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Distribution and abundance of copepod nauplii in the vicinity of a submarine canyon (NW Mediterranean)

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Abstract. Distribution and abundance of copepod nauplii in relation to oceanic features detected by *in situ* data in the vicinity of the Palamos Canyon (NW Mediterranean) was analyzed. Vertical trawls (60-µm mesh) and physical data (CTD and ADCP), were obtained in a spring period (May 1992). The vicinity of the canyon was dominated by the Liguro-Provençal-Catalan Current (slope current), influenced by the fresh water from of the Rhône River runoffs, and perturbations of its flow induced by the submarine topography. High abundance of copepod nauplii were associated with the slope current waters and its intrusions into the canyon, showing an offshore-nearshore abundance gradient. The highest concentrations of copepod nauplii were found at the eastern margin of the slope current along of a shallow salinity front. Results showed that the spawning of dominant copepod species in the offshore zone could be related to retention areas, such as the salinity front, and to the biological enrichment of the slope current influenced by Rhône river discharges during the rainy period and ice melting of the Provençal mountains.

Key words: Copepod nauplii, submarine canyon, slope current, salinity front, NW Mediterranean.

The Catalan Sea (NW Mediterranean) has a high heterogeneity along its continental shelf, with several submarine canyons. These canyons induce perturbations in the slope current circulation, causing deviations of its flow coastwards the coast (Masó *et al.* 1992, Shirasago 1996). The offshore area is dominated by the dynamics of the Liguro-Provençal-Catalan Current (slope current), which appears geostrophicaly balanced with a weak permanent shelf-slope density front (Font *et al.* 1988, Castellón *et al.* 1990). This current flows from northeast to southwest and is influenced by cold Rhône River runoffs, generating shallow salinity gradients along the Catalonian and Provençal coast, varying in intensity throughout the year (Masó and Tintoré 1991).

An extensive research on the copepod fauna has been done during the last 30 years because they are important contributors to zooplankton biomass in the northwestern Mediterranean (e.g. Furnestin 1960, Vives 1963, Mazza 1966, 1967, Razouls 1972, Gaudy 1974, Furnestin 1979, Estrada *et al.* 1985, Kouwenberg 1993, 1994). Most common copepods in this region are cosmopolitan and their diversity is considerable with more than 469 species recorded (Razouls and Durands 1991). Studies about ecology of some copepod species in the Catalan Sea has been done (e.g. Saiz and Alcaraz 1990, Saiz *et al.* 1992), but scarce attention has been given to the spatial distribution of the copepod in relation to oceanographic features.

Particularly, the copepod nauplii of dominant species in productive areas are the feeding base of most marine fish larvae (e.g. Hunter 1981, Sánchez-Velasco 1998) and the other zooplanktonic groups (Alvarez-Cadena

1993, Behrends and Schneider 1995), being their distribution associated to the biological enrichment of the marine currents and the retention areas such as fronts, eddies etc. (Arthur 1977, Boucher 1984).

The aim of this study is to analyze the distribution and abundance of the copepod nauplii in relation to oceanic features detected by *in situ* data in the vicinity of the Palamos Canyon (Catalan Sea - NW Mediterranean) during spring (May 1992).

MATERIAL AND METHODS

The study was focused on the vicinity of the Palamos Submarine Canyon. Samples were obtained at 52 oceanographic stations distributed along 8 transects perpendicular to the coast, but biological samples were not obtained in the stations A21 and A22. The physical data and biological samples were collected during the PRIM-1 on board the R/V "García del Cid" (14 - 20 May, 1992). Salinity and temperature (not used) of the water column at each station were obtained with a CTD (Conductivity Temperature Depth Profiler) Neil Brown Mark III. Current profile measurements were recorded with an ADCP (Acoustic Doppler Current Profiler) RD Instruments VM150. ADCP data were analyzed at the minimum recording level (16 m). Four drifting buoys were deployed to the northeast of the canyon.

Vertical hauls of microzooplankton were made using a conical net with a 14.5-cm mouth diameter and 60-m mesh. Samples were taken at two depth levels, from 40 to 25 m and from 15 m to the surface using opening-closing devices (hereafter referred to as subsurface and surface levels). The volume of water filtered by the net was calculated by multiplying the area of the mouth by the sampling distance. Each sample was fixed in 5% borax-buffered formalin immediately after capture. Copepod nauplii (from 0.05 to 0.14 mm caparace width) of the samples of both depth levels were counted. Data were standardized to number of organisms per cubic meters.

RESULTS

Distribution of salinity values obtained from CTD data at 10 and 30 m reflected the oceanographic conditions prevailing in the zone (Fig. 1). The presence of an offshore low-salinity tongue, parallel to the coast (NE-SW) and 15 km wide, is noticeable at both levels. Intrusion of this low-salinity water into the canyon was also observed. In addition, salinity gradients were detected on both sides of this tongue, being more intense along its eastern offshore margin. ADCP data revealed the presence of the slope current, coinciding with this tongue of low-salinity water, flowing from northeast to southwest, at speeds of up to 25 cm/s (Fig.2). A branch of this current entering and exiting the canyon was also observed with the ADCP data, and this was corroborated by the drifting buoy D1 deployed upstream, describing an incoming and outgoing path over the canyon. Buoy D2 followed the main trajectory of the slope current while Buoy D4 derived toward offshore areas. Buoy D3 was lost because of an electronic failure (Fig. 3).

Copepod nauplii were the group most abundant in the microzooplankton samples at both levels (Fig. 4). Most of them were nauplii of the *Paracalanus* sp., *Clausocalanus* sp., *Oithona helgolandica, Centropages typicus* and *Microsetella* sp., corresponding with the dominant species of the copepodites collected in the same samples. The copepod nauplii were distributed over all the study area, but they were most abundant in offshore stations located over depths $\geq$ 1000 m, at both surface and subsurface levels, including the canyon zone and its deep head, even though it is located very close to the coast (5 km) (Fig. 5). Highest organism concentration was at the eastern margin of the slope current, which coincided with the most intense salinity gradient detected in the study (Fig. 6).

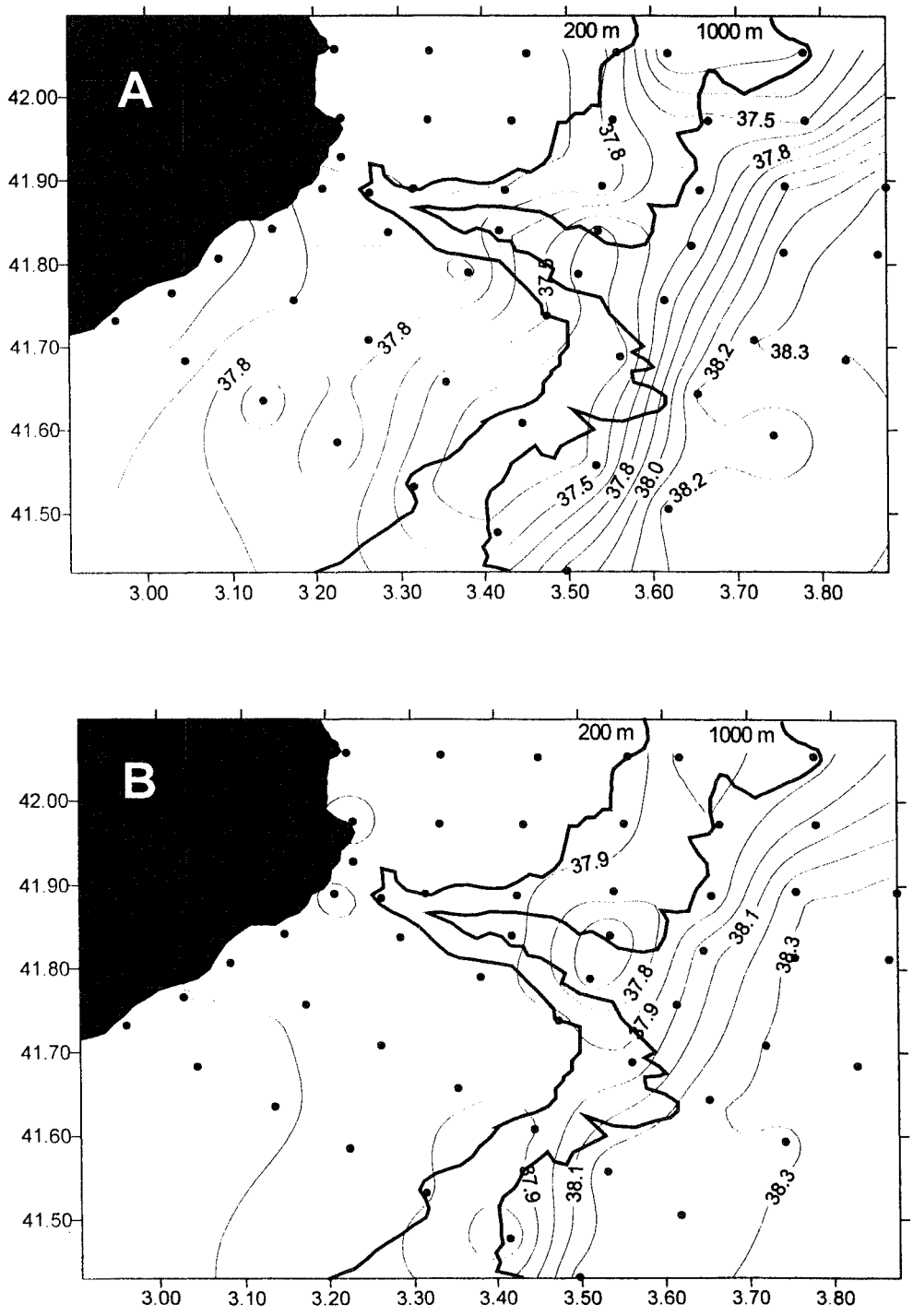

Fig. 1.- Spatial distribution of salinity values in the vicinity of Palamos Canyon. A) Surface level (10m depth) and B) Subsurface level (30m depth).

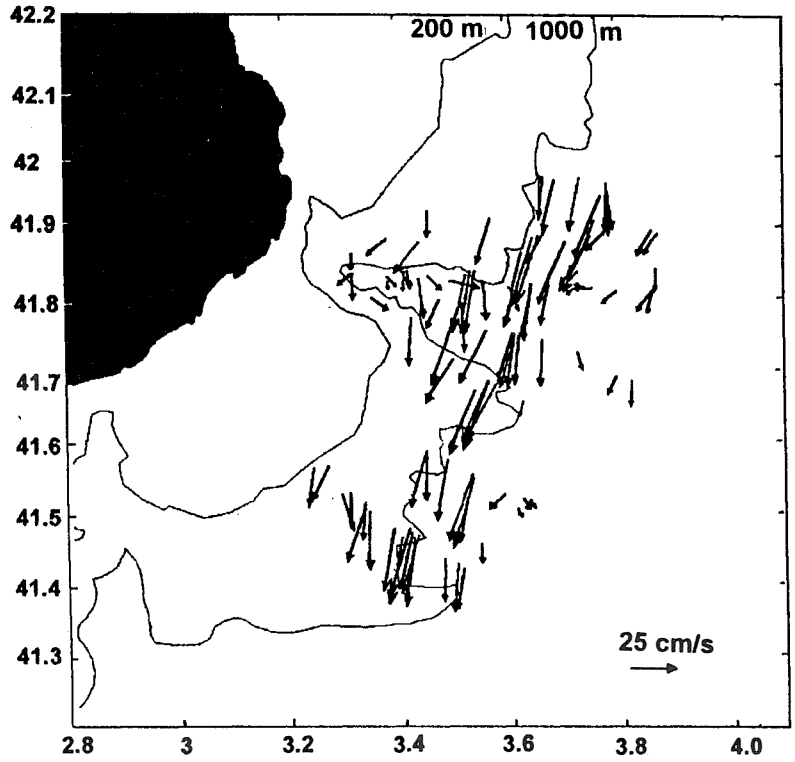

Fig. 2.- ADCP velocity vectors (cm/s) at the minimum recording level of 16 m in the vicinity of Palamos Canyon.

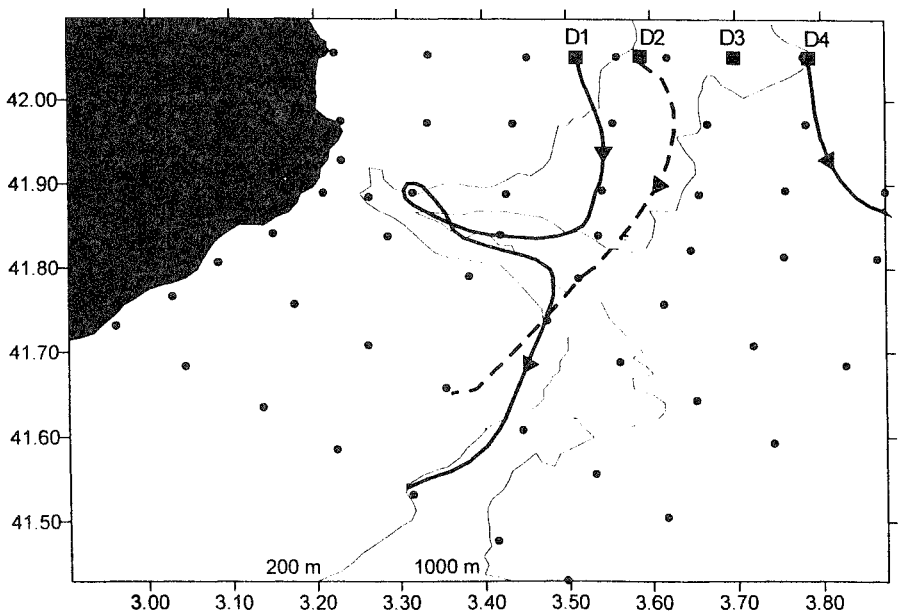

Fig. 3.- Trajectory of the drifting buoys deployed to the northeast of the Palamos Canyon.

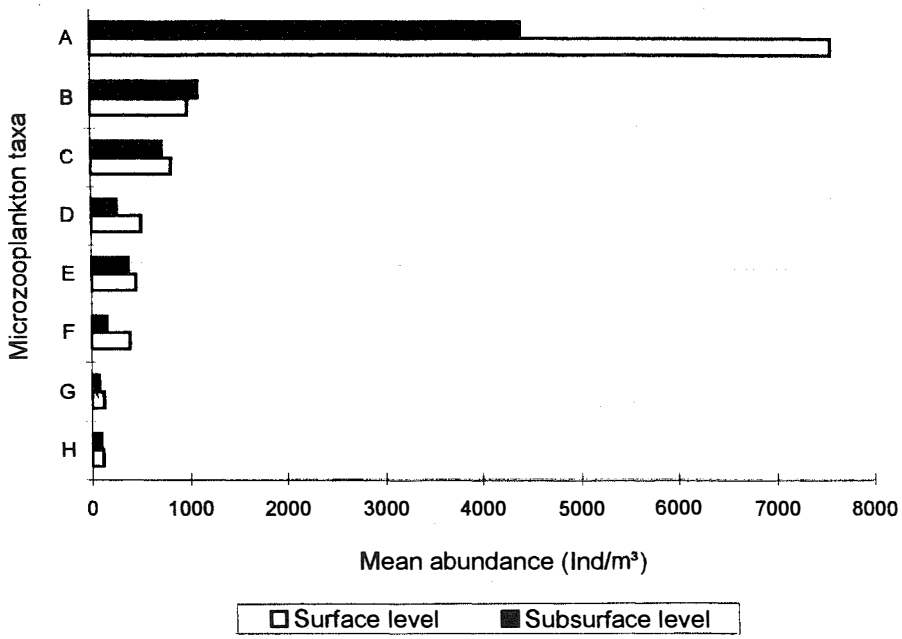

Fig. 4.-Mean density of the most abundant microzooplankton taxa collected in the vicinity of Palamos Canyon. A, copepod nauplii; B, copepodites *Paracalanus-Clausocalanus* spp.; C, Copepodites *Oithona* spp.; D, larvacea; E, Copepodites *Centropages* spp.; F, *Oithona helgolandica;* G, Pelecypoda veliger; H, *Microsetella* sp.

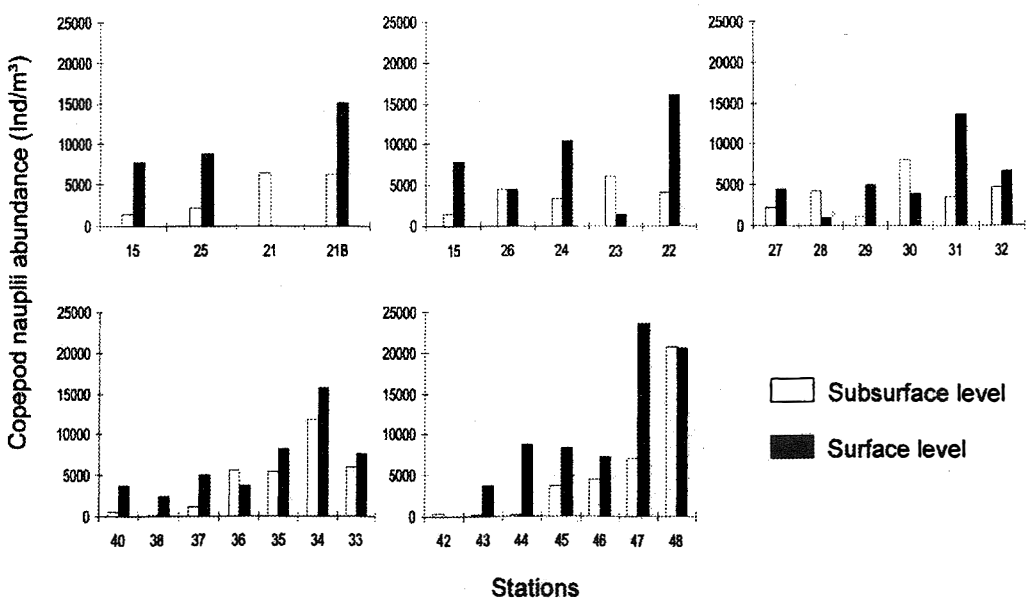

Fig. 5.- Abundance of copepod nauplii in transects perpendicular to the coast. Coastal stations to the left and oceanic stations to the right.

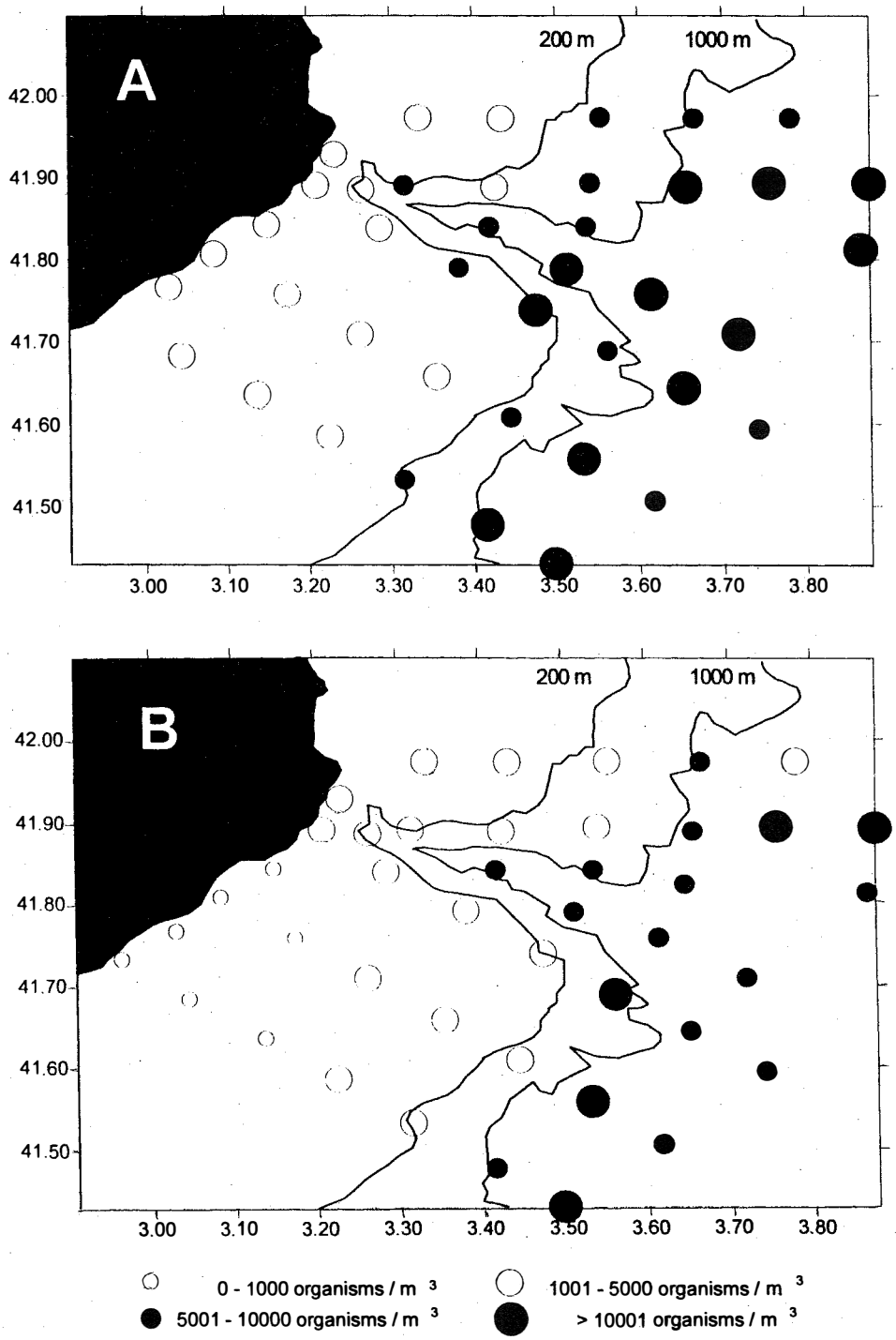

Fig. 6.- Distribution of copepod nauplii in the vicinity of Palamos Canyon. A) Surface level (15-0 m) and B) Subsurface level (40-25 m).

DISCUSSION

High abundance of copepod nauplii was associated with the slope-current waters, its intrusions into the canyon, and the shallow salinity gradient detected at its eastern margin. Physical data showed that the slope current was influenced by the Rhône River runoffs because of the fresh water that characterized this current. Maso and Tintoré (1991) and Shirasago (1996) mentioned that the Rhône River runoff incorporates high concentrations of organic material into the slope current, increasing such discharges in the spring as a result of the ice melting on the Provençal mountains and the beginning of the rainy season. Estrada and Margalef (1988) recorded high primary productivity in the slope-current area during the same period. Thus, it is possible that the great concentrations of copepod nauplii recorded in this area are associated with biological enrichment of the slope-current waters by the Rhône River discharges during spring.

The intrusions of the western branch of the slope current into the canyon, have been explained in terms of the conservation of potential vorticity by Masó *et al.* (1992) in a neighbouring canyon of Blanes, and by Alvarez (1995) and Shirasago (1996) in the Palamos Canyon that. Our observations on the distribution of the copepod nauplii showed high abundance occurs in the canyon zone, suggesting there is an oceanic influence near the coastal zone. It seems likely the slope-current intrusions are transporting high planktonic biomass into the canyon up to its head and consequently increase the food availability to organisms that inhabit the continental shelf edge and slope.

The highest abundances of copepod nauplii were recorded in the eastern margin of the slope current, close to the shallow salinity gradient, influenced by the Rhône river runoffs over the slope current water during the study period. Shirasago (1996) detected a cyclonic eddy by NOAA-AVHRR data which appears on the eastern edge of the shallow salinity gradient. This author mentioned that even though there is not sufficient information about this eddy, the interaction of the western edge of the eddy with the salinity gradient could contribute to the enhancement of planktonic-biomass concentration. The shallow salinity front might create conditions that increase the plankton retention or concentration. Bowman and Iverson (1979) and Owen (1981) mentioned that the frontal zones are areas of enhanced primary productivity, aggregations of plankton, and elevated abundance of nekton.

A general trend is to find high concentrations of copepods nearshore, associated to estuarine systems and lagoons, where the primary productivity is higher (Margalef, 1989). In contrast, our results shows that the presence of high abundance of copepod nauplii in the offshore zone of the Catalan Sea imply a preferential spawning of the ocean-dominant species in the region (e.g. *Paracalanus*, *Clausocalanus, Oithona* and *Centropages* genera), which could be related to retention areas, as the salinity front and other ocean features like eddies, and the biological enrichment of the slope current influenced by the river discharges during rainy period as well as the ice melting on the Provençal mountains.

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RESUMEN

Se analizó la distribución y abundancia de nauplios de copépodos en relación con

estructuras oceánicas detectadas mediante datos *in situ* en las proximidades del Cañón de Palamós (Mediterráneo Noroccidental). Se hicieron arrastres verticales de plancton (60-µm de ancho de malla) y parámetros hidrográficos (CTD y ADCP) durante la primavera (Mayo 1992). EL área del cañón estuvo dominada por la corriente Liguro-Provenzal-Catalana (corriente de talud), influenciada por las descargas del Río Ródano y perturbaciones de su flujo inducido por la topografía submarina. Altas abundancias de nauplios de copépodos se asociaron con la corriente de talud y sus intrusiones hacia el cañón, mostrando un gradiente de abundancia oceánico-costero. Las máximas concentraciones de nauplios de copépodos se ubicaron sobre el margen oriental de la corriente a lo largo de un frente salino superficial. Los resultados muestran que el desove de las especies de copépodos dominantes en la área oceánica, podría estar relacionado a zonas de retención, tales como el frente salino, y al enriquecimiento biológico de la corriente influenciado por las descargas del Río Ródano durante el periodo de lluvias y deshiele de las montañas de la región Provenzal.

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