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Hydromedusae (Cnidaria) of the Chilean southern channels (from the Corcovado Gulf to the Pulluche-Chacabuco Channels)

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SUMMARY: Hydromedusae collected in epipelagic waters of the channels in southern Chile, between the Corcovado Gulf and the Pulluche-Chacabuco channels, were analysed. A total of 23 species were identified and recorded for the first time in this region. The most abundant species were *Hydractinia minuta* (44.4%), *Clytia* spp. (21.0%), *Solmundella bitentaculata* (14.5%), and *Amphogona apicata* (9.8%). *H. minuta* was the only species whose maximum abundance occurred in interior, low temperature, low salinity waters. Most of the species identified in the southern channels are common inhabitants of the Humboldt Current System, although a rare species (*Heterotiara minor*) was recorded for the first time in Chilean waters. High-diversity values (> 2.5 bits) were recorded in the oceanic waters of the adjacent Pacific Ocean.

Keywords: Hydrozoa, medusae, distribution, diversity, southern channels, Chile.

RESUMEN: Hydromedusas (Cnidaria) de los canales del sur de Chile (del Golfo Corcovado a los Canales Pulluche-Chacabuco). – Se analizaron las hidromedusas colectadas en aguas epipelágicas de los canales del sur de Chile, entre el golfo Corcovado y los canales Pulluche-Chacabuco. Se identificó un total de 23 especies de hidromedusas, todas ellas registradas por primera vez en esta región y *Heterotiara minor* fue registrada por primera vez en aguas chilenas. Las especies más abundantes fueron *Hydractinia minuta* (44.4%), *Clytia* spp. (21.0%), *Solmundella bitentaculata* (14.5%), y *Amphogona apicata* (9.8%). *H. minuta* fue la única especie cuya abundancia máxima ocurrió en aguas interiores de baja temperatura y baja salinidad. La mayoría de las especies identificadas en los canales australes son habitats comunes del Sistema de la Corriente de Humboldt. Los mayores valores de diversidad (> 2.5 bits) se estimaron en aguas oceánicas del Pacífico adyacente.

Palabras clave: Hidrozoos, medusas, distribución, diversidad, canales australes, Chile.

INTRODUCTION

Over the last ten years, a systematic research programme has been carried out in southern Chile, particularly in the interior waters of the fjords and channels, resulting in significantly increased knowledge and understanding of the oceanographic and zooplankton characteristics of the interior waters between Puerto Montt and Cape Horn (Palma and Silva, 2004).

Zooplankton studies in Chile's southern fjords and channels have focused on chitinous organisms such as copepods, euphausiids, and the larvae of decapod crustaceans (Guglielmo and Ianora, 1995, 1997; Mujica and Medina, 1997, 2000; Palma *et al.*, 1999; Marín and Delgado, 2001; Palma and Aravena, 2001) and some gelatinous (siphonophores) or semigelatinous (chaetognaths) organisms (Palma and Rosales, 1997; Palma *et al.*, 1999; Palma and Aravena, 2001, 2002). Although hydromedusae are common to all the oceans, no information is available regarding these conspicuous gelatinous organisms in this extensive southern channel region except for the work of Pagès and Orejas (1999), which describes the presence of 17 species around the Strait of Magellan.

Hydromedusae are also known as craspedota medusae because they have velum and several species have a metagenetic life cycle, and because their sexual stage consists of an alternation in which asexual polyps are generated. The geographic distribution of these largely epipelagic planktonic organisms is closely associated with coastal waters. Several species of hydromedusae have a high capacity of asexual reproduction and they can form dense aggregates in these areas, especially during the warmest periods of the year. Gelatinous organisms frequently invade coastal upwelling areas, taking advantage of the greater trophic availability (Pagès, 1992; Palma and Rosales, 1995; Palma and Apablaza, 2004). Recent studies show a steady increase in the populations of gelatinous organisms in diverse marine areas (Mills, 2001; Brodeur *et al.*, 2002). These organisms play a preponderant role in zooplankton structure and dynamics due to the heavy impact of their predatory activity (Matsakis and Conover, 1991). Some medusae species have also proliferated in the interior waters of Chile's southern region. In fact, from February to June 2002, proliferations of *Aequorea coerulescens, Chrysaora plocamia*, and *Phacellophora camtschatica* affected salmon farming installations in the interior waters off Chiloé Island, with high mortality rates for the farmed fish (unpublished data).

The purpose of the present study was to investigate the composition, abundance, and diversity of hydromedusae and their relationship with the oceanographic conditions present in the southern Chilean channels, between the Corcovado Gulf and the Pulluche-Chacabuco channels.

MATERIALS AND METHODS

During the CIMAR 8 Fiordos Cruise (16-24 November 2002), 38 oceanographic stations were sampled in one longitudinal (Corcovado Gulf-Moraleda Channel) and several transverse channels (Tuamapu, King, Ninualac, Darwin, Chacabuco, and Pulluche channels) between the Corcovado Gulf (43°40'S) and the Pulluche-Chacabuco channels

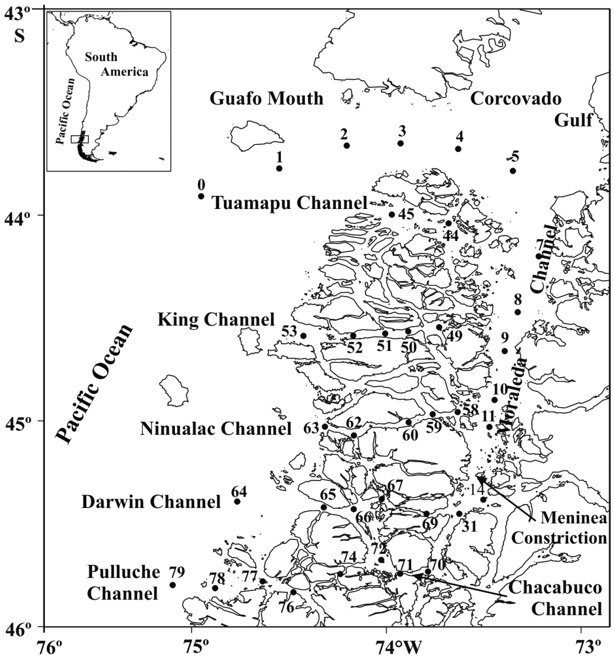

FIG. 1. – Geographic location of sampling stations in the southern Chilean channels.

(45°47'S) (Fig. 1). Vertical profiles were taken for temperature, salinity, and dissolved oxygen with a CTDO SeaBird 25. The maximum sampling depth was 300 m (Rojas *et al.*, 2005). The CTDO did not work properly at Stations 0 to 3 at the Guafo Mouth. Water masses were analysed based on T-S diagrams according to Silva *et al.* (1997, 1998).

At all stations, zooplankton catches were made with oblique tows from a maximum of 200 m to the surface, using Bongo nets (60 cm diameter, 350 µm mesh). The nets were equipped with flowmeters to estimate the volume of water filtered. Plankton samples were taken with day and night-time hauls. Specimens were conserved in seawater with 5% borax buffered formalin and deposited in the collection of Laboratorio de Planctología, Escuela de Ciencias del Mar, Pontificia Universidad Católica de Valparaíso, Chile. All species were identified based on the current status of taxonomic information and classification (Bouillon *et al.*, 2004). The geographic distribution of the medusae was analysed according to the dominant species, which were considered to be those whose abundance was greater than 5% of the total collected specimens.

A cluster analysis was carried out using the log (x+1) relative abundance transformation to describe the species' distribution patterns, and to determine the sample group with the greatest specific affinity. The Bray-Curtis Index of Similarity (Bloom, 1981) was used to perform the clusters analysis. Furthermore, we estimated the Shannon-Wiener Diversity Index (ind bits^{-1}) and Pearson's correlation coefficient between the relative abundance of dominant species and surface values of temperature and salinity in the study area.

RESULTS

Oceanographic characteristics

Due to the scope of this paper, only the most important oceanographic features for understanding

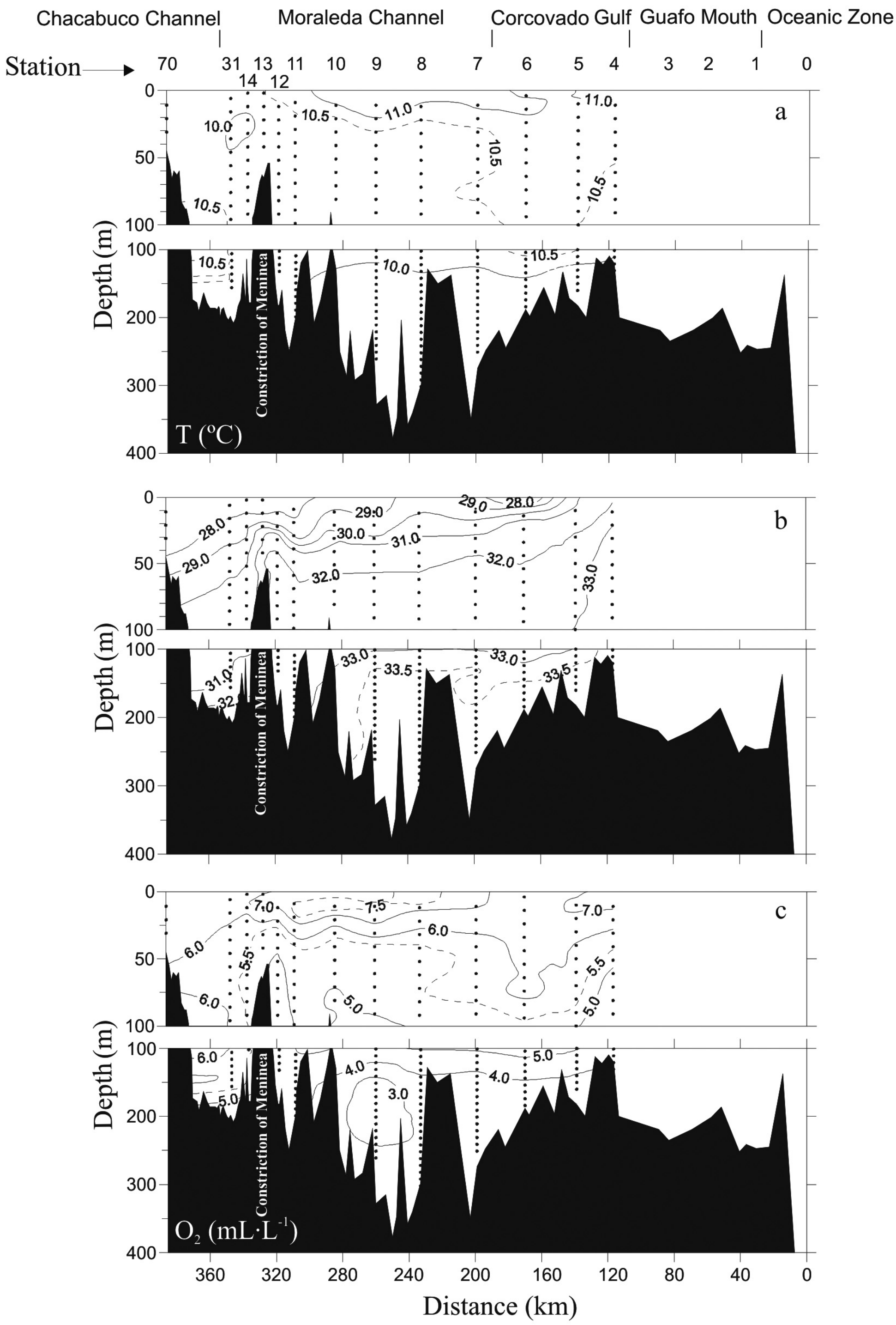

FIG. 2. – Vertical distribution of a) temperature, b) salinity, and c) dissolved oxygen in an oceanographic transect between the Guafo Mouth and the Chacabuco Channel.

the geographic distribution of the hydromedusae are analysed. The vertical temperature distribution was very homogenous between the Corcovado Gulf and the Chacabuco Channel (Fig. 2). In the longitudinal section, surface temperatures fluctuated between 10.5 and 11.0°C, the highest temperatures being found in the Moraleda Channel. In this section, the vertical temperature distribution was very homogeneous and no seasonal thermocline was present (Fig. 2). Surface salinity values (32; Corcovado Gulf) decreased gradually toward the south (28; Meninea Constriction). Vertical salinity distribution showed a strong halocline, especially in the upper 50 m. Below 50 m, salinity was higher to the north of the Meninea Constriction (32-33) and lower to the south of it (30-31). The high dissolved oxygen levels (> 6 mL L^{-1}) at the surface decreased to 150 m depth and were lower to the north of the Meninea Constriction (3-4 mL L^{-1}) and higher to the south of it (5-6 mL L^{-1}) (Fig. 2).

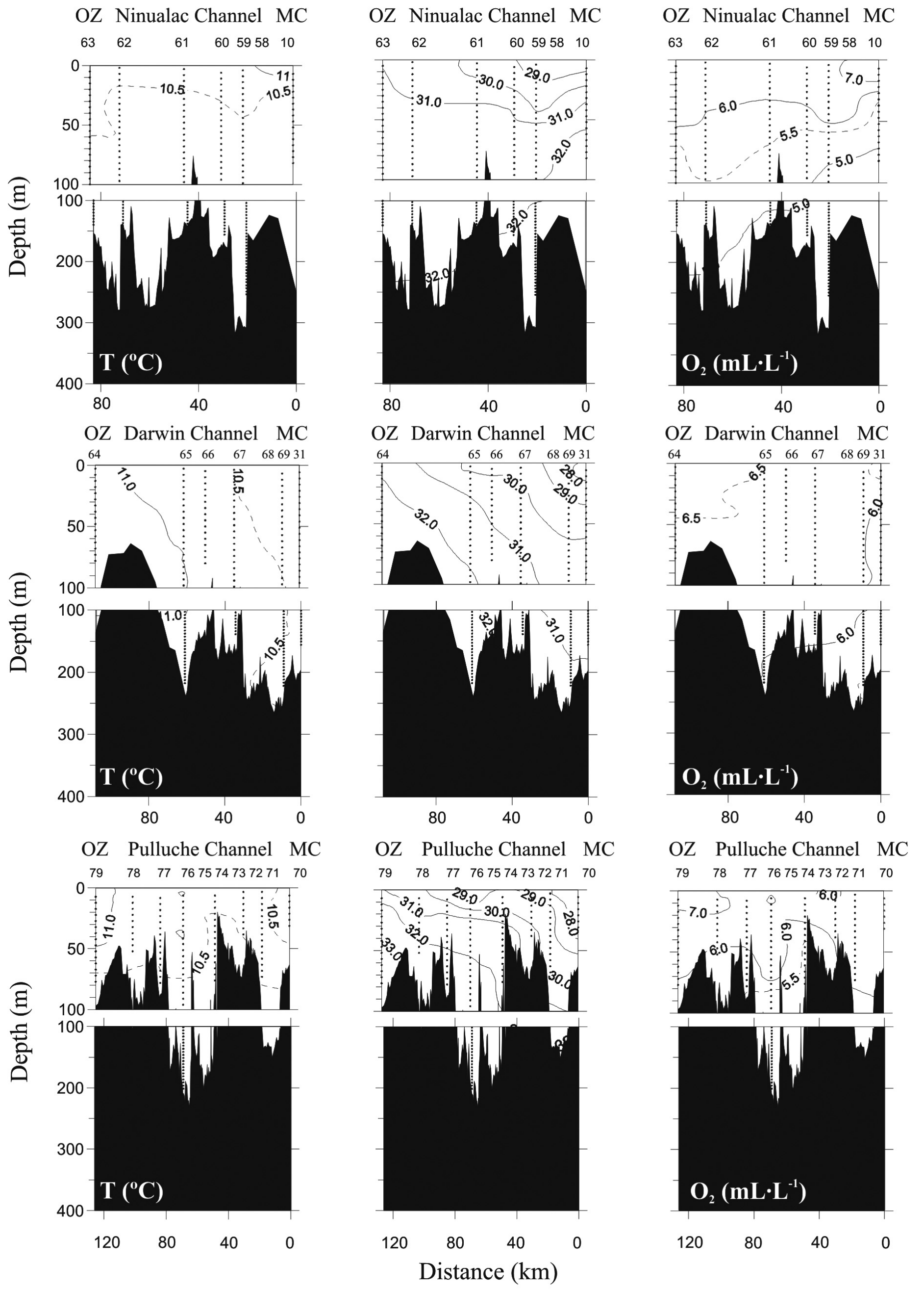

FIG. 3. – Vertical distribution of temperature, salinity, and dissolved oxygen in the Ninualac, Darwin, and Pulluche channels. OZ: Oceanic Zone, MC: Moraleda Channel.

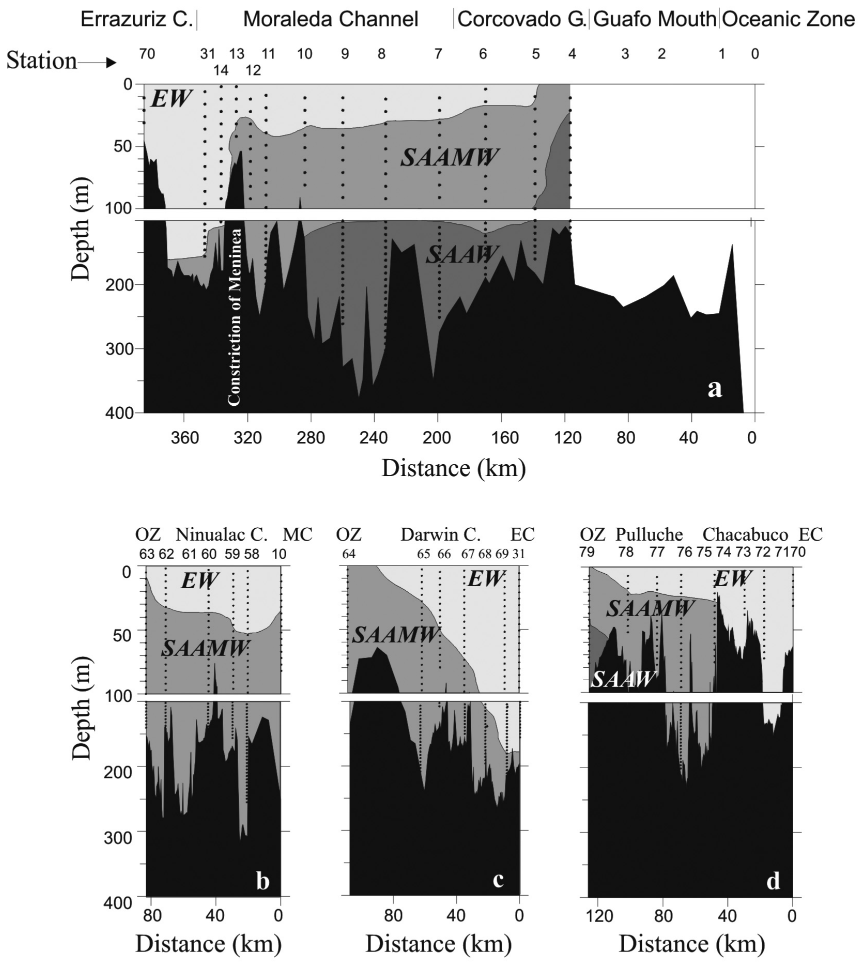

FIG. 4. – Vertical distribution of water masses in the study area, a) Moraleda Channel, b) Ninualac Channel, c) Darwin Channel, and d) Pulluche-Chacabuco channels. OZ: Oceanic Zone, MC: Moraleda Channel, EC: Errázuriz Channel, EW: Estuarine Water, SAAW: Sub-Antarctic Water, SAAMW: Sub-Antarctic Modified Water.

The vertical sections of the transverse channels (Ninualac, Darwin, and Pulluche) were similar to those of the longitudinal channel described above. The most characteristic features in these channels were increased surface salinity from east (interior waters; 28-29) to west (adjacent Pacific Ocean waters; 32-33) and the absence of low-oxygen waters (< 2.5 mL L^{-1}) near the bottom (Fig. 3).

According to the T-S diagrams (not shown) and the descriptions in Silva *et al*. (1997), three water masses have been identified in this area:

a) Sub-Antarctic Water (SAAW), 0-100 m, from the adjacent coastal zone enters through the Guafo Mouth into the Moraleda Channel and sinks below 100 m depth. However, it does not enter the Moraleda and Errázuriz channels through the transverse channels. The temperature of SAAW ranges between 9 and 13ºC, salinity of between 33.0 and 33.9, and dissolved oxygen between 5 and 8 mL L^{-1}.

b) Sub-Antarctic Modified Water (SAAMW), characteristic of the upper layer (30-100 m) in interior channels and distinguished by a salinity of between 31 and 33.

c) Estuarine Water (EW) in the upper layer (0-50 m) of the inner channels, characterised by lower salinity (2 to 31). SAAMW and EW are formed when SAAW is mixed with variable amounts of fresh water from rain, rivers, and glacial melting as SAAMW penetrates towards the continental channels and fjords (Fig. 4).

Species composition and distribution

In total, 23 species of hydromedusae were identified (Table 1) and recorded in this zone (43º40'-45º47'S) for the first time. Moreover, *Heterotiara minor* was registered for the first time ever in Chilean waters. Dominant species were: *Hydractinia* (=*Podocoryna*) *minuta* (44.4%), *Clytia* spp. (21.0%), *Solmundella bitentaculata* (14.5%), and *Amphogona*

TABLE 1. – Mean abundance, standard deviation, total abundance and percentage of hydromedusae collected in the study area. Asterisk indicates the species recorded in the Magellan region by Pagès and Orejas (1999).

Species	Mean (ind 1000/m^3)	Standard deviation	Total abundance (ind/1000 m^3)	Percentage (%)
Hydractinia minuta (Mayer, 1900) *	1867.9	6884.0	70981	44.4
Clytia spp.	882.1	1344.1	33519	21.0
Solmundella bitentaculata (Quoy and Gaimard, 1833) *	611.3	792.0	23231	14.5
Amphogona apicata Kramp, 1957 *	413.9	512.1	15727	9.8
Obelia spp. *	135.0	255.4	5128	3.2
Bougainvillia sp. *	60.9	94.9	2315	1.4
Proboscidactyla ornata (McCrady, 1857)	56.2	119.2	2137	1.3
Hydromedusa sp. 1	35.3	60.1	1340	0.8
Rhopalonema velatum Gegenbaur, 1856 *	27.6	50.6	1051	0.7
Phialella quadrata (Forbes, 1848)	26.3	94.0	1000	0.6
Euphysa aurata Forbes, 1848 *	23.7	40.8	901	0.6
Leuckartiara octona (Fleming, 1823) *	14.4	28.3	545	0.3
Halopsis ocellata A. Agassiz, 1863 *	13.3	43.0	506	0.3
Liriope tetraphylla (Chamisso and Eysenhardt, 1821)	10.0	20.1	378	0.2
Proboscidactyla stellata (Forbes, 1846)	9.9	15.4	375	0.2
Hydractinia borealis (Mayer, 1900) *	7.3	28.6	278	0.2
Proboscidactyla mutabilis (Browne, 1902) *	3.1	6.2	119	0.1
Cunina peregrina Bigelow, 1909	2.9	8.7	108	0.1
Amphinema rugosum (Mayer, 1900) *	2.2	6.2	85	0.1
Aglaura hemistoma Péron and Lesueur, 1810	1.5	6.6	58	0.01
Sarsia eximia (Allman, 1859)	1.3	4.6	48	0.01
Ectopleura dumortieri (van Beneden, 1844)	0.4	1.7	15	0.01
Heterotiara minor Vanhöffen, 1911	0.3	2.1	13	0.01
Dipurena sp.	0.2	1.0	6	0.01

apicata (9.8%). *Clytia* spp. was the most frequently observed species, being present at 97.4% of the sampled stations. The remaining species were scarce and some (e.g. *Heterotiara minor* and *Dipurena* sp.) were found at only one station.

Medusae were found throughout the study area and were most abundant in interior waters. Abundance fluctuated between 193 ind/1000 m^3 at Station 45 at the west end of the Ninualac Channel and 42500 ind/1000 m^3 at Station 14 in the Moraleda Channel; the average per station was 4172 ind/1000 m^3. A general east-west decrease in the total abundance distribution was found in the transverse channels (Fig. 5).

The predominant species, *Hydractinia minuta*, was distributed mainly in interior waters, with the greatest densities in the eastern segments of the Ninualac, Darwin, and Chacabuco channels and a maximum of 41032 ind/1000 m^3 at Station 14. The lowest densities (<260 ind/1000 m^3) were registered mainly in the oceanic waters, the Corcovado Gulf and the Moraleda Channel, and at the western stations of the transverse channels (Fig. 5a). In general, *H. minuta* populations were mostly made up of juveniles; most mature adult specimens were budding.

The second most abundant species, *Clytia* spp., was distributed widely throughout the study area. The highest densities were registered in the oceanic area off the Guafo Mouth, in the King Channel, and at some stations in the Ninualac and Darwin channels, and a maximum of 7784 ind/1000 m^3 was found at Station 51. Densities were lowest in the Corcovado Gulf and the Moraleda and Chacabuco channels (Fig. 5b). This was the only dominant species with high concentrations in the oceanic sector off the Guafo Mouth.

Solmundella bitentaculata was distributed throughout the study area, with peaks in the King and Ninualac channels. Density was highest (4152 ind/1000 m^3) at Station 49 at the eastern tip of the King Channel and lowest in oceanic waters, the Corcovado Gulf, and the Chacabuco Channel (Fig. 5c).

Amphogona apicata was also found throughout the study area. Densities for this species were highest in the Ninualac Channel (maximum 2410 ind/1000 m^3) at Station 58 and, as for *H. minuta* and *S. bitentaculata*, lowest in oceanic waters, the Corcovado Gulf, and the Darwin and Chacabuco channels (Fig. 5d).

Specimens of the remaining species were scarce and infrequent, except for *Bougainvillia* sp. (454 ind/1000 m^3) and *Obelia* spp. (1206 ind/1000 m^3), which were highly concentrated at some stations in the King and Pulluche channels, respectively.

Similarity analysis

Based on the Bray-Curtis similarity analysis, two groups of stations were defined (Fig. 6). The first,

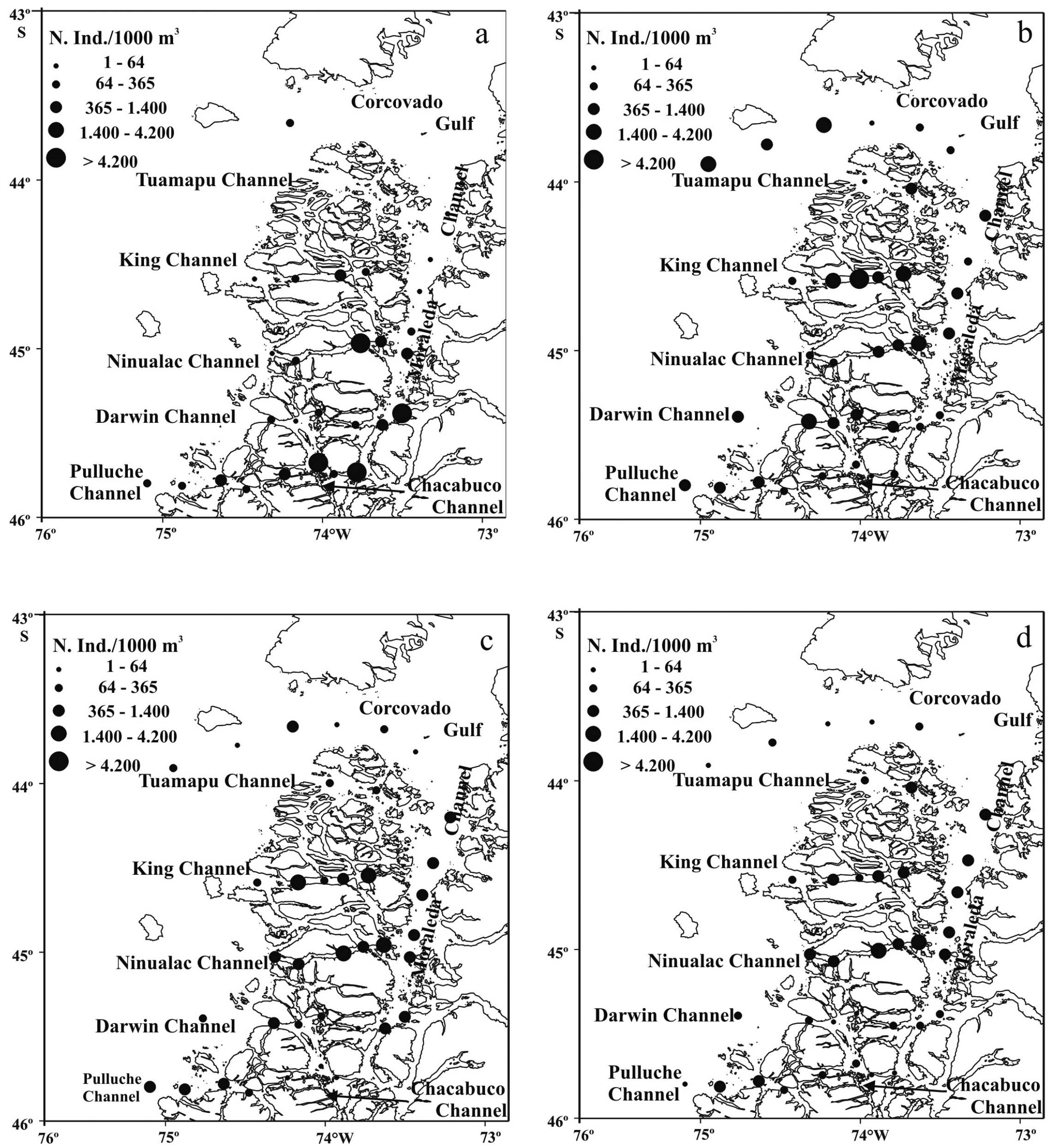

FIG. 5. – Geographic distribution and abundance of a) *Hydractinia minuta*, b) *Clytia* sp., c) *Solmundella bitentaculata*, and d) *Amphogona apicata*.

Group A, included a large number of analysed stations (82%) whereas the second, Group B, consisted of a few stations (18%) located in the most south-eastern area and characterised by high densities of *Hydractinia minuta*.

Diversity index

Diversity index values fluctuated between 0.28 and 3.31 bits at Stations 3 and 14, respectively (Fig. 7). The greatest values (>2.5 bits) were found at the Guafo Mouth and the western stations of the King, Darwin, and Pulluche channels. Diversity was highest at the latter channel.

Correlation coefficient

Results of the correlation analysis between the relative abundance of dominant species and the surface values of oceanographic parameters showed significant values only for *Hydractinia minuta* and *Clytia* spp. (Table 2). *H. minuta* abundance was negatively correlated with temperature and salinity and *Clytia* spp. abundance was positively correlated with temperature.

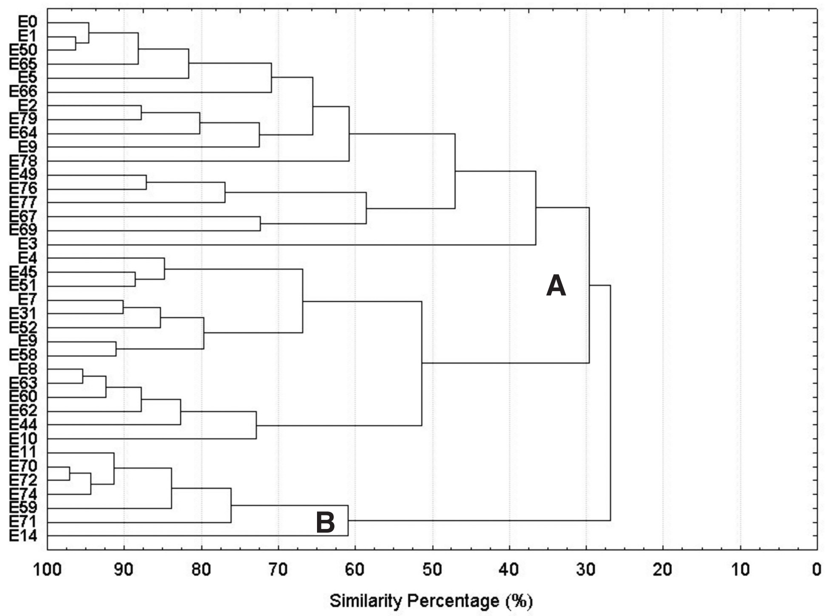

FIG. 6. – Dendrogram from analysis based on Bray-Curtis Index showing distribution of the clusters in the surveyed area.

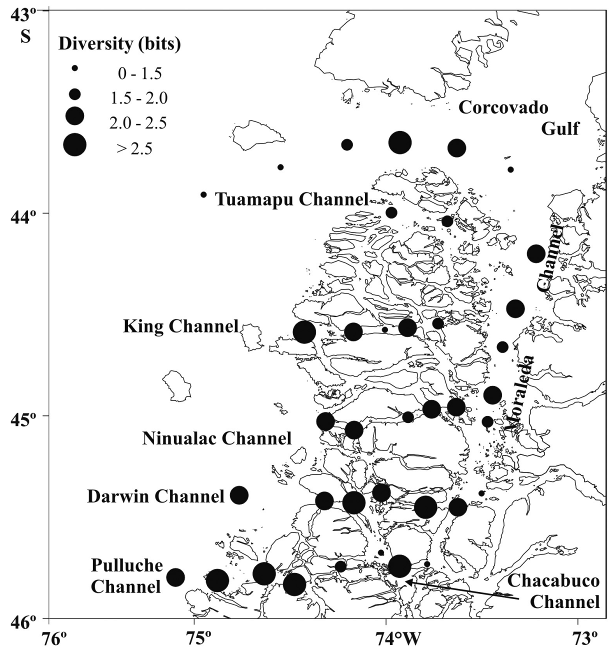

FIG. 7. – Diversity index of hydromedusae in the southern Chilean channels.

DISCUSSION

Our observations of oceanographic characteristics in the study area confirm those previously reported for this channel zone. However, on this occasion, bottom waters of the Corcovado Gulf and the Moraleda Channel did not show a salinity higher than 34.0 psu or a level of dissolved oxygen lower than 3.0 mL L^{-1}. This implies the absence of remnants of ESSW in the Moraleda Channel, as found on previous cruises (Silva *et al*., 1997, 1998). The most characteristic feature is the variation in salinity between oceanic and interior waters (Silva *et al*., 1997, 1998; Guzmán and Silva, 2002). Low salinity oceanographic conditions generated in interior waters can affect the presence, distribution and aggregation of zooplanktonic organisms (Palma and Silva, 2004).

The geographic distribution of the hydromedusae (Fig. 5) was characterised by low densities at the Guafo Mouth and in the Corcovado Gulf due to lower stability in the vertical water column caused by wind mixing. This less environmentally stable area is characterised by low biomass values and zooplanktonic abundance (Mujica and Medina, 1997; Palma and Rosales, 1997; Palma and Silva, 2004). On the other hand, the areas with the greatest aggregates of medusae corresponded to eastern stations in the King, Ninualac, and Pulluche channels; these are characterised by lower salinity EW, which increases the water column stability (Fig. 7). The overall increase in the total abundance distribution from west to east in the transverse channels (Fig. 5) was probably associated with the west-east increase in water column stability. This characteristic is probably more suitable for the aggregation of this species. Most of the non-dominant medusae species occurred in low numbers, which is common in medusan communities. Furthermore, communities of planktonic cnidarians are frequently dominated

TABLE 2. – Correlation values between the relative abundances and the environmental variables. Significant values are indicated in bold (p <0.05).

	Hydractinia minuta	*Clytia* spp.	*Solmundella bitentaculata*	*Amphogona apicata*
Hydractinia minuta				
Clytia spp.	-0.21			
Solmundella bitentaculata	-0.19	0.23		
Amphogona apicata	0.15	0.08	**0.63**	
Temperature	**-0.53**	**0.44**	0.03	-0.22
Salinity	**-0.66**	0.36	0.34	-0.09
Dissolved oxygen	-0.25	0.20	-0.07	-0.13

by a few of the most common species, particularly in the southern Chilean channels (Palma and Rosales, 1997; Palma and Silva, 2004).

The known geographic distribution ranges (for Chilean waters) of all the species identified in this study increased due to the new geographic records presented herein. *Heterotiara minor* was observed for the first time in Chilean waters. Three quarters of the species identified in this area (Table 1) have also been observed in the Magellan channels (Pagès and Orejas, 1999) and the majority of the observed species are epipelagic and commonly found in the Humboldt Current System (HCS) (Kramp, 1966, 1968; Fagetti, 1973; Palma, 1994; Palma and Rosales, 1995; Palma and Apablaza, 2004).

Hydractinia minuta had the smallest geographic distribution of the dominant species and its largest aggregates were observed in interior waters (Figs. 5 and 6). Aggregates were observed in interior waters with low temperatures and salinity (Pearson, r = –0.53 and –0.66 respectively; Table 2) associated with EW, and the SAAMW found at the eastern end of the Ninualac, Darwin, and Pulluche channels (Fig. 4). In this area, the oceanic influence is weak, with low species diversity. This is confirmed by the Bray-Curtis clustering stations (Fig. 6). This species has also been found in very low numbers in the Magellan channels and is rare in temperate waters of both hemispheres (Pagès and Orejas, 1999).

Medusae of the genus *Clytia* were most abundant in the oceanic waters off the Guafo mouth and the King Channel (Fig. 5b). *Clytia* is made up of some twelve species, several of which are cosmopolitan and found mostly in temperate and warm waters (Kramp, 1968). In the HCS, *Clytia* medusae are common and abundant (Fagetti, 1973; Palma, 1994; Palma and Rosales, 1995; Pagès *et al*., 2001; Palma and Apablaza, 2004), with *Clytia simplex* probably the predominant species (Kramp, 1966). These results confirm the wide geographic distribution of this species off the Chilean coast (Kramp, 1966), and its abundance in low-salinity inner waters suggests a marked euryhaline nature.

The maximum abundances of *Solmundella bitentaculata*, registered in King and Ninualac channels (Fig. 5c), were two orders of magnitude greater than those registered in the Strait of Magellan (Pagès and Orejas, 1999). *S. bitentaculata* is very frequent from Mejillones to the Strait of Magellan (Kramp, 1966; Fagetti, 1973; Palma and Rosales, 1995; Pagès and Orejas, 1999; Pagès *et al*., 2001; Palma and Apablaza, 2004). This species is widely distributed in tropical and subtropical seas, mainly in the southern hemisphere, and in Antarctic and Sub-Antarctic waters (Kramp, 1952, 1968).

Amphogona apicata was most abundant in the areas least influenced by oceanic waters, such as the Moraleda Channel and interior sectors of the King and Ninualac channels (Fig. 5d), where EW and SAAMW predominated (Fig. 4). Abundance was similar to that registered in the Beagle Channel (55ºS), where this species was the most abundant medusa found between 100 and 400 m depth (Pagès and Orejas, 1999). *A. apicata* is a mesopelagic species widely distributed throughout the Atlantic but rarely observed in the Indian and Pacific oceans. In the Pacific, it has been found off New Zealand (Kramp, 1968), from Mexico to Peru (Segura-Puertas, 1984), and later in the Magellanic channels (Pagès and Orejas, 1999).

The high diversity values (>2.5 bits) estimated for the Guafo Mouth and the oceanic stations in the King, Darwin, and Pulluche channels (Fig. 6) were due to the predominance of oceanic waters from the adjacent Pacific Ocean. In these areas, the density of medusae was lower and we collected several species that we did not find in the interior waters, such as *Aglaura hemistoma*, *Amphinema rugosum*, *Dipurena* sp., *Hydractinia borealis* and *Liriope tetraphylla*. A similar feature was found in the siphonophoran communities of in the same area (Palma and Rosales, 1997).

The faunistic similarity among the stations of interior waters (Fig. 6), typified by the abundance of *H. minuta*, suggested that this species is highly associated with low salinity EW and does not proliferate in the more oceanic, higher-salinity waters with a marked prevalence of SAAMW below 50 m depth.

We also observed a significant correlation between the high densities of *Hydractinia minuta* and the low-temperature and low-salinity EW. The majority of *Clytia* spp. were found in areas with water temperatures associated with SAAMW.

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