The suitability of a topographical instrument for an integrated approach to the cartography of *Posidonia oceanica* meadows *

Posidonia oceanica
Cartography
Upper limit
Geodimeter

Posidonia oceanica
Cartographie
Limite supérieure
Géodimètre

Sebastiano CALVO, Carla FRADÀ ORESTANO, Paolo ABBADESSA

Laboratorio di Ecologia Acquatica, Dipartimento di Scienze Botaniche, Universita' degli Studi di Palermo, Via Archirafi, 38, 90123, Palermo, Italy.

Received 19/11/92, in revised form 10/05/93, accepted 11/05/93.

ABSTRACT

A large-scale map of the phytobenthic communities and, in particular, of the *Posidonia oceanica* meadow in the Bay of Mondello (Palermo, Italy) was made. The map was set up from aerial photography, which was verified by divers along ground-lines. The upper limit of the underwater vegetation, with special reference to the *Posidonia oceanica* meadow, was accurately located using a geodimeter. This topographical instrument proved to be very useful in realizing such cartography.

Oceanologica Acta, 1993. **16**, 3, 273-278.

RÉSUMÉ

L'utilisation d'un instrument topographique pour une approche intégrée de la cartographie des herbiers de *Posidonia oceanica*

Une cartographie à grande échelle des phytocénoses benthiques et plus particulièrement de l'herbier superficiel de *Posidonia oceanica* a été effectuée dans la baie de Mondello (Palerme, Italie). La carte a été réalisée grâce à une image aérophotogrammétrique interprétée par des observations directes le long de radiales. La limite supérieure de la végétation submergée, se référant en particulier à l'herbier de *Posidonia oceanica*, a été localisée avec précision à l'aide d'un géodimètre. Cet instrument topographique est particulièrement adapté à ce type de cartographie.

Oceanologica Acta, 1993. **16**, 3, 273-278.

INTRODUCTION

Posidonia oceanica meadows (Linnaeus) Delile represent one of the most stable and complex ecosystems of the Mediterranean Sea. They grow on soft sandy bottoms in the infralittoral zone, at depths ranging between 0 and about 40 m.

Many studies have been carried out on *Posidonia oceanica* meadows concerning their structures, dynamics and evolution, leaf biometry and phenology (*e. g.* Molinier and Picard, 1952; Giraud, 1977; 1979; Ott, 1980; Mazzella *et al.*, 1984; Pergent and Pergent-Martini, 1988). Their function in establishing littoral equilibrium as well as the natural regression and antrophic processes affecting the whole *Posidonia* ecosystem have also been investigated (*e. g.* Peres, 1984; Peres and Picard, 1975).

However, despite the importance attributed to highly accurate mapping as an aid to the management of the coastal

* Work carried out with the Ministero dell'Università e della Ricerca Scientifica e Tecnologica grant, 60 % quota.

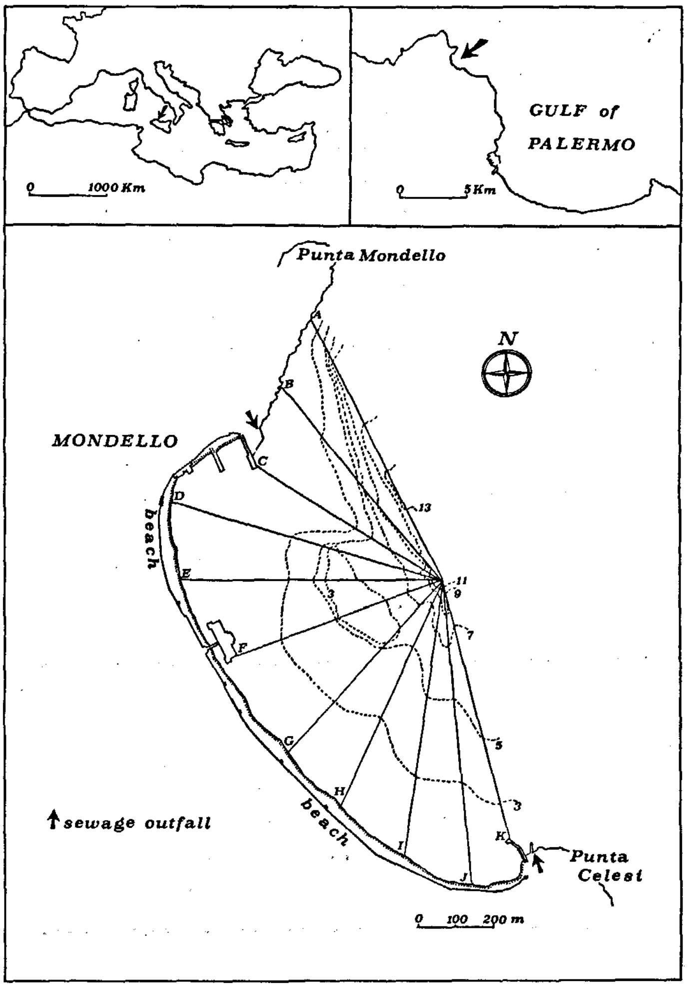


Figure 1

The Bay of Mondello. Transects (A-K) and bathymetric lines in metres.

La baie de Mondello. Transects (A-K) et lignes bathymétriques en mètres.

zone and its resources (Augier, 1985 *a*; Meinesz *et al.*, 1985), only a few large-scale maps of *Posidonia oceanica* meadows can be found in the literature (Augier, 1985 *a*; Boudouresque *et al.*, 1985 *b*; Colantoni *et al.*, 1982; Gili and Ros, 1985; Meinesz *et al.*, 1991; Meinesz *et al.*, 1988; Meinesz and Simonian, 1983; Pergent *et al.*, 1985).

As part of a survey of the northwest Sicilian coastal zone, cartographic research has already been carried out to study the effects of human impact on phototrophic components of the neritic ecosystem and on *Posidonia oceanica* meadows in particular (Fradà Orestano *et al.*, 1989; Fradà Orestano and Calvo, 1990).

In the present paper the upper limit of the underwater vegetation is traced by means of a topographical instrument (geodimeter). In addition, this original method is both compared and used in conjunction with two different techniques to produce an integrated large-scale (1:2000) map of the underwater vegetation.

MATERIALS AND METHODS

The Bay of Mondello covers an area of about 85 ha and is located on the northwest coast of the Gulf of Palermo (Northwest Sicily, Italy), between Punta Mondello and Punta Celesi (Fig. 1).

The area surveyed in this investigation is subjected for most of the year to organic pollution (Genchi *et al.*, 1982) due to sewage discharged from the village of Mondello. However, during summer periods, this sewage is diverted away from the bay to the east, close to the harbour of Palermo. The bay of Mondello is popular with tourists and, especially in summer, hundreds of pleasure boats are present in the bay.

The data for the mapping were collected using aerial photography, transects (carried out by divers) and with the help of a topographical instrument (geodimeter).

Standard aerial photography

Aerial colour photographs (scale 1:10 000), taken by Compagnia Generale Riprese Aeree (Fontana-Parma) in March 1987, were used. Because of the high water transparency, phytobenthic communities were visible to a depth of about 13 m. A provisional map (scale 1:2000) was prepared from the photographs and used in the plotting of the final integrated map of the vegetation. In the Table, specific problems of photo-interpretation as well as those encountered by other authors are listed (Augier, 1985 *b*; Boudouresque *et al.*, 1985 *b*; Meinesz *et al.*, 1988).

Transects

Topographical and phytocoenotic observations were carried out by divers along eleven transects (Meinesz *et al.*, 1981) converging on a fixed point in the centre of the bay (Fig. 1). During each dive the depth of the sea-bottom and the nature of the substratum were recorded every 5 m along each ground-line, as were the features of the phytobenthic communities.

Table

Specific problems encountered in interpreting the aerial photographs.

Problèmes spécifiques rencontrés pour l'interprétation des photographies aériennes.

Highly epiphytic emergent *Posidonia oceanica* = dead matte with photophilous algae
High density *Cymodocea nodosa* prairie on sand or dead matte = *Posidonia oceanica* meadow
Low density *Cymodocea nodosa* prairie on dead matte = photophilous algae on dead matte
Photophilous algae on rocky sea-bottoms and stacks of dead leaves of *Posidonia oceanica* = *Posidonia oceanica* meadow
Rocky sea-bottoms = dead matte
Stacks of dead leaves of *Posidonia oceanica* = dead matte

Geodimeter

The location of the upper limit of the phytobenthic communities was determined by means of a topographical instrument (geodimeter).

The original procedure adopted was the following (Fig. 2): a diver, assisted by crew on a boat, followed the upper limit of the underwater vegetation from the surface, stopping every 10-15 m. At these points the boat drew near the diver and, once stationary, the crew transmitted by radio to the geodimeter operator to locate his position. Simultaneously the crew noted the depth and the composition of the phytobenthic communities. This method assures a high degree of accuracy, since the nominal precision of the geodimeter is ± 5 mm between 0.2 and 7,000 m.

Surveying techniques using geodimeters have also been reported recently by Roy *et al.* (1988) and Fredj *et al.* (1990) to map with accuracy the transects dived by the operators.

The maps of both the substratum and the underwater vegetation of the Bay of Mondello were completed using the system of international symbols proposed by Meinesz *et al.* (1983).

RESULTS AND DISCUSSION

Three different types of substratum (Fig. 3) and five phytobenthic communities (Fig. 4) were identified.

In Figure 5 the nature of both the substratum and the phytobenthic communities along the transects (A-K) is shown.

Substratum

Sand predominates the other bottom typologies (rock and "matte"). In particular sand was found all along the beachline and in a channel with erosive features in the central-eastern section of the bay. This channel provides an outlet for water driven towards the surface by onshore wind and currents (Blanc, 1958; Blanc and Jeudy De Grissac, 1984).

Rocky bottoms were only found in some formations close to Punta Celesi (Fig. 3, Fig. 5 K), along the sides of the erosive channel and in a calcareous strip in the northwestern sector (Fig. 3; Fig. 5 A).

Posidonia oceanica "matte" (Fig. 3; Fig. 5 F), interrupted by frequent sandy "intermattes" patches, completed the different substratum typologies and appeared discontinuously located between the little port of Mondello village and Punta Celesi.

Phytobenthic communities

Posidonia oceanica meadow appears to be the most conspicuous benthic community and is found both on sandy and on organogenous layers deposited on rocky substratum. In both cases the meadow has distinctive "matte" features. These vary in height from a few decimetres to 1.8 m (Fig. 5 F).

Large sandy "intermattes", due to erosive processes under way, were identified during the observations. The presence of dead *Posidonia oceanica* "mattes", colonized by *Cymodocea nodosa* (Ucria) Ascherson (Fig. 4; Fig. 5 C, E), shows the state of regression of the upper limit of *Posidonia oceanica*.

However it should be pointed out that patches (intermattes) of dead "matte" in areas of human activity are also the result, at least in part, of a natural hydrodynamic equilibrium between the constructive and destructive phases of meadow evolution, rather than the consequence of man-made disturbance (Meinesz *et al.*, 1988).

With respect to the upper limit, a certain amount of recolonization activity with hill-like formations

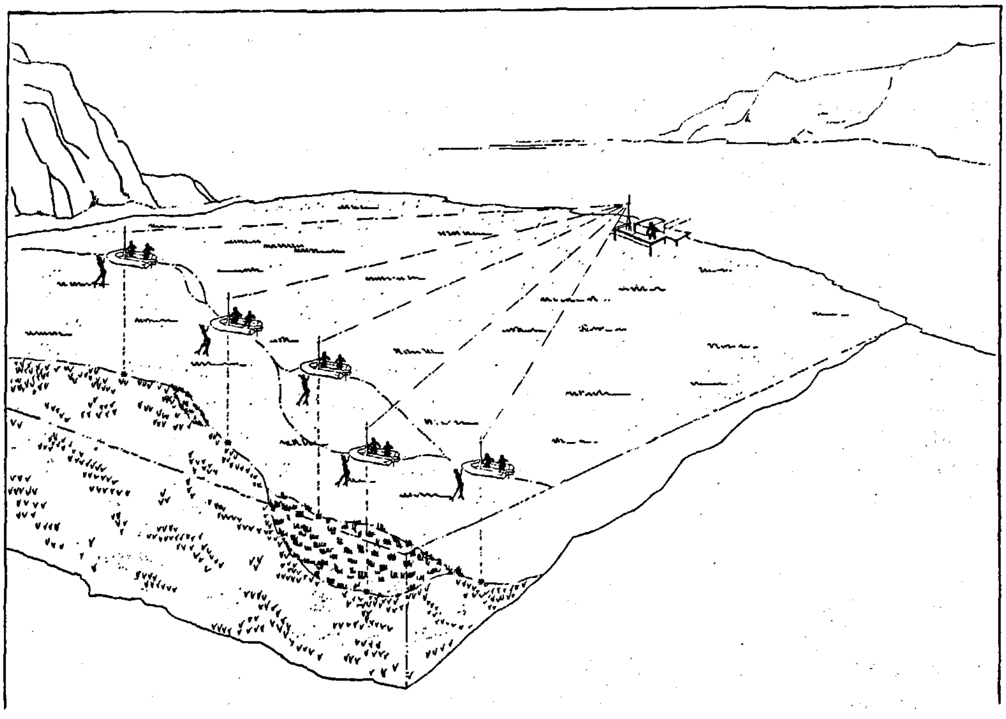


Figure 2

Simplified representation of a method employing a topographic instrument (geodimeter) to trace the upper limit of the submerged vegetation.

Représentation simplifiée de la méthode employée en utilisant un instrument topographique (géodimètre) pour tracer la limite supérieure de la végétation submergée.

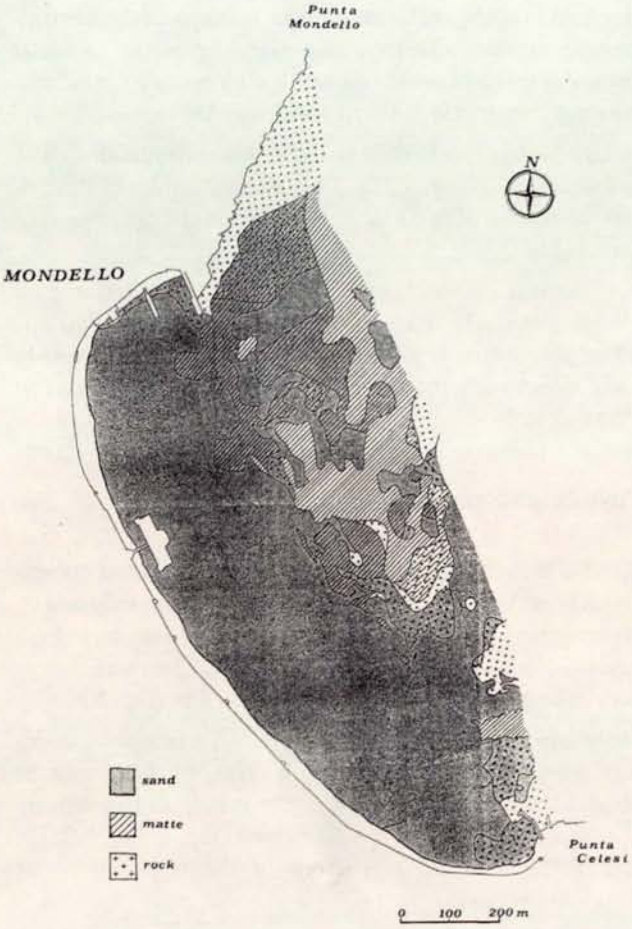


Figure 3

Map of the substratum.

Carte des substrats.

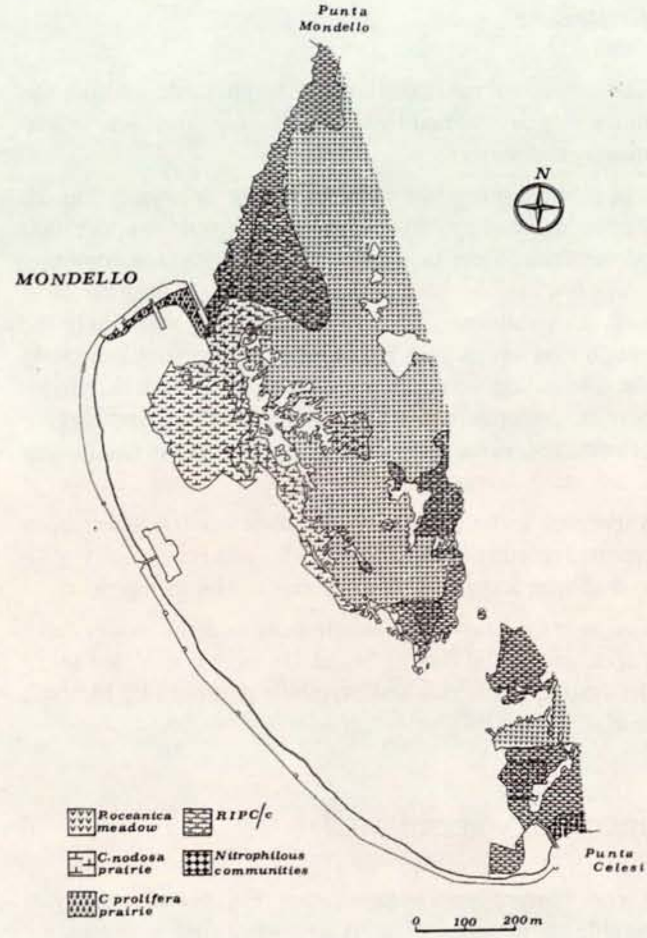


Figure 4

Map of the phytobenthic communities.

Carte des communautés phytobenthiques.

(Boudouresque *et al.*, 1985 *a*) was observed within the *Cymodocea nodosa* meadow.

The meadow area mostly at risk is that near the village of Mondello. There, the effects of sewage as well as activities connected with the tourist trade (anchorages, buoy installations, accidental loss of fuel oil, *etc.*) are mostly felt.

In particular, close to the village of Mondello, eroded areas have been identified in the shape of circular basins with a diameter ranging between 1.5 and 2.5 m and having an average depth of 0.5 m. Concrete blocks used for anchoring small pleasure boats have been observed in all these basins; thus it would appear that the latter have been formed through a series of erosive processes of the meadow due to the installation and use of anchorage blocks (Porcher, 1984; Porcher and Jeudy de Grissac, 1985).

The depth of the upper limit of the phanerogamic vegetation (Fig. 4) varies between 2.5 and 9 m and is located close to the coastline in the eastern and western sections and at an average distance of 350 m from the shoreline in the central section of the bay.

The effects of *Posidonia oceanica* meadow erosion and the regression of its upper limit have already been documented (Jeudy de Grissac and Boudouresque, 1985). These effects have not yet been studied in the Bay of Mondello, but erosion of the beach can be suspected because, in order to maintain the beach, the company managing it has had to add about 5,000 m^3 of sand every year for the past thirty years.

A preliminary investigation of the phenology of *Posidonia oceanica* in the bay (Fradà Orestano *et al.*, 1991) revealed the presence of rather dense shoots, corresponding to types I and II (Giraud, 1977).

The rocky bottoms are colonized by photophilous communities (Fig. 4; Fig. 5 A, B, K) with a predominance of brown algae (*Cystoseira stricta* (Montagne) Sauvageau, *Cystoseira crinita* (Desfontaines) Bory, *Dictyota dichotoma* (Hudson) Lamouroux, *Dictyopteris membranacea* (Stackhouse) Batters, *Padina pavonica* (Linnaeus) Thivy and *Colpomenia sinuosa* (Mertens) Derbes and Solier) where antropic effects are less evident.

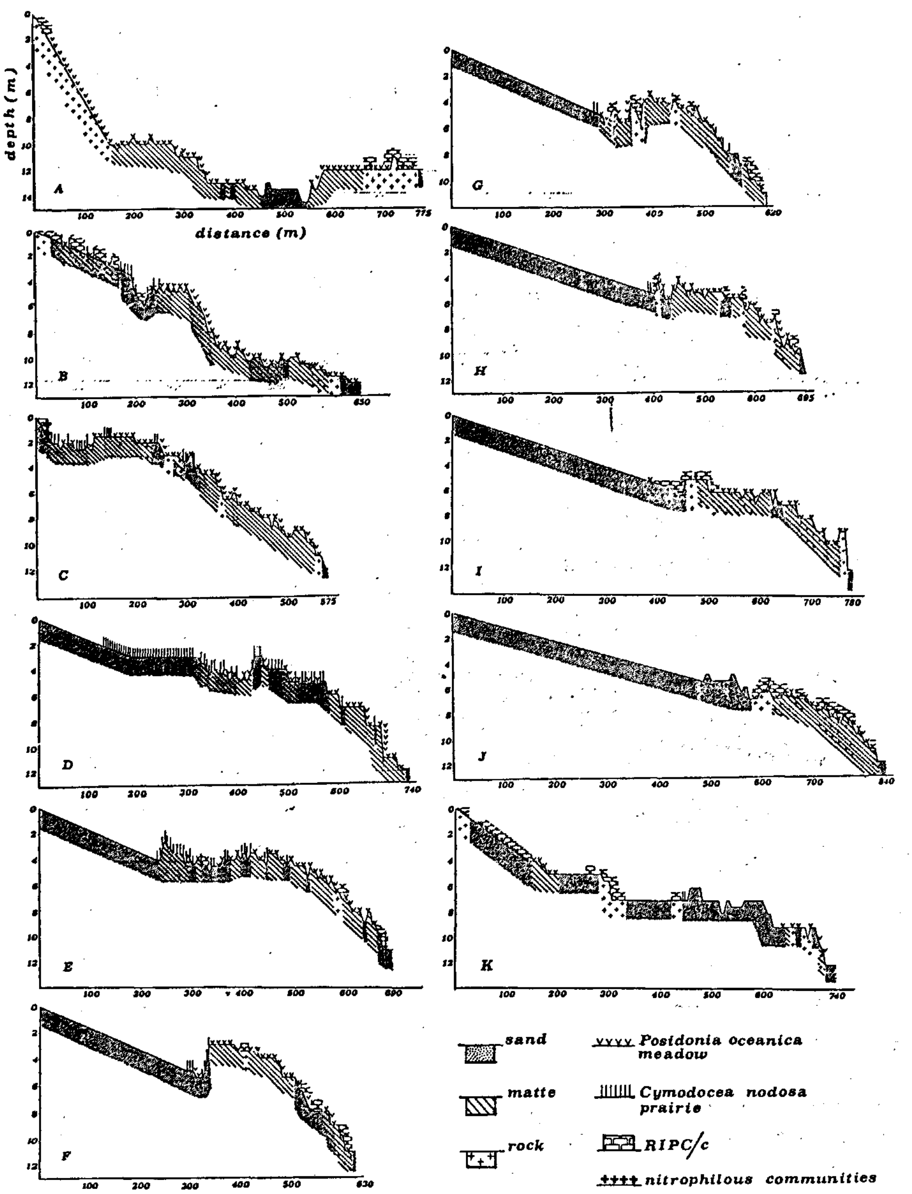
Communities indicating sewage-type pollution, with a prevalence of *Enteromorpha compressa* (Linnaeus) Greville, *Pterocladia capillacea* (Gmelin) Bornet and Thuret, *Ulva rigida* C. Agardh, *Corallina elongata* Ellis and Solander, *etc.* are found close to the two sewage outfalls and in the most sheltered areas of the port of Mondello (Fig. 4; Fig. 5 C).

In particular, within the port a patchy distribution of certain phytobenthic communities (*Pterocladio-Ulvetum* Molinier and galenophilous communities dominated by *Caulerpa prolifera* (Forsskål) Lamouroux) indicates further sewage pollution.

Figure 5

Phytobenthic communities and substratum along the transects.

Communautés phytobenthiques et substrats le long des transects.



CONCLUSIONS

By integrating the results of various techniques in the study of phytobenthic communities (aerial photography, observation by divers along transects, and the use of a geodimeter), it was possible to produce an accurate map of the underwater vegetation of the Bay of Mondello at a low cost.

The general resolution of the map is approximate to 5 m, but the upper limit of the phanerogamic vegetation has been accurately determined and mapped with a resolution less than 1 m. The geodimeter is more precise, faster and simpler to use than other methods, and constitutes a valuable aid in the process of mapping the biocoenosis of marine coastal waters.

Topographical instruments may be used for several applications in checking and managing coastal marine ecosystems. The possibility of using the geodimeter to trace with accuracy the upper limit of underwater communities adds a fast and reliable technique to the methods available for environmental impact assessment.

The use of geodimeter also provides an ideal support for cartographic technologies (side scan sonar, underwater video-cameras, *etc.*) as a way of significantly increasing the level of precision.

The technique using a geodimeter to trace with accuracy the upper limit of the underwater vegetation has shown a striking analogy with the one using a submarine to map the lowest limit of the *Posidonia oceanica* meadows (Meinesz and Laurent, 1978; Falconetti and Meinesz, 1989).

It is finally confirmed that the accuracy of maps of underwater vegetation increases when different technologies are applied and the results are cross-referenced in a single survey (Boudouresque *et al.*, 1985 *b*; Gili and Ros, 1985; Meinesz and Lefèvre, 1984; Meinesz *et al.*, 1988).

Acknowledgements

We would like to thank Dr. Lucia Mazzella for the critical comments on the manuscript and S. Aricò, S. Ferla and F. Minutillo for their friendly collaboration during the sea operations.

REFERENCES

Augier H. (1985 *a*). Carte biocénotique de la baie de Carry-le-Rouet et balisage de la limite supérieure de l'herbier de Posidonies avant l'agrandissement du port ; impacts prévisibles. *Posidonia Newslett.*, **1**, 1, 31-41.

Augier H. (1985 *b*). L'herbier à *Posidonia oceanica*, son importance pour le littoral méditerranéen, sa valeur comme indicateur biologique de l'état de santé de la mer, son utilisation dans la surveillance du milieu, les bilans écologiques et les études d'impact. *Vie mar.*, **7**, 85-113.

Blanc J.J. (1958). Recherches de sédimentologie littorale et sous-marine en Provence occidentale. *Thèse, Faculté des Sciences, Université de Paris*, Masson, Paris, 140 pp.

Blanc J.J. and A. Jeudy de Grissac (1984). Érosion sous-marine des herbiers à *Posidonia oceanica* (Méditerranée). *Proceedings of the 1st International Workshop on Posidonia beds, GIS Posidonie publ., France*, **1**, 23-28.

Boudouresque C.F., A. Jeudy de Grissac and A. Meinesz (1985 *a*). Un nouveau type d'herbier à *Posidonia oceanica* : l'herbier de colline. *Rapp. P.-v. Réun. Commn int. Explor. scient. Mer médit.*, **29**, 5, 173-175.

Boudouresque C.F., A. Meinesz and J.-R. Lefèvre (1985 *b*). Cartographie des peuplements benthiques marins de la Corse : I : La formation récifale à *Posidonia oceanica* de Saint-Florent. *Annls Inst. océanogr., Paris*, **61**, 1, 27-38.

Colantoni P., P. Gallignani, E. Fresi and F. Cinelli (1982). Patterns of *Posidonia oceanica* (L.) Delile beds around the Island of Ischia (Gulf of Naples) and in adjacent waters. *Pubbl. Staz. zool. Napoli: Mar. Ecol.*, **3**, 1, 53-74.

Falconetti C. and A. Meinesz (1989). Charting the seaward limit of *Posidonia oceanica* meadows and of circalittoral biocoenoses along the coast of Monaco. *Oceanologica Acta*, **12**, 4, 443-447.

Fradà Orestano C. and S. Calvo (1990). L'impact des activités anthropiques sur les herbiers de *Posidonia oceanica* (Linnaeus) Delile le long des côtes siciliennes. *Colloques Phytosociologiques*, **19**, 523-531.

Fradà Orestano C., S. Calvo, S. Ferla and F. Minutillo (1989). Impatto delle attività antropiche sulla prateria di *Posidonia oceanica* (Linneo) Delile nel Golfo di Palermo: analisi strutturale. *Giorn. Bot. Ital.*, **123**, 1, 78.

Fradà Orestano C., S. Calvo and S. Aricò (1991). Structural analysis of the *Posidonia oceanica* (L.) Delile meadow in the Bay of Mondello (Sicily, Italy). *Posidonia Newslett.*, **4**, 2, 21-30.

Fredj G., M. Meinardi, S. Pierrot and P. Roy (1990). Cartographie par le satellite Spot 1 de communautés benthiques littorales en Méditerranée occidentale. *Bull. Inst. océanogr., Monaco*, **6**, 71-85.

Genchi G., F. Di Bernardo, A. Lugaro, S. Calvo, S. Ragonese and S. Riggio (1982). Dystrophic and eutrophic states of coastal seawater in Palermo bay during the summer season (August 1981). *VI^èmes Journées Études Pollutions, CIESM, Cannes*, 635-639.

Gili J.M. and J. Ros (1985). Study and cartography of the benthic communities of Medes Islands (NE Spain). *Pubbl. Staz. zool. Napoli: Mar. Ecol.*, **6**, 3, 219-238.

Giraud G. (1977). Essai de classement des herbiers de *Posidonia oceanica* (Linn) Delile. *Bot. Mar.*, **20**, 8, 487-491.

Giraud G. (1979). Sur une méthode de mesure et de comptage des structures foliaires de *Posidonia oceanica* (Linnaeus) Delile. *Bull. Mus. Hist. nat., Marseille*, **39**, 33-39.

Jeudy de Grissac A. and C.F. Boudouresque (1985). Rôle des herbiers de phanérogames marines dans les mouvements des sédiments côtiers : les herbiers à *Posidonia oceanica. Colloque franco-japonais. d'Océanographie, Marseille*, **1**, 143-151.

Mazzella L., M.C. Gambi, G.F. Russo and M.C. Buia (1984). Deep flowering and fruiting of *Posidonia oceanica* beds around the island of Ischia (Gulf of Naples, Italy). *Proceedings of the 1st International Workshop on Posidonia beds, GIS Posidonie publ., France*, **1**, 203-209.

Meinesz A. and R. Laurent (1978). Cartographie et état de la limite inférieure de l'herbier de *Posidonia oceanica* dans les Alpes-Maritimes (France). *Botanica mar.*, **21**, 513-526.

Meinesz A. and J.-R. Lefèvre (1984). Régénération d'un herbier de *Posidonia oceanica* quarante années après sa destruction par une bombe dans la rade de Villefranche (Alpes-Maritimes, France). *Proceedings 1st International Workshop on Posidonia beds, GIS Posidonie publ., France*, **1**, 39-44.

Meinesz A. and M. Simonian (1983). Cartes de la végétation sous-marine des Alpes Maritimes (côtes françaises de la Méditerranée). II : La végétation mixte à *Cymodocea nodosa, Zostera noltii, Caulerpa prolifera* et la limite supérieure de l'herbier de *Posidonia oceanica* entre Juan-les-Pins et Golfe Juan. *Annls Inst. océanogr., Paris*, **59**, 1, 21-35.

Meinesz A., M. Cuvelier and R. Laurent (1981). Méthodes récentes de cartographie et de surveillance des herbiers de phanérogames marines. *Vie Milieu*, **31**, 1, 27-34.

Meinesz A., C.F. Boudouresque, C. Falconetti, J.-M. Astier, D. Bay, J.-J. Blanc, M. Bourcier, F. Cinelli, S. Cirik, G. Cristiani, I. Di Geronimo, G. Giaccone, J.-G. Harmelin, L. Laubier, A.Z. Lovrik, R. Molinier, J. Soyer and C. Vamvakas (1983). Normalisation des symboles pour la représentation et la cartographie des biocénoses benthiques littorales de Méditerranée. *Annls Inst. océanogr., Paris*, **59**, 2, 155-172.

Meinesz A., C.F. Boudouresque, A. Jeudy de Grissac, J.-P. Lamare, J.-R. Lefèvre and A. Manche (1985). Aménagement et préservation du milieu marin littoral en région Provence-Alpes-Côte d'Azur : bilan et perspectives. *Colloque franco-japonais d'Océanographie, Marseille, France*, **1**, 133-142.

Meinesz A., C.F. Boudouresque and J.-R. Lefèvre (1988). A map of the *Posidonia oceanica* beds of Marina d'Elbu (Corsica, Mediterranean). *Pubbl. Staz. zool. Napoli: Mar. Ecol.*, **9**, 3, 243-252.

Meinesz A., T. Belsher, C.F. Boudouresque and J-R. Lefèvre (1991). Première évaluation du satellite SPOT pour la cartographie des peuplements benthiques superficiels de Méditerranée occidentale. *Oceanologica Acta*, **14**, 3, 299-307.

Molinier R. and J. Picard (1952). Recherches sur les herbiers de phanérogames marines du littoral méditerranéen français. *Annls Inst. océanogr.*, Paris, **9**, 2, 157-234.

Ott J.A. (1980). Growth and production in *Posidonia oceanica* (L.) Delile. *Pubbl. Staz. zool. Napoli: Mar. Ecol.*, **1**, 1, 47-64.

Peres J.-M. (1984). La régression des herbiers à *Posidonia oceanica. Proceedings 1st International Workshop on Posidonia beds, GIS Posidonie publ., France*, **1**, 445-454.

Peres J.-M. and J. Picard (1975). Causes de la raréfaction et de la disparition des herbiers de *Posidonia oceanica* sur les côtes françaises de la Méditerranée. *Aquat. Bot.*, **1**, 133-137.

Pergent G. and C. Pergent-Martini (1988). Phénologie de *Posidonia oceanica* (Linnaeus) Delile dans le bassin méditerranéen. *Annls Inst. océanogr., Paris*, **64**, 2, 79-100.

Pergent G., C.F. Boudouresque and B. Vadier (1985). Étude préliminaire des herbiers à *Posidonia oceanica* (L.) Delile de la côte des Albères (Pyrénées-Orientales, France). *Annls Inst. océanogr,. Paris*, **61**, 2, 97-114.

Porcher M. (1984). Impact des mouillages forains sur les herbiers à *Posidonia oceanica. Proceedings 1st International Workshop on Posidonia beds, GIS Posidonie publ., France*, **1**, 145-148.

Porcher M. and A. Jeudy de Grissac (1985). Inventaire des mouillages forains autour de l'île de Porquerolles (Var, France). *Posidonia Newslett.*, **1**, 1, 23-30.

Roy P., S. Pierrot, G. Fredj, M. Menardi and G. Bellaiche (1988). Une méthode originale de positionnement des plongeurs en vue de terre. *Rapp. P.-v. Réun. Comm. int. Explor. scient. Mer médit.*, **31**, 2, 118.