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Distribution of *Gryphus vitreus* (Born, 1778) (Brachiopoda) on transect P2 (Continental margin, French Mediterranean coast) investigated by submersible*

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SUMMARY: Direct observations by submersible are recorded on a Provence transect, between 88 to 603 m. On the Bathyal detritic sand biocoenosis, characterized by the brachiopod *Gryphus vitreus*, extending from the shelf edge (103 m) down to 260 m, they corroborate the five distributional density zones of this brachiopod (in density, but not for all their bathymetric limits), previously estimated from dredging data, and the environmental factors responsible for this distribution. Nervertheless, the two deepest density zones have quite different bathymetric limits, i.e. Zone 4: 151-245 m (previously estimated 150-200 m), and Zone 5: 245-260 m (estimated 200-250 m). Near-bottom currents are directly responsible for the density zone extension and depht range of this biocoenosis, which corresponds to the intermediate Mediterranean water layer. The currents move perpendicular to the slope and their strongest velocity occurs over the offshore-shelf where the highest brachiopod density is recorded; however, according to the larger extension of Zone 4, the currents have a larger influence downwards than previously expected.

Key words: Bathyal, Currents, Brachiopoda, Distribution, Mediterranean.

RESUMEN: DISTRIBUCIÓN DE *Gryphus vitreus* (BRACHIOPODA) A LO LARGO DEL TRANSECTO P2 (MARGEN CONTINENTAL, COSTA MEDITERRÁNEA FRANCESA) INVESTIGADA CON SUMERGIBLE. — Se describen observaciones del fondo a lo largo de un transecto en la costa provenzal, entre 88 y 603 m de profundidad. En la biocenosis batial de las arenas detríticas, caracterizada por el braquiópodo *Gryphus vitreus*, que se extiende desde la ruptura de pendiente de la plataforma continental (103 m) hasta 260 m, se confirma la presencia de las cinco zonas de densidad de este braquiópodo pero no de todos sus límites batimétricos previamente estimados por dragados y se comentan los factores ambientales responsables de esta distribución. Así, las dos zonas más profundas tienen como límite 151-245 m para la Zona 4 (antes 150-200 m) y 245-260 m para la Zona 5 (antes 200-500 m). Las corrientes de fondo son directamente responsables de la densidad y extensión de las zonas, así como del rango de profundidad de esta biocoenosis, que corresponde a la capa de agua intermedia mediterránea. Estas corrientes fluyen perpendicularmente a la pendiente y sus máximos de velocidad se dan en la plataforma «offshore» donde se registran las máximas densidades de *Gryphus*. Sin embargo, de acuerdo con la extensión de la Zona 4, las corrientes tienen influencia a mayor profundidad de lo que se esperaba previamente.

Palabras clave: batial, corrientes, Brachiopoda, distribución, Mediterráneo.

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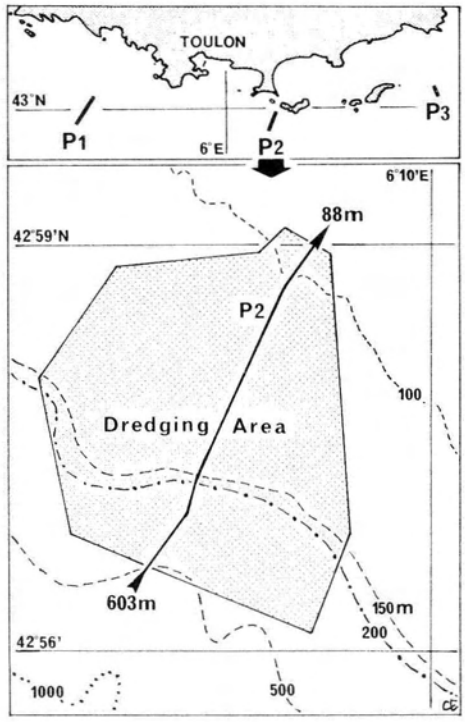

FIG. 1 — Location of the three transects investigated by submersible off the coast of Provence (South of France) with detailed area of Transect P2.

INTRODUCTION

Transect P2 is the last of the three profile types, investigated by direct observations using a submersible on the continental margin along the Provence coast (French Mediterranean) (Fig. 1); it belongs to the profile type II C (EMIG, 1987, 1989a, 1989b; EMIG and ARNAUD, 1988). The distribution of the brachiopod *Gryphus vitreus* (Born) on this transect, located SW of Porquerolles Island, was estimated previously from data obtained by dredging and converted to density (individual m^{-2}) in relation to direct counting by diving on Transects P1 and P3 (see EMIG, 1989b). Thus, one of the main concerns of this paper is to compare the previously estimated distribution, in density and bathymetric limits, and the hypothesized environmental factors responsible for this distribution, with the present direct observations.

MATERIAL AND METHODS

Transect P2 was investigated in 1987 by three dredging and trawling cruises (BRAPROV 6, 7, 9) with the French oceanographic vessels *N/O Catherine-Laurence, Antedon,* and *Korotneff.* The data obtained by dredging have been compared to density per square meter observed previously during submersible dives, and expressed as individuals m^{-2} from dredge hauls (see EMIG, 1989b; and Table 1).

The submersible dive on Transect P2 took place on 13 October 1989 from 603 m up to 88 m, with the submersible *SMI Griffon,* using its support-vessel *BSM Triton,* both belonging to the French Marine Nationale. The route is given on figure 1. The surface conditions were SE wind 4, momentarily up to 5, on the Beaufort scale and fair to slightly rough sea. The near-bottom currents evaluated in speed (using the enlarged scale of the speedometer on the submersible, about 1 m above the sediment surface), direction, and bathymetric limits during the dive were completed by the use of a low frequency Chromascope Sonar with the *N/O Korotneff* (on the color TV screen of this sonar the water masses appear according to their density).

RESULTS

The previous results of the estimated distribution of *Gryphus vitreus* compared with the observed one are given on figure 2 and table 1. According to EMIG

TABLE 1. — Comparative data in the distributional density zones of *Gryphus vitreus* on Transect P2, obtained by dredging (using a Charcot-Picard dredge, with a 10 mm mesh net, trawled during 15 minutes on the bottom at 1 knot) and by direct observations by submersible.

	Dredging					*Diving*	
Zones	*Depth range in m*	*Range ind. per haul*	*Mean*	*N.° of samples*	*Estimated density*	*Depth range*	*Density per m²*
1	103-120	5, 8		2	< 10	106-120	< 10
2	120-131	33-70	51	4	20-100	120-127	20-50
3	131-150	127-250	171	3	200-700	127-151	200-300
4	150-200	34-72	39	3	20-100	151-245	10-100
5	200-250	2-12	9	4	< 10	245-260	< 10

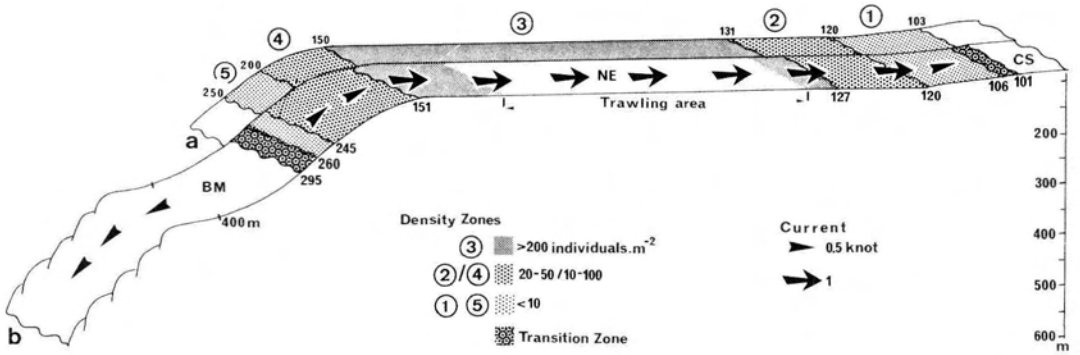

FIG. 2. — Extension and distributional limits of the density zones of the brachiopod *Gryphus vitreus* on Transect P2. a. Estimated from dredging data (modified, after EMIG and ARNAUD, 1988; EMIG, 1989b); b. from direct observations by submersible. CS: continental shelf; BM: Bathyal Mud biocoenosis.

(1989b), the estimated distribution revealed four brachiopod density distributional zones. Each zone has its own bathymetric limits, with the entire *G. vitreus* belt extending from 103 m to 250 m. Reconsideration of the dredging results after diving necessitates a revision of Zone 2 from 120 m to 131 m (Fig. 2a; Table 1) because this zone had been confused previously with Zone 3 on Transect P2. Zone 2 occurs in all the other transects belonging to the same C type (studied in Corsica; EMIG, 1989b). Through direct observations the presence of these five zones is corroborated but their bathymetric limits and extension, rather similar in Zones 1, 2 and 3, are very different in Zones 4 and 5 (Fig. 2b).

At the continental shelf-edge, the transition zone (from 101 m down to 106 m) from the circalittoral Coastal Detritic biocoenosis to the Bathyal Detritic Sand biocoenosis, characterized by the presence of the brachiopod *Gryphus vitreus*, occurs rapidly over several tens of meters; this zone is particularly expressed by the changes of organisms, hydrodynamics and substratum, e.g. from a detrital bottom with coarse sand and large deposits of altered *Posidonia* leaves, mainly in small depressed areas, to a flat bottom of finer sand covered by various small hard substrata (i.e. empty shells, valve fragments, pebbles, gravels...). Zone 1 (106-120 m; density: < 10 individuals m^{-2} of *G. vitreus*) covers the short slope between the shelf edge and a large offshore shelf, at the beginning of which occurs a rather short Zone 2 (120-127 m; density 20-50 ind. m^{-2}) while Zone 3 (density 200-300 ind. m^{-2}) extends, downwards from 127 m depth, over all this offshore shelf (gradient 1-2°) up to its lower boundary at 151 m. Nevertheless, the main part of Zone 3 is daily trawled by small fishing boats that remove nearly all epifauna. Beyond the offshore shelf-edge begins Zone 4 (density 10-100 ind. m^{-2}) which extends from 151 m down to 245 m depth on a incline of about 14°; this latter limit is much deeper than that estimated by dredging at only 200 m depth, thus Zone 4 has a larger extension than expected previously. Zone 5 (density: < 10 ind. m^{-2}) is limited between 245 to 260 m depth and not 200-250 m as recorded by dredging; in this zone the sediment becomes muddier with depth. The transition zone from the Bathyal Detritic Sand biocoenosis to the Bathyal Mud biocoenosis (from 260 m down to 295 m) is characterized by rapid increase of the muddy fraction, a decrease of the detrital fraction, mainly shelly, at the bottom surface, and the occurrence of more and more numerous burrow holes.

The sea-urchin *Cidaris cidaris*, generally isolated individuals, has been recorded from 98 m down to 586 m, with 1-2 individuals m^{-2} between 105 to 185 m and occasionally up to 20-30 individuals m^{-2} at 108-110 m depth. Traces of living heart-urchins *(Neolampas, Echinocardium)* are observed from120 to 200 m, numerous between 140 and 150 m, but empty tests on the sediment occur from 98 down to 400 m. Some rare specimens of *Echinus* sp., of Cerianthids and of embedded asterids are distributed down to 140 m. These observations are consistent with the previous ones on Transects P1 and P3 (EMIG and ARNAUD, 1988).

Below 295 m depth, the sediment of the Bathyal Mud biocoenosis is a superficial fluid mud, grey-brownish colored, which becomes harder within the substrate. Three kinds of burrow holes have been observed according to their diameter, respectively 2-3 cm, 8-10 cm, and 15-20 cm; the largest holes become more numerous with depth increase. The rare epifau-

na is composed of the echinoderm *Cidaris cidaris*, some crabs and sea-stars. From 395 m to 603 m depth, the slope is steep (25-30°) with many vertical rocky cliffs, over which occurs a downward near-bottom current, about 0.5 knot from E-NE to W-SW. The substrate remains the same, but grey-colored; the largest burrow holes are predominant, but the megafauna is rare on the mud; just one holothurian and some flat fishes have been observed, while the rocky surfaces appeared largely devoid of visible fauna.

On the Bathyal Detritic Sand biocoenosis, the bottom-current, moving SW to NE, appears suddenly beyond the continental shelf-edge, with about 0.5 knot. Its velocity increases in Zone 2 to reach 1 knot over all the offshore shelf (Zone 3); then, the bottom current decreases to 0.5 knot beyond the offshore shelf-edge to stop suddenly at the limit between Zones 4 and 5 (245 m). The distributional density zones of the suspension feeder *Gryphus vitreus* are consistent with the bottom current velocity (see Fig. 2a and Table 1): the highest density is recorded where the current velocity is 1 knot (Zone 3), then the density decreases when the current becomes weaker (Zones 2 and 4) and a low density is observed at the limit of current influence (Zones 1 and 5).

The estimated density (dredging) versus observed density (Table 1) appears consistent: the use of gear for qualitative investigation, i.e. the Charcot-Picard dredge, leads to semi-quantitative data, at least in the *Gryphus* distribution. Nevertheless, to record strict bathymetric limits of the distributional zones requires direct observations, especially when the slope becomes steeper.

DISCUSSION

The observations during the present submersible dive on the third Transect P2 (Fig.1) provided confirmation of most of the suggested features.

The strongest near-bottom currents move beyond the continental shelf-edge (presently about 100 m depth) and about 250 m, and they are always weaker or absent above and below. This depth range corresponds to the intermediate Mediterranean water layer which generally circulates E-W along the northwestern Mediterranean coast and belongs partly to the Ligurian current. These bottom currents are directly responsible for the extension and depth range of the Bathyal Detritic Sand biocoenosis, characterized by the brachiopod *Gryphus vitreus*.

Direction and velocity of these bottom currents, directly related to the physiography of the bottom, induce the distributional density zones of *Gryphus vitreus*. On Model C herein investigated (see also EMIG, 1989a, b), direction and velocity of the current were previously deduced from these zones: the current is oriented perpendicular to the isobaths and the strongest velocity occurs over the offshore shelf, and is corroborated by direct observations. However, the extension of Zone 4 down to 245 m (not 200 m as estimated previously) indicates that the current, which may reach up to 1-1.5 knots over this zone as expected in other transects, has a larger influence downwards than stated by EMIG (1989b). This extension of Zone 4, as in the other models, reduces the breadth of Zone 5 whose lower limit is at 260 m depth on Transect P2 and at 255 m on the two other transects also investigated by submersible (EMIG, 1987; EMIG and ARNAUD, 1988). The occurence of clear-cut transitional zones (Fig. 2a) is induced by the rapid descent of the near-bottom currents with changes in the sediment and fauna composition.

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