anchoring by pleasure boats (PORCHER, 1984) play an important role as well. Furthermore, precise maps of benthic communities, making it possible to accurately assess this phenomenon, are rarely available. Most maps are of too small scale to allow an evaluation of changes with time (BLANC, 1975; JEUDY DE GRISSAC, 1975) and are localized along the French continental coast between Marseilles and Nice.

The aim of this work is to compile a large-scale map in a region free from pollution (apart from a possible effect due to anchoring of pleasure boats in a small part of the area). This map, with a scale allowing inclusion of very small-sized structures, is to be a tool (i) for comparison with polluted areas, and (ii) for the study of natural change. In this context, the cartography of *Posidonia oceanica* beds in the waters around Ischia Island, Italy, was a first attempt to establish a baseline and to document possible changes (COLANTONI *et al.,* 1982), although on a considerably smaller scale than our map.

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Material and Methods

Marina d'Elbu is a small cove (1.7 ha) located within Elbu Bay (42°22'30"N, 8°24'20"E), between Calvi and Porto, Corsica (Fig. 1). Localities are given according to the Corsican spelling and follow the IGN map (1 : 25 000). Since 1975, Marina d'Elbu has been a part of the terrestrial and marine reserve of Scandola (Parc Naturel Régional de la Corse). The marine reserve, in which SCUBA diving and amateur fishing are prohibited, covers 590 ha (MEINESZ *et al.,* 1983 b) and has no road access. The nearest permanently inhabited places are Galeria (298 inh.) and Calvi (2824 inh.), 8 and 23 km away in a straight line.

The human impact is restricted to the anchoring of 5–20 pleasure boats on summer days (boats not allowed to stay more than 24 h).

The coast is volcanic (red porphiry), and no permanent stream runs in the thalweg. Nevertheless, during rainy periods small amounts of water flow into the cove. The sea-floor of the cove slopes gently from the shingle beach down to a depth of 15 m at its mouth, whereas the side faces are quite abrupt (Fig. 2).

A low altitude aerial photographic survey was carried out in June, 1981 (Fig. 3), on board a plane with a ventral door (NIKON F2, lens 55 mm with polarizing filter, 100 ASA Kodacolor film). Due to high water transparency, details of the benthos were conspicuous down to a depth of 15 m, *i. e.,* in the whole study area. The shoreline, together with all boundaries visible on the sea-floor, were transfered from the photographs to a polyvinyl chloride underwater slate (scale = 1 : 500). Diving exploration was performed during May and July, 1982.

Supralittoral and mediolittoral communities (as defined by PÉRÈS & PICARD, 1964) were not taken into consideration. The infralittoral benthic community and/or the substratum were identified in detail by diving within each patch and along both sides of each boundary. Additional boundaries, anchoring by pleasure boats (PORCHER, 1984) play an important role as well. Furthermore, precise maps of benthic communities, making it possible to accurately assess this phenomenon, are rarely available. Most maps are of too small scale to allow an evaluation of changes with time (BLANC, 1975; JEUDY DE GRISSAC, 1975) and are localized along the French continental coast between Marseilles and Nice.

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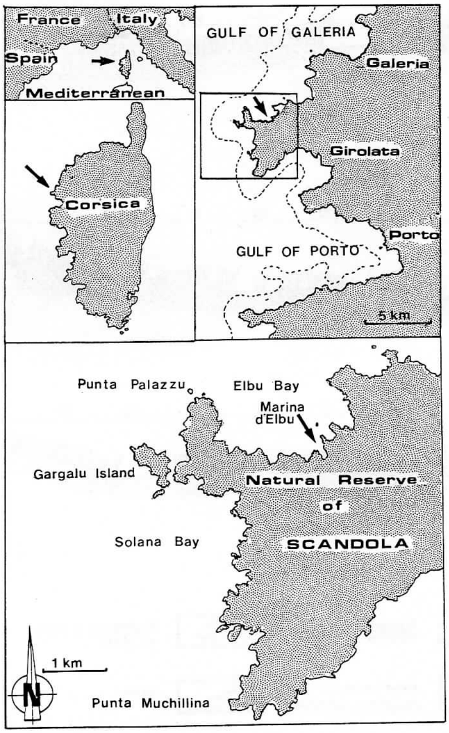

Fig. 1. Corsica and study locality.

not readily apparent on the photographs, could be traced in the course of the diving exploration, *e. g.*, in a *P. oceanica* meadow, demarcation of dead "matte" from healthy meadow. On the other hand, we failed to locate a few patches or boundaries which were conspicuous on the photograph. Possible reasons for this are discussed below. Depth was noted at the center of each patch and along its boundaries by means of a depth guage accurate to ± 0.5 m. This diving procedure provided a draft map.

To correct the draft map for photographic distortion due to margin effect and to optical phenomena within the water column, transects were set up between accurately located points on the shore. A graduated ground-line (smallest graduation = one metre) was uncoiled along the sea-floor, then travelled along. Depth, benthic community, and substratum nature were noted metre by metre. Transects were drawn with the same horizontal and vertical scale (Fig. 2), and boundaries were projected onto the sea surface, allowing correction of the draft map. The final map was drawn according to standardized signs (Meinesz *et al.*, 1983 a).

Results

Aerial photographs and diving observations result in the map shown in Fig. 4. Six benthic communities and kinds of substratum are distinguished:

(1) Shingle: the shingle beach extends down to 2–3 m depth; shingle is moved by waves and swell, but during summer calm periods deeper shingle may bear a short turf of photophilous algae.

(2) Sand: coarse sand is found below the beach and in a network of channels which stretch from the head to the mouth of the cove. A main channel (more than 10 m in width) is conspicuous in both deep (> 13 m) and shallow (< 7 m)

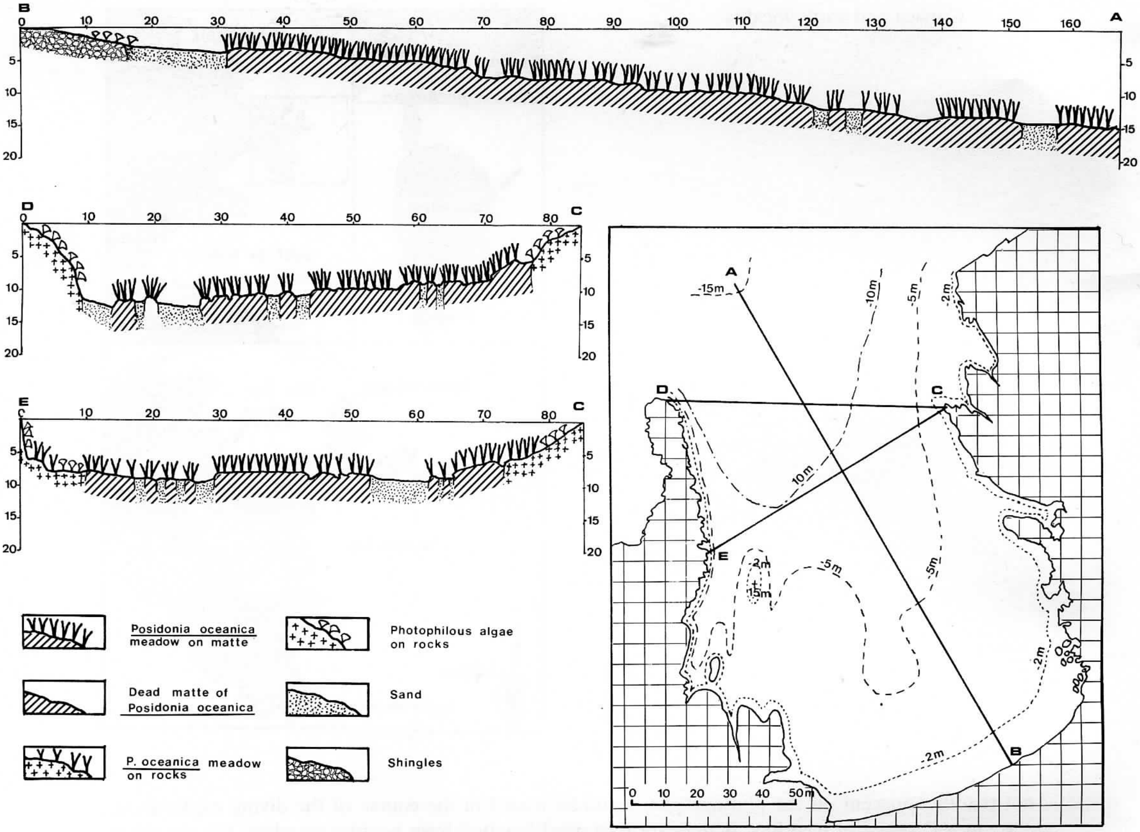

Fig. 2. Elbu cove with isobaths and location of transects AB, CD, and CE. Benthic communities and types of substratum along transects; depth and distances in metres; the underground extension of substratum type was not recorded.

parts of the cove; in intermediate depths, up to 6 narrower, more or less parallel channels (2 to 6 m) are present.

(3) Photophilous algae: hard substrata are colonized by photophilous communities (Order *Cystoseiretalia,* according to MOLINIER, 1960) dominated by brown algae, *e. g., Cystoseira balearica* SAUVAGEAU, *Dictyota dichotoma* (HUDSON) LAMOUROUX, *Padina pavonica* (LINNAEUS) THIVY, and *Stypocaulon scoparium* (LINNAEUS) KÜTZING. *Cystoseira stricta* (MONTAGNE) SAUVAGEAU constitutes a narrow belt under the sea level, under exposed conditions near the mouth of the cove. Strongly sloping walls on the eastern side of the cove are occupied by sciaphilous communities which are not extensive enough to be mapped. Small dead biogenic structures produced by the hermatypic scleractinian coral *Cladocora caespitosa* LINNAEUS occur at a depth of 1 m. They are about 1 m across and 30 cm thick.

(4) Dark cave: a small cave, 15 m long and 1–2 m wide, opens on the western side of the cove at a depth of 6 m; the fish *Phycis phycis* (LINNAEUS) is usually found in this cave during daytime.

Fig. 3. Low altitude aerial photograph of Elbu cove.

(5) *Posidonia oceanica* meadows: more than half of the cove is occupied by *P. oceanica,* whose upward growth produces a "matte" at least 1 m thick. Some "matte" margins end in small eroded cliffs; these cliffs are shown on the map where they exceed 20 cm in height. Between a depth of 4 and 7 m the meadow is dense, corresponding to types I and II of the GIRAUD (1977) scale (*i. e.,* >400 shoots $\cdot$ m^{-2}); intermattes (patches of sand or dead "matte") are absent or rare; in places, *P. oceanica* creeps directly on rocks or boulders, without any underlying "matte". Between a depth of 7 and 14 m, the *P. oceanica* meadow is less continuous. Here, small patches, 0.5–2 m in diameter, of dense *P. oceanica* and of dead "matte" form a mosaic. Below 14 m, near the seaward side of our map, *P. oceanica* forms ovoid patches up to 1 m in height called "hills". They are surrounded by sand and are representative of the "hill-type" meadows (BOUDOURESQUE *et al.,* 1985 a). Here, *P. oceanica* shoots are rather dense, corresponding to types III (300–400 · m^{-2}) or II (400–700 · m^{-2}) according to the GIRAUD scale. The large lamellibranch *Pinna nobilis* LINNAEUS is not uncommon.

(6) Dead *P. oceanica* "matte": dead rhizomes and roots of *P. oceanica* decay very slowly and can remain in place for millenia (MOLINIER & PICARD, 1952; BOUDOURESQUE *et al.* 1980). After the death of leaf shoots or the rooting up of living rhizomes by waves or currents, dead "mattes" constitute a distinct type of bottom. These "mattes" are more or less covered by algae such as *Jania rubens* (LINNAEUS) LAMOUROUX and *Udotea petiolata* (TURRA) BØRGESEN.

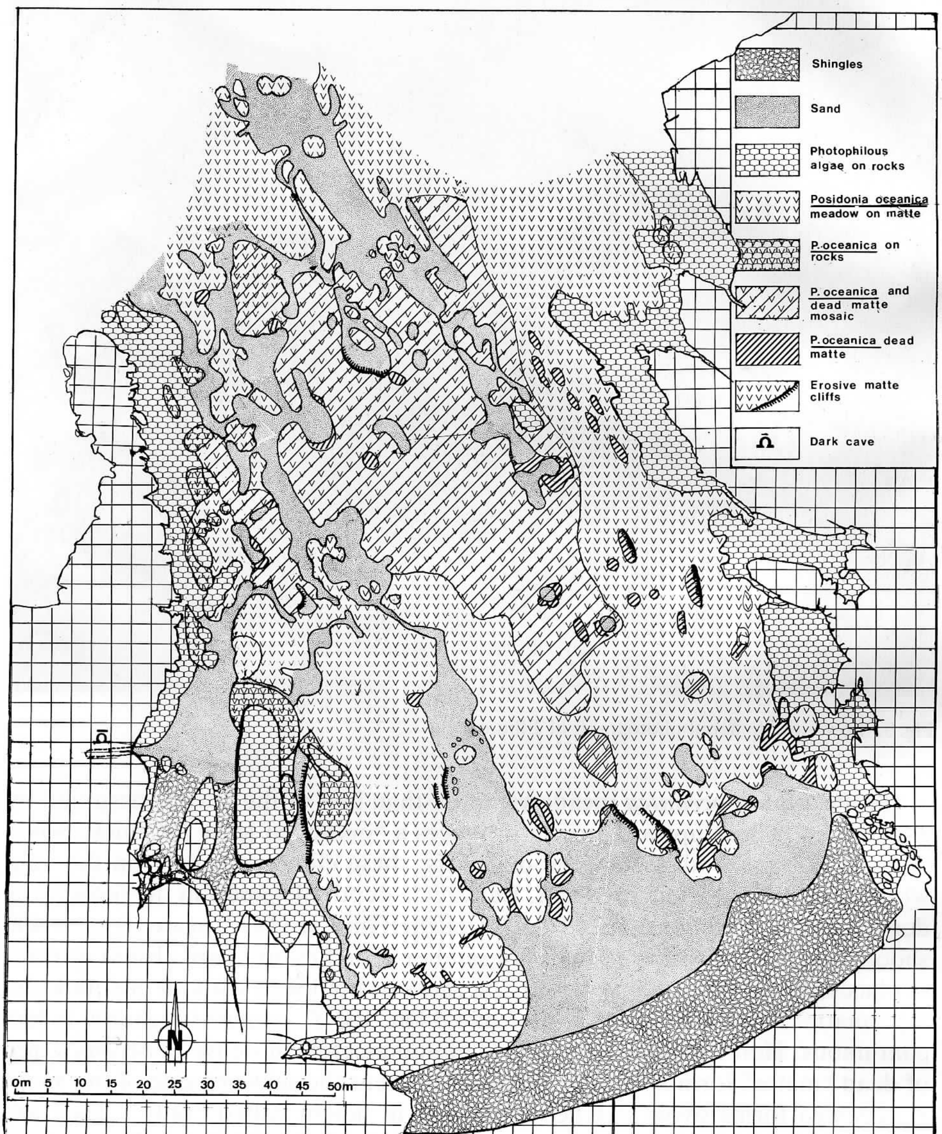

Fig. 4. Elbu cove with benthic communities and types of substratum.

Discussion

The *P. oceanica* meadow of Elbu corresponds to a small part of the large Elbu Bay meadow, which extends down to 37 m (MEINESZ, 1977); in Sulana Bay, isolated living shoots were observed at 43 m, an unusual depth for this seagrass (unpublished data). An axial channel, corresponding to the outflow along the bottom (undertow) of surface waters pushed inside the cove by dominant winds blowing from the open sea, is classical for seagrass meadows of Mediterranean bays (BLANC, 1958). For the most part sharply cut, at Elbu cove this channel appears to be dissected into several more or less parallel elements joined by bridges; this could be due to the fact that the prevailing winds blow from different directions (GOFFART, 1982), so the channel or channels in which the "undertow" flows depends on the wind at the time. The survey of long-term changes within a 100 m^2 permanent quadrat, set up accross the axial channel near the open sea side of the study area (BOUDOURESQUE *et al.,* 1981), shows that these channels slowly move: the *P. oceanica* matte is eroded on one side, whereas the meadow spreads on the other side by means of creeping rhizomes colonizing the sand channel (BOUDOURESQUE *et al.,* 1986).

The presence of up to 8 m long patches (intermattes) of dead *P. oceanica* "matte" and their density in a large part of the study area must be emphasized. As far as the human impact is concerned, pleasure boat anchorage is the only possible factor which could generate dead matte patches (AUGIER & BOUDOURESQUE, 1970). At present, however, boats anchor here for just a few weeks of the year, and anchorage takes place indiscriminately on dead "mattes" as well as on dense *P. oceanica* beds. The patches of dead "matte" may therefore result from a natural hydrodynamic equilibrium between building and erosion of the "mattes". Patches of dead "matte" in areas of greater human activity may also arise, at least in part, naturally rather than by man-made disturbance. Continued study of the mapped area, particularly in relation to any increase in human activity, will be necessary to test the above hypotheses.

As pointed out by BOUDOURESQUE *et al.* (1985 b), dead "mattes" of *P. oceanica* and rocks bearing photophilous algae both appeared brown on aerial photographs and could not be distinguished. Similarly, both meadows and dead "mattes" mosaic appeared dark blue on aerial photographs. Observations by divers, however, succeeded in distinguishing these bottoms. Another problem arose from drift leaves of *P. oceanica.* Such leaves are shed throughout the year (PANAYOTIDIS & GIRAUD, 1981; CAYE, 1982), but accumulate during calm late spring and summer periods within intermattes or parts of channels at depths between 6 and 15 m; their position can change after a storm. On aerial photographs, drift leaf accumulations were difficult to distinguish from *P. oceanica* meadow, so some intermattes and channels were concealed.

The degree of accuracy of our map ranges from 1 to 2 m. This is more than enough to allow a long-term survey of the study area. More sophisticated cartographical techniques are of little use for our purpose. Diving in all the boxes of a grid marked by ropes stretched out on the sea floor is more accurate but very time-consuming. The survey of a localized permanent quadrat (BOUDOURESQUE *et al.,* 1981, 1986) is more suitable for higher accuracy of long-term monitoring. The side-scan sonar is an expensive technique, better adapted to larger and more homogeneous areas than the study cove. Recently, BELSHER *et al.* (1988) attempted to map *P. oceanica* meadows by satellite remote sensing; this method is not suitable for large-scale mapping due to the size of the pixel : 20 m × 20 m (satellite SPOT), *i. e.,* less than 50 pixels for the whole study area. Furthermore, both side-scan sonar and satellite remote sensing techniques require diving controls, a method not usually realized by most authors.

Most of the mapping methods, when used alone, may lead to misinterpretations (see BOUDOURESQUE *et al.,* 1985 b and above for aerial photography). In order to maximize efficiency and to cross control results, several methods are often simultaneously applied in a single survey (MEINESZ & LEFEVRE, 1984; BOUDOURESQUE *et al.,* 1985 b; GILI & ROS, 1985). The combination of (i) aerial photography, (ii) the identification by diving of patches and boundaries, and (iii) the exploration of control transects along graduated ground-lines is suitable for an accurate and low-cost monitoring of the *P. oceanica* meadow.

Summary

1) A large-scale map of *Posidonia oceanica* meadows as well as other benthic substrata and communities was carried out in a cove free from pollution and man-made disturbance, except for a small possible impact due to the anchoring of pleasure boats.

2) The greater part of the cove is occupied by the *P. oceanica* meadow. At depths between 7 and 14 m, small patches of dense *P. oceanica* and dead "matte" adjoin one another to form a mosaic. Several sand channels, running more or less parallel to the main axis of the cove, may be formed by undertow currents.

3) The patches of dead "matte" may be the result of a natural hydrodynamic equilibrium between building and erosion, rather than to human impact such as the anchoring of pleasure boats.

4) The interpretation derived from an extensive diving survey of the cove, using transects along graduated ground-ropes, was compared with that derived from aerial colour photographs. Several types of benthic communities found by diving could not be distinguished from each other on the aerial photographs.

5) The combination of the three used mapping techniques seems to be quite suitable for an accurate and low-cost monitoring of the *P. oceanica* meadow.

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