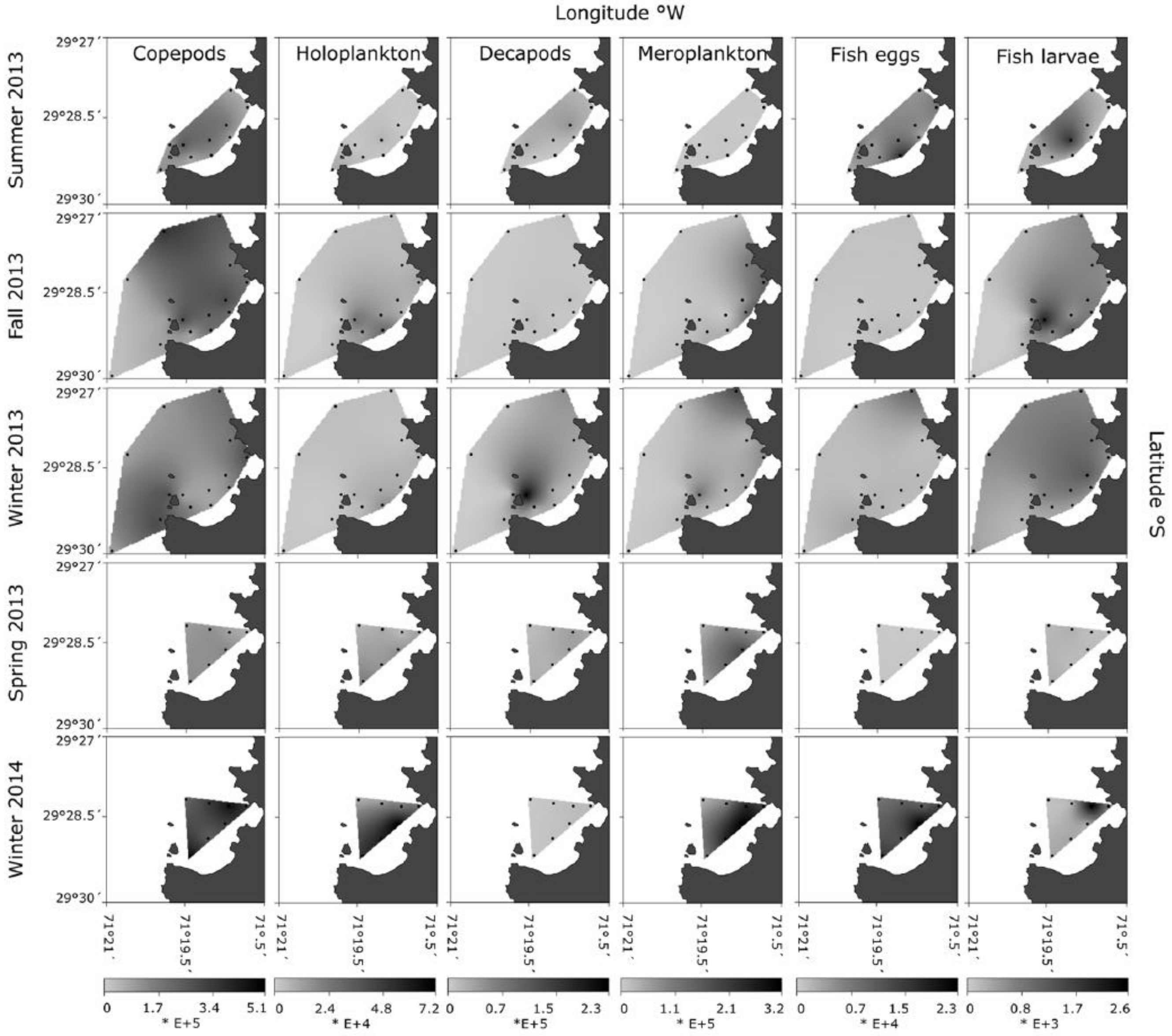

Figure 7. Horizontal distribution of categories of zooplankton community (individual 100 m^{-3}): copepods, holoplankton, decapods, meroplankton, fish eggs and fish larvae. This figure was created using Surfer® version 11 and kriging interpolation method. Dots represent sampling points/ Distribución horizontal de las categorías de la comunidad de zooplancton (individuos 100 m^{-3}): copépodos, holoplancton, decápodos, meroplancton, huevos de peces y larvas de peces. Esta figura fue creada usando Surfer® versión 11 y kriging como método de interpolación. Los puntos representan sitios de muestreo

Table 1. List of zooplankton species identified in Totoralillo Bay from summer 2013 to winter 2014. (+) indicates de presence of a species in a given season. In the case of decapods and fishes the distinction between different larval stages were made: Z: zoea, M: megalopa, E: egg, L: fish larvae. (Cat.) indicates the categories in which the species were grouped: 1: holoplankton, 2: meroplankton, 3: copepods, 4: decapods, 5: fish eggs, 6: fish larvae / Lista de especies de zooplancton identificadas en la Bahía de Totoralillo desde el verano 2013 hasta el invierno del 2014. (+) indica la presencia de una especie en una temporada determinada. En el caso de decápodos y peces la distinción entre diferentes estados larvales fueron indicados como: Z: zoea, M: megalopa, E: huevo, L: larva de pez. (Cat.) indica las categorías en que las especies fueron agrupadas: 1: holoplancton, 2: meroplancton, 3: copépodos, 4: decápodos, 5: huevos de peces, 6: larva de pez

Phylum	Class	Order	Family	Species	Cat.	Summer 2013		Fall 2013		Winter 2013		Winter 2014		Spring 2013	
Rhizaria	Foraminifera	Globigerinida	Globigerinidae	*Globigerina* sp.	1	+									
Cnidaria	Hydrozoa	Anthoathecata	Bougainvilliidae	*Bougainvillia* sp.	1	+									
			Corymorphidae	*Euphysa aurata*	1	+				+					
			Corynidae	*Sarsia eximia*	1	+		+		+		+		+	
				Stauridiosarsia sp.	1	+									
			Pandeidae	*Leuckartiara octona*	1	+		+							
			Tubulariidae	*Ectopleura dumortierii*	1	+		+		+		+		+	
Cnidaria	Hydrozoa	Hydroida	Oceanidae	*Turritopsis nutricula*	1					+				+	
Cnidaria	Hydrozoa	Leptomedusae	Campanulariidae	*Obelia* sp.	1	+		+		+		+		+	
Cnidaria	Hydrozoa	Leptothecata	Phialellidae	*Phialella quadrata*	1	+		+		+		+		+	
			Campanulariidae	*Phialidium* sp.	1	+		+		+		+		+	
			Eirenidae	*Phialopsis diegensis*	1									+	
Cnidaria	Hydrozoa	Narcomedusae	Cuninidae	*Cunina perigrima*	1									+	
Cnidaria	Hydrozoa	Siphonophorae	Abylidae	*Abylopsis tetragona*	1	+		+		+				+	
			Diphyidae	*Muggiaea atlantica*	1	+		+		+				+	
			Calycophorae	*Sphaeronectes gracilis*	1									+	
			Prayidae	*Rosacea* sp.	1										
Cnidaria	Hydrozoa	Trachymedusae	Geryoniidae	*Liriope tetraphylla*	1							+		+	
			Halicreatidae	*Botrynema brucei*	1	+				+					
			Rhopalonematidae	*Sminthea eurygaster*	1	+		+						+	
Cnidaria	Scyphozoa	Coronatae	Periphylla	*Periphylla periphylla*	1									+	
Ctenophora	Nuda	Beroida	Beroidae	*Beroe cucumis*	1	+						+		+	
Ctenophora	Tentaculata	Cydippida	Pleurobrachiidae	*Pleurobrachia* sp.	1	+		+		+		+		+	
Platyhelminthes	Rhabditophora	Polycladida	Notoplanidae	*Notoplana* sp.	2			+		+		+		+	
Annelida	Polychaeta	Aciculata	Tomopteridae	*Tomopteris* sp.	1	+		+		+		+		+	
Annelida	Polychaeta	Phyllodocida	Alciopidae	*Vanadis* sp.	1	+									
						Z	M	Z	M	Z	M	Z	M	Z	M
Arthropoda	Malacostraca	Decapoda (Anomura)	Albuneidae	*Lepidopa* sp.	4	+		+	+	+		+		+	+
			Blepharipodidae	*Blepharipoda* sp.	4	+		+		+		+		+	
			Hippidae	*Emerita analoga*	4	+	+	+	+	+	+	+	+	+	+
			Munididae	*Cervimunida johni*	4					+		+		+	
				Pleuroncodes monodon	4	+		+		+		+		+	
			Paguridae	*Pagurus* sp.	4	+	+	+	+	+	+		+	+	+
			Porcellanidae	*Allopetrolisthes angulosus*	4	+	+	+	+	+	+	+		+	+
				Petrolisthes granulosus	4	+	+	+	+	+	+	+		+	+
				Petrolisthes violaceus	4	+		+		+	+	+		+	+
				Porcellana sp.	4	+	+	+	+	+	+	+	+	+	+
Arthropoda	Malacostraca	Decapoda (Axiidea)	Callianassidae	*Callianassa* sp.	4	+		+		+		+		+	
Arthropoda	Malacostraca	Decapoda (Brachyura)	Aethridae	*Hepatus chiliensis*	4									+	
			Atelecyclidae	*Pseudocorystes sicarius*	4						+				+
			Belliidae	*Acanthocyclus albatrossis*	4										+
				Acanthocyclus gayi	4	+		+		+	+	+	+	+	+
				Corystoides chilensis	4			+		+	+	+	+	+	+

Table 1. Continued / Continuación

			Cancridae	*Cancer coronatus*	4							+		+	
				Cancer porteri	4							+		+	
				Cancer setosus	4			+	+	+	+	+		+	+
			Epialtidae	*Pisoides edwardsii*	4	+	+	+	+	+	+	+	+	+	+
				Taliepus dentatus	4	+	+	+	+	+	+	+	+	+	+
			Grapsidae	*Leptograpsus variegatus*	4	+		+		+	+	+	+	+	+
			Hymenosomatidae	*Halicarcinus planatus*	4		+	+		+	+	+		+	+
			Inachoididae	*Pyromaia tuberculata*	4										+
			Majidae	*Eurypodius latreillei*	4			+	+	+	+	+		+	+
				Libidoclaea granaria	4			+						+	
			Pilumnoididae	*Pilumnoides perlatus*	4	+		+				+		+	
			Pinnotheridae	*Pinnixa* sp.	4	+	+	+		+		+	+	+	+
				Pinnotheres sp.	4							+	+	+	+
			Platyxanthidae	*Homalaspis plana*	4	+	+	+	+	+	+	+	+	+	+
				Platyxanthus sp.	4			+		+		+		+	
			Portunidae	*Ovalipes* sp.	4										+
			Trichopeltariidae	*Peltarion spinulosum*	4										+
			Varunidae	*Cyclograpsus cinereus*	4	+	+	+	+	+	+	+	+	+	+
			Xanthidae	*Paraxanthus barbiger*	4										+
Arthropoda	Malacostraca	Halocyprida	Halocyprididae	*Conchoecia* sp.	1	+		+		+		+		+	
Arthropoda	Malacostraca	Euphausiacea	Euphausiidae	*Euphausia mucronata*	1	+		+		+				+	
				Euphausia sp.	1					+				+	
				Stylocheiron sp.	1					+					
Arthropoda	Malacostraca	Amphipoda	Hyperiidae	*Hyperia* sp.	1	+									
			Lestrigonidae	*Hyperietta* sp.	1	+		+		+		+		+	
				Lestrigonus schizogeneios	1	+		+		+		+			
			Phronimidae	*Phronima sedentaria*	1					+					
			Phrosinidae	*Primno macropa*	1			+							
			Vibiliidae	*Vibilia armata*	1			+		+		+		+	
Arthropoda	Malacostraca	Isopoda	Cirolanidae	*Cirolana* sp.	1	+		+		+		+		+	
		Cumacea	Bodotriidae	*Cyclaspis* sp.	1			+		+					
Arthropoda	Malacostraca	Mysida	Mysidae	Mysidae NI	2	+		+				+		+	
Arthropoda	Malacostraca	Stomatopoda	Gonodactylidae	Gonodactylidae NI	2	+		+		+		+		+	
Arthropoda	Maxillopoda	Calanoida	Acartiidae	*Acartia tonsa*	3	+		+		+		+		+	
			Aetideidae	*Aetideus armatus*	3	+		+		+		+		+	
				Chiridius poppei	3			+		+				+	
				Euchirella sp.	3			+		+					
				Gaetanus sp.	3									+	
			Augaptilidae	*Haloptilus acutifrons*	3					+					
			Calanidae	*Calanoides patagonensis*	3	+									
				Calanus chilensis	3	+		+		+		+		+	
				Mesocalanus tenuicornis	3	+		+		+		+		+	
				Nannocalanus minor	3	+		+		+		+		+	
			Centropagidae	*Centropages brachiatus*	3	+		+		+		+		+	
				Centropages bradyi	3							+			

Table 1. Continued / Continuación

			Clausocalanidae	*Clausocalanus arcuicornis*	3		+	+	+	+
				Clausocalanus furcatus	3		+	+	+	+
				Clausocalanus ingens	3		+	+	+	+
				Clausocalanus jobei	3				+	
				Ctenocalanus vanus	3		+	+	+	+
				Microcalanus pygmaeus	3	+	+	+	+	+
			Eucalanidae	*Eucalanus hyalinus*	3	+	+	+	+	+
				Eucalanus inermis	3			+		+
				Subeucalanus subtenuis	3		+	+	+	
			Euchaetidae	*Euchaeta marina*	3			+		
			Heterorhabdidae	*Heterorhabdus abyssalis*	3			+		
				Heterorhabdus papilliger	3		+	+		+
			Lucicutiidae	*Lucicutia* sp.	3		+	+		+
			Metridinidae	*Metridia lucens*	3		+			
				Pleuromamma gracilis	3	+	+	+	+	+
			Paracalanidae	*Acrocalanus monachus*	3				+	+
				Calocalanus pavo	3		+			
				Calocalanus tenuis	3			+	+	
				Paracalanus cf. *indicus*	3	+	+	+	+	+
			Rhincalanidae	*Rhincalanus nasutus*	3	+		+		+
			Scolecitrichidae	*Lophothrix* sp.	3		+	+		
				Scaphocalanus sp.	3		+	+		+
				Scolecithricella abyssalis	3		+	+		+
				Scolecithrix bradyi	3		+	+		
			Temoridae	*Temora* sp.	3					+
Arthropoda	Maxillopoda	Cyclopoida	Corycaeidae	*Corycaeus erythraeus*	3	+	+	+	+	+
				Corycaeus lautus	3			+		+
				Corycaeus typicus	3		+	+	+	+
			Oithonidae	*Oithona nana*	3				+	
				Oithona setigera	3		+	+	+	+
				Oithona similis	3	+	+	+	+	+
			Oncaeidae	*Oncaea venusta*	3	+	+	+	+	+
				Triconia conifera	3		+	+	+	+
			Sapphirinidae	*Sapphirina* sp.	3		+	+		+
			incertae sedis	*Pachos punctatum*	3		+	+	+	+
Arthropoda	Maxillopoda	Harpacticoida	Clytemnestrida	*Clytemnestra rostrata*	3			+		
				Clytemnestra scutellata	3		+	+		
			Ectinosomatidae	*Microsetella norvegica*	3		+			
Arthropoda	Maxillopoda	Siphonostomatoida	Caligidae	*Caligus* sp.	3		+	+	+	+
Arthropoda	Maxillopoda	Sessilia		Cirripedia NI	2	+	+	+	+	+
Arthropoda	Branchiopoda	Cladocera	Podonidae	*Evadne* sp.	1				+	
Mollusca	Gastropoda	Mesogastropoda	Atlantidae	*Atlanta* sp.	1		+	+		
			Pterotracheidae	*Firoloida desmaresti*	1					+
		Thecosomata	Peraclididae	*Peraclis apicifulva*	1	+	+	+		+
		Neogastropoda	Muricidae	*Concholepas concholepas*	2	+	+	+	+	+
		Octopoda	Octopodidae	*Octopus* sp.	2		+			
Bryozoa	Gymnolaemata	Cheilostomatida	Membraniporidae	*Membranipora* sp.	2	+	+	+	+	+
Chaetognatha	Sagittoidea	Aphragmophora	Sagittidae	*Sagitta bipunctata*	1			+	+	+
			Sagittidae	*Sagitta enflata*	1		+	+	+	+
			Sagittidae	*Sagitta lyra*	1		+	+		
			Sagittidae	*Sagitta maxima*	1		+	+		
			Sagittidae	*Sagitta minima*	1	+	+	+	+	+

Table 1. Continued / Continuación

Chordata	Ascidiacea			Ascidiacea NI	2							+		+	
Chordata	Thaliacea	Salpida	Salpidae	*Thalia democratica*	1	+		+				+		+	
Chordata	Appendicularia	Copelata	Oikopleuridae	*Oikopleura* sp.	1	+		+		+		+		+	
						E	L	E	L	E	L	E	L	E	L
Chordata	Actinopterygii	Atheriniformes	Atherinopsidae	*Odontesthes regia regia*	6				+		+		+		+
Chordata	Actinopterygii	Clupeiformes	Clupeidae	*Ethmidium maculatum*	5, 6					+	+	+		+	
				Sardinops sagax	5, 6	+	+			+		+		+	
				Strangomera bentincki	5, 6			+	+	+	+	+	+	+	+
			Engraulidae	*Engraulis ringens*	5, 6	+	+	+	+	+	+	+	+	+	+
Chordata	Actinopterygii	Gadiformes	Merlucciidae	*Merluccius gayi gayi*	6				+		+				+
Chordata	Actinopterygii	Gobiesociformes	Gobiesocidae	*Gobiesox marmoratus*	6		+		+		+		+		+
				Sicyases sanguineus	6		+		+		+				+
Chordata	Actinopterygii	Myctophiformes	Myctophidae	*Diaphus* sp.	6		+		+		+				+
				Hygophum bruuni	6										+
				Lampanyctus iselinoides	6				+						+
Chordata	Actinopterygii	Perciformes	Blenniidae	*Hypsoblennius sordidus*	6		+		+		+		+		+
			Bovichtidae	*Bovichtus chilensis*	6						+		+		
			Centrolophidae	*Seriolella violacea*	6		+		+		+		+		
			Clinidae	*Myxodes viridis*	6		+		+		+		+		+
			Gobiidae	*Ophiogobius jenynsi*	6				+		+		+		
			Labrisomidae	*Auchenionchus microcirrhis*	6		+		+		+		+		+
			Pinguipedidae	*Prolatilus jugularis*	6		+		+		+		+		+
			Pomacentridae	*Chromis crusma*	6		+				+		+		+
			Stromateidae	*Stromateus stellatus*	5			+		+		+		+	
			Tripterygiidae	*Helcogrammoides chilensis*	6		+		+		+		+		+
Chordata	Actinopterygii	Pleuronectiformes	Paralichthyidae	*Paralichthys adspersus*	6						+		+		+
Chordata	Actinopterygii	Scorpaeniformes	Normanichthyidae	*Normanichthys crockeri*	5, 6	+	+	+	+	+	+	+	+	+	+
			Sebastidae	*Sebastes oculatus*	6		+		+		+		+		+

Table 2. Statistical summary for zooplankton abundance by category (Individuals 100 m^{-3}) in relation to seasons and wind regimes (cumulated Ekman transport, CET) in Totoralillo Norte Bay, northern Chile. CET values were categorized as downwelling (DWN, ≈14,000 m^2 s^{-1}), weak upwelling (LUP, ≈20,000 m^2 s^{-1}), moderate upwelling (MUP, ≈40,000 m^2 s^{-1}) and strong upwelling (HUP, ≈80,000 m^2 s^{-1}). Q25 and Q75 indicate 25 and 75% quartiles, respectively / Resumen estadístico de la abundancia de zooplancton por categoría (Individuos 100 m^{-3}) en relación a estaciones del año y regímenes de viento (Transporte de Ekman acumulado, CET) en bahía Totoralillo Norte, Norte de Chile. Valores CET fueron categorizados como convergencia (DWN, ≈14,000 m^2 s^{-1}), surgencia débil (LUP, ≈20,000 m^2 s^{-1}), surgencia moderada (MUP, ≈40,000 m^2 s^{-1}) y surgencia fuerte (HUP, ≈80,000 m^2 s^{-1}). Q25 y Q75 indican los cuartiles 25 y 75% respectivamente

Category	Season	Median	Q25	Q75	Ekman effect	Median	Q25	Q75
Holoplankton	Summer 2013	1385	590	3564	MUP	1385	590	3564
	Fall 2013	8652	5247	20942	DWN	8652	5247	20942
	Winter 2013	2327	1386	8620	HUP	2327	1386	8620
	Spring 2013	12551	2056	31612	LUP	14962	4181	49556
	Winter 2014	45532	13371	74844				
Meroplankton	Summer 2013	3608	1516	8508	MUP	3608	1516	8508
	Fall 2013	6881	3257	13969	DWN	6881	3257	13969
	Winter 2013	33177	20030	54060	HUP	33177	20030	54060
	Spring 2013	19922	9224	107887	LUP	70122	14876	185943
	Winter 2014	149810	70122	356808				
Decapods	Summer 2013	11686	2899	26959	MUP	11686	2899	26959
	Fall 2013	3036	1621	5535	DWN	3036	1621	5535
	Winter 2013	10595	7051	46196	HUP	10595	7051	46196
	Spring 2013	18684	8830	39093	LUP	14455	6072	28745
	Winter 2014	7651	3550	18331				
Fish eggs	Summer 2013	4169	3461	11096	MUP	4169	3461	11096
	Fall 2013	702	468	1482	DWN	702	468	1482
	Winter 2013	890	409	2643	HUP	890	409	2643
	Spring 2013	53	21	938	LUP	988	38	12781
	Winter 2014	14849	11543	23144				
Fish larvae	Summer 2013	275	124	652	MUP	275	124	652
	Fall 2013	516	266	825	DWN	516	266	825
	Winter 2013	483	197	1071	HUP	483	197	1071
	Spring 2013	158	98	296	LUP	232	102	361
	Winter 2014	333	191	417				
Copepods	Summer 2013	67732	14113	199841	MUP	67732	14113	199841
	Fall 2013	119538	82111	197496	DWN	119538	82111	197496
	Winter 2013	99854	57770	161902	HUP	99854	57770	161902
	Spring 2013	53821	14562	118739	LUP	140663	34117	292465
	Winter 2014	290837	239939	327971				

Table 3. Analysis of similarity (ANOSIM) showing Global R and pairwise test for differences among seasons and wind regimes (cumulated Ekman transport, CET) in Totoralillo Bay, northern Chile. CET values were categorized as downwelling (DWN, ≈14,000 $m^2 s^{-1}$), weak upwelling (LUP, ≈20,000 $m^2 s^{-1}$), moderate upwelling (MUP, ≈40,000 $m^2 s^{-1}$) and strong upwelling (HUP, ≈80,000 $m^2 s^{-1}$) / Análisis de similitud (ANOSIM) que muestra el R global y comparaciones pareadas para diferentes estaciones del año y regímenes de viento (Transporte de Ekman acumulado, CET) en bahía Totoralillo Norte, norte de Chile. Valores de CET fueron categorizados como convergencia (DWN, ≈14,000 $m^2 s^{-1}$), surgencia débil (LUP, ≈20,000 $m^2 s^{-1}$), surgencia moderada (MUP, ≈40,000 $m^2 s^{-1}$) y surgencia fuerte (HUP, ≈80,000 $m^2 s^{-1}$)

	R Statistic	p-value
Pairwise Tests for Season		
Sample statistic (Global R): 0.369		
Summer 2013 vs Fall 2013	0,250	0,0002
Summer 2013 *vs* Winter 2013	0,262	0,0002
Summer 2013 *vs* Spring 2013	0,390	0,0001
Summer 2013 *vs* Winter 2014	0,626	0,0001
Fall 2013 *vs* Winter 2013	0,241	0,0005
Fall 2013 *vs* Spring 2013	0,291	0,0002
Fall 2013 *vs* Winter 2014	0,657	0,0001
Winter 2013 *vs* Spring 2013	0,156	0,0060
Winter 2013 *vs* Winter 2014	0,698	0,0001
Spring 2013 *vs* Winter 2014	0,484	0,0001
Pairwise Tests for Ekman effect		
Sample statistic (Global R): 0.213		
MUP *vs* DWN	0,250	0,0002
MUP *vs* HUP	0,262	0,0003
MUP *vs* LUP	0,340	0,0001
DWN *vs* HUP	0,241	0,0007
DWN *vs* LUP	0,168	0,0030
HUP *vs* LUP	0,077	0,0560

include a strong human-related pollution/eutrophication that alters natural seasonal changes (Kwang-Hyeon *et al*. 2009). Here, we describe the seasonal dynamics of the entire zooplankton community for an important spatial span of the coastal area, including sites close to shore (~200 m) to points well outside the bay of Totoralillo Norte (several km offshore) stressing on the relevance of hydrographic processes that not necessarily operate with similar strength on a seasonal basis. Such basic understanding of how a wide variety of zooplankton behaves both spatially and temporally is fundamental given the degree of anthropic intervention over coastal environments (Viles & Spencer 2014).

From October 2012 through November 2014, we uncovered a seasonal pattern regarding the thermal structure of the water column and prevailing winds of Totoralillo Norte Bay consistent with patterns of seasonal occurrence of upwelling conditions (i.e. peak upwelling typically observed during the Spring-Summer seasons) that have been described for this area of the Chilean coastline (Montecino & Quiroz 2000, Montecino *et al.* 2005, Letelier *et al.* 2009, Tapia *et al.* 2009). Moreover, the high temporal sampling frequency used in this study revealed that upwelling events can be frequent in this bay even in seasons (*i.e.*, winter 2013) when they are least expected.

These wind stress patterns were integrated with zooplankton abundance data in order to assess how upwelling may determine the distribution and abundance patterns of zooplankton at these specific spatial (bay) and temporal (seasonal) scales (Tapia *et al.* 2004, Daneri *et al.* 2012). Generally, upwelling events result in higher plankton abundance towards the interior parts of bays (Mace & Morgan 2006a, b; Palma *et al.* 2006, Vander Woude *et al.* 2006, Morgan & Fisher 2010). The mechanisms by which this occurs are not evident, since superficial plankton should be transported off-shore by advection (Wing *et al.* 1995, Miller & Emlet 1997, Morgan & Fisher 2010, Morgan *et al.* 2012), but may be associated with the high retention rates at protected systems (Roughan *et al.* 2005, Mace & Morgan 2006a) or alternatively with the ability of certain groups within the zooplankton to move throughout the water column (*i.e.*, daily vertical migration) and thus avoid being advected offshore (Poulin *et al.* 2002b, Sponaugle *et al.* 2002). For instance, in upwelling regions, upwelling shadows form in the lee of large headlands and are characterized by reduced local wind forcing, localized reversal of alongshore flow, and warm surface waters (Graham & Largier 1997). When the wind is not sufficiently diminished by a small headland (which is the case of Totoralillo) alongshore transport of surface water into the bay with recirculation at depth can occur, more so during upwelling events, and can promote retention of plankton, particularly the type capable of daily vertical migration (Roughan *et al.* 2005). Our results are coherent with such previous studies showing increased abundance in the inner part of Totoralillo bay. However, the novelty found here is that this pattern emerges not only on an annual basis, but during all seasons studied.

In this study, we found higher abundance of zooplankton in winter 2014 that were concomitant with downwelling prevailing conditions, particularly during the sampling period (*i.e.*, 10-13 July 2014). Such an association between local wind patterns and zooplankton abundance may indicate that stronger winds do not necessarily imply higher zooplankton abundances, but rather calm or variable periods promote higher concentration

Table 4. Kruskal-Wallis test of multiple comparisons for statistical differences in the zooplankton abundances between seasons and upwelling regimes in Totoralillo Norte Bay, northern Chile. CET values were categorized as downwelling (DWN, ≈14,000 m^2 s^{-1}), weak upwelling (LUP, ≈20,000 m^2 s^{-1}), moderate upwelling (MUP, ≈40,000 m^2 s^{-1}) and strong upwelling (HUP, ≈80,000 m^2 s^{-1}). NS, no significant / Test de Kruskal-Wallis con comparaciones múltiples para diferencias estadísticas en las abundancias del zooplancton entre estaciones y regímenes de surgencia en bahía Totoralillo Norte, Norte de Chile. Valores de CET fueron categorizados como convergencia (DWN, ≈14,000 m^2 s^{-1}), surgencia débil (LUP, ≈20,000 m^2 s^{-1}), surgencia moderada (MUP, ≈40,000 m^2 s^{-1}) y surgencia fuerte (HUP, ≈80,000 m^2 s^{-1}). NS, valor no significativo

Category	Seasons		*P*-value	Upwelling regimes		*P*-value
Holoplankton	Summer 2013 *vs*	Fall 2013	<0.05	MUP *vs*	DWN	<0.05
	Summer 2013 *vs*	Spring 2013	<0.05	MUP *vs*	LUP	<0.0001
	Summer 2013 *vs*	Winter 2014	<0.00001	HUP *vs*	LUP	<0.01
	Winter 2013 *vs*	Winter 2014	<0.0001			
Meroplankton	Summer 2013 *vs*	Winter 2013	<0.01	MUP *vs*	HUP	<0.001
	Summer 2013 *vs*	Spring 2013	<0.001	MUP *vs*	LUP	<0.00001
	Summer 2013 *vs*	Winter 2014	<0.00001	DWN *vs*	LUP	<0.01
	Fall 2013 *vs*	Winter 2014	<0.001			
Decapods	Fall 2013 *vs*	Winter 2013	<0.01	DWN *vs*	HUP	<0.01
	Fall 2013 *vs*	Spring 2013	<0.001	DWN *vs*	LUP	<0.01
Fish eggs	Summer 2013 *vs*	Fall 2013	<0.01	MUP *vs*	DWN	<0.01
	Summer 2013 *vs*	Spring 2013	<0.00001	MUP *vs*	LUP	<0.05
	Fall 2013 *vs*	Winter 2014	<0.0001			
	Winter 2013 *vs*	Winter 2014	<0.001			
	Spring 2013 *vs*	Winter 2014	<0.00001			
Fish larvae	Fall 2013 *vs*	Spring 2013	<0.05	DWN *vs*	LUP	<0.05
	Winter 2013 *vs*	Spring 2013	<0.01	HUP *vs*	LUP	<0.05
Copepods	Summer 2013 *vs*	Winter 2014	<0.01	NS		
	Winter 2013 *vs*	Winter 2014	<0.05			
	Spring 2013 *vs*	Winter 2014	<0.001			

of pelagic organisms by influencing (increasing) the retention times within bays like Totoralillo. Similarly, Cury & Roy (1989) demonstrated that fish larvae recruitment was highest at intermediate, rather than strong upwelling intensity in the Peruvian, California, Moroccon, and Senegalese upwelling systems.

We identified 166 taxa, highlighting the importance that these environments have for holoplanktonic species, and the role of such species in coastal trophic webs (Escribano 1998, Vargas *et al.* 2006, El-Sabaawi *et al.* 2010). This is also true for meroplankton, and emphasis should be placed in realizing how these coastal environments serve as breeding/nursery grounds for pelagic species (*i.e.*, anchovies and sardines Hernández-Miranda *et al.* 2003) or nurseries for benthic species (*i.e.*, decapod crustaceans Palma *et al.* 2006, mollusks Poulin *et al.* 2002a, b). If the prevailing physical conditions (*i.e.*, occurrence of upwelling or downwelling favorable events) alongside other mechanisms -that determine the patterns of zooplankton distribution and abundance- are recurring; then it becomes of utmost importance to recognize that embayment systems, such as Totoralillo Norte, represent discrete, yet complex environments along the Chilean coast and their conservation should be a priority that future sustainable endeavors should embrace.

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