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Research Article

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Occurrence and distribution of different bed types of seagrass *Posidonia oceanica* around the Maltese Islands

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Abstract

The small-scale distribution of Posidonia oceanica bed types was mapped at four locations off the northern coast of the Maltese Islands, using aerial photography supplemented by surveys using SCUBA diving. Results showed a similar pattern of occurrence of the seagrass at all locations surveyed. In shallow waters (2 m – 4 m), P. oceanica occurred as patches of variable size on a rocky and/or sandy substratum. In deeper waters (5 m – 10 m), the patches of seagrass were often replaced by reticulate beds consisting of P. oceanica interspersed with areas of bare sand. Deeper still (11 m – 13 m), a transition from reticulate to continuous beds occurred. Continuous beds extended to depths of around 25 - 30 m and eventually became reticulate or patchy in deeper waters (>25 m). Values of total seagrass percentage cover increased, while the ratio of fragmented:continuous bed cover decreased for the four study locations on moving southwards (Ramla Bay to St Thomas Bay), indicating that P. oceanica habitat was more abundant and less fragmented in the south-eastern parts of the Maltese Islands. However, values calculated using an exposure index did not did indicate a relationship between exposure and the observed decease in fragmentation of seagrass beds on moving northwest to southwest along the north-eastern coast. Data from the four sites surveyed, together with data from other surveys, were used to show the large-scale distribution of P. oceanica beds around the Maltese Islands. The implications of the study findings for the conservation and management of P. oceanica habitat around the Maltese Islands are discussed.

Keywords: Maltese Islands; Mapping surveys; *Posidonia oceanica;* Seagrass.

Introduction

Seagrasses form beds that constitute habitats which are highly productive and support a high diversity of associated biota (HEMMINGA & DUARTE, 2000; HECK & ORTH, 2006). Several faunal species associated with seagrass beds constitute important commercially-fished species (see review by JACKSON *et al.*, 2001). Seagrass beds also have a considerable influence on the physical environment; their leaf canopy traps suspended matter (WARD *et al.*, 1984) and acts as a buffer against strong water movement (FONSECA *et al.*, 1982; FONSECA and CAHALAN, 1992). In addition, their root-rhizome layer consolidates soft sediments (DEN HARTOG & PHILLIPS, 2001), thereby reducing coastal erosion. Because of their high productivity and interaction with the physical environment, seagrass beds constitute important shallow-water ecosystems of high ecological and economic value (COSTANZA *et al.*, 1997). However, as with other shallow-water habitats located in close proximity to human settlements, seagrass beds are bearing the brunt of anthropogenic disturbance, and degradation and decimation of the habitat is occurring at an alarming rate, such that a global decline is evident (RUCKELSHAUS & HAYS, 1998; DUARTE, 2002; GREEN & SHORT, 2003). In the meantime, effective conservation is hindered by a lack of baseline data on the distribution of the habitat, on the different bed types formed by seagrasses, and on the environmental factors and processes (both natural and anthropogenic) that influence the spatial distribution, formation and fragmentation of seagrass habitat. Consequently, coastal managers and conservation biologists often lack the necessary information for effective management and conservation of seagrass habitat.

The spatial organisation of seagrass beds varies greatly, and natural units range from small patches to large continuous beds that cover vast expanses of the seabed (ROBBINS & BELL, 1994; FONSECA & BELL, 1998). Seagrass beds may also occur interspersed with other habitat types, for example, bare sand, to form extensive reticulate beds (see BORG *et al.*, 2005), which are also known as 'semi-continuous' beds, 'interconnected patches' or beds with 'blow-outs'; KIRKMAN & KUO, 1990; FONSECA & BELL, 1998; HOVEL & LIPCIUS, 2001; 2002). Such patterned beds, or landscapes (ROBBINS & BELL, 1994; BOSTRÖM *et al.*, 2006), are thought to result from the growth response of the seagrass to the physical setting of the particular locality where it occurs (FONSECA *et al.*, 1983; KIRKMAN & KUO, 1990; FONSECA & BELL, 1998).

The endemic *Posidonia oceanica* (L.) Delile is the dominant seagrass in the Mediterranean Sea, where it forms extensive beds (estimated total cover of 2.5 – 5.5 million hectares; BUIA *et al.*, 2000) at depths ranging between 1 and 40m (PROCACCINI *et al.*, 2003; BOUDOURESQUE *et al.*, 2006). *P. oceanica* is considered a key species and beds formed by this seagrass constitute one of the most important shallow-water marine habitats in the Mediterranean Sea (BUIA *et al.*, 2000; BOUDOURESQUE *et al.*, 2006). The spatial extent of *P. oceanica* beds has been mapped in several areas of the Mediterranean, mainly by using side-scan sonar (e.g. PIAZZI *et al.*, 2000; ARDIZZONE *et al.*, 2006) or aerial photography (e.g. RAMOS ESPLÁ , 1984; BOUDOURESQUE *et al.*, 1985) in combination with diving surveys for ground-truthing of the remotely collected data. The results of such surveys indicate a general trend of decrease in shoot density and cover of the seagrass during the past few decades (PROCACCINI *et al.*, 2003). While the ecology of *P. oceanica* beds is relatively well studied (see review by BUIA *et al.*, 2000), little information on landscape ecological features (ROBBINS & BELL, 1994) of the habitat is available. For example, there is a dearth of knowledge of the factors that influence the occurrence, conformation and spatial distribution of different bed types (hence landscape ecological characteristics) of *P. oceanica*. Information on the occurrence and distribution of beds of this seagrass is necessary for decisions concerning habitat conservation and protection measures, particularly in view of the fact that *P. oceanica* is listed as a priority natural habitat in Annex I of the EC Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora (EEC, 1992), which lists natural habitat types whose conservation requires the designation of Special Areas of Conservation (SACs).

In the Maltese Islands, *P. oceanica* beds, together with bare sand habitats and those of infralittoral algae on hard substrata, constitute the dominant habitat types in shallow coastal waters to a depth of around 43 m (BORG & SCHEMBRI, 1995; BORG *et al.*, 1997). The spatial distribution of *P. oceanica* beds in some local coastal areas has been described (e.g. BORG & SCHEMBRI, 1995; BORG *et al.*, 1997; BORG & SCHEMBRI, 2003). In addition, a more detailed map showing the distribution of the seagrass around the Maltese islands is available from a side-scan sonar survey commissioned by the Malta Environment and Planning Authority in 2002 (GAS/MEPA, 2003; MIFSUD *et al.*, 2006). However, information on the small-scale distribution (i.e. detailed distribution within single localities) of *P. oceanica*, and particularly of the different bed types formed by this seagrass remains lacking. Such a lack of information hinders effective conservation and management of this habitat in the Maltese Islands.

The aims of the present study were to: (i) map the small-scale distribution of *P. oceanica* habitats and the different bed types of this seagrass at four locations; (ii) obtain cover values of fragmented (i.e. patchy and reticulate) and non-fragmented (i.e. continuous) bed types of *P. oceanica* habitat at each location, and explore the potential relationship between exposure and the observed distribution of seagrass habitat and bed type; and (iii) produce an updated map showing the large-scale distribution of *P. oceanica* habitats around the Maltese Islands, using data from the present study and that from other surveys made previously.

Material and Methods

Four locations on the north-eastern coast of the Maltese Islands: (i) Ramla Bay; (ii) Mellieha Bay; (iii) White Rocks; and (iv) St Thomas Bay (Fig. 1), were selected for the study. The locations are separated from each other by a distance of 10 km – 15 km, and all support extensive beds of *Posidonia oceanica*. Furthermore, the same locations were used as part of a larger programme of research concerning aspects of the ecology of fragmented and non-fragmented *P. oceanica* beds (e.g. BORG *et al.*, 2005). Data on the spatial distribution of *P. oceanica* at the four study locations were obtained from colour aerial photographs (scale 1:10,000) taken in May 1998 by Datatrak Ltd (Malta). The aerial photographs were scanned at a resolution of 300 dpi and the area occupied by *P. oceanica* beds and other habitat types delineated using PC imaging software (Corel Photo Paint). Differences in colour and shade of different habitats makes them easily identifiable from aerial photographs (KIRKMAN, 1996), especially given the clear coastal waters of the Maltese Islands, and since the more abundant seagrasses (*P. oceanica* and *Cymodocea nodosa*) mainly occur locally in monospecific beds. Since Mellieha Bay and St Thomas Bay comprised relatively large inlets compared to the other two study locations, only the north-western half of each of these two bays was selected for the analy-

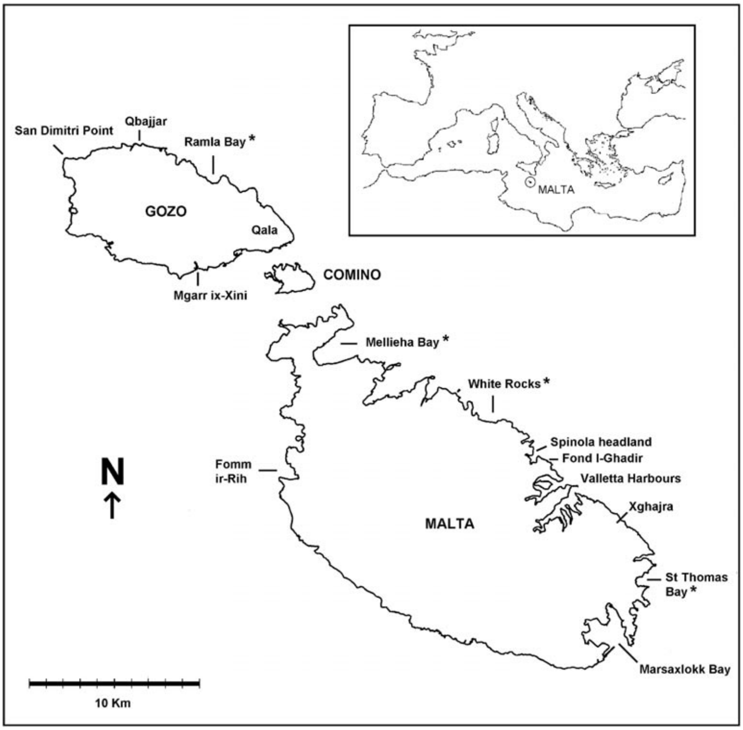

Fig. 1: Map showing the location of the Maltese Islands at the centre of the Mediterranean (inset), the four study locations, and other localities mentioned in the text.

sis. This ensured that the study areas from the four different locations had a broadly similar spatial extent.

Ground-truthing of the data obtained from the aerial photographs was carried out from January to July 1998 using SCUBA diving (e.g. ORTH & MOORE, 1983; KIRKMAN, 1996). This technique has been used widely in the Maltese Islands to survey marine benthic habitats (BORG *et al.*, 1997; BORG & SCHEMBRI, 2003). During the diving surveys, shore-normal transect lines graduated at 5 m intervals were laid underwater by scientific divers. As they swam along the transects, the divers recorded the distance from the shore to the boundaries of *P. oceanica* beds, and also took note of the occurrence and distribution of other main benthic habitats present. Data on the overall state of health of the seagrass beds were collected by the divers, using expert judgement, while data on seagrass shoot density and morphometric attributes were also obtained by collecting shoots and making estimates of these in the laboratory (see methodology and results in BORG *et al.*, 2005). Water depth was recorded using the divers' electronic depth gauges. Adjacent transects were separated by a distance of circa 150 m, while the transect length varied between 200 m and 800 m. The maximum water depth reached during the surveys in all four study locations was 25 – 30 m. Because of the limitation of the maximum time that could be spent underwater during any one SCUBA dive, transects longer than 300 m were subdivided into shorter ones (maximum length of 100 – 300 m) and surveyed during separate dives, but were all aligned along the same compass bearing (shore-normal). To survey transects located offshore at distances greater than 300 m from the land, divers were transported to the transect starting points using a 4.5 m boat, which remained on site to accompany the divers. Position finding, to record the geographical location of the two ends of each transect, was made from the boat using a portable Geographical positioning System (GPS) set (Garmin 45, USA).

To produce maps showing the distribution of *P. oceanica* beds and other benthic habitats at the four study locations, electronic images of the aerial photographs were georeferenced and orthorectified (GREEN *et al.*, 2000; LILLESAND & KIEFER, 2000) against accurate digital survey maps (Mapping Unit, Malta Environment and Planning Authority) using the GIS computer program Erdas Imagine 8.4 (Erdas Inc., USA). Following fieldwork, transect data were compared with the *P. oceanica* spatial distribution data acquired from the aerial photographs and, where necessary, adjustments made such that the spatial extent of the seagrass, as shown on the map, was a true representation of its cover in the field. Using the same GIS computer program, the electronic images were analysed to obtain cover estimates for the two main seagrass bed types (continuous and fragmented) at each of the four study locations. A standard length of shore (600m) was selected, which included both fragmented and continuous seagrass beds, and the area sandwiched between the shore and the 13 m depth contour was analysed. The relative cover of each bed type was then estimated using unsupervised classification techniques (GREEN *et al.*, 2000; LILLESAND & KIEFER, 2000).

To obtain an estimate of the exposure at each of the four study locations, the Relative Exposure Index (REI) proposed by KEDDY (1982) and adapted by FONSECA & BELL (1998), was used:

$$REI = \sum_{i=1}^{8} (Vi \times Pi \times Fi)$$

where i = *i*th compass heading (1 to 8; i.e. N, NE, E, SE, S, SW, W and NW); V = mean monthly maximum wind speed in m s^{-1}; P = percent frequency of wind in the *i*th direction, and F = effective fetch. For the Maltese Islands, values of REI typically range between 0.5×10^6 for the most sheltered sites and 4.5×10^6 for the most exposed sites. Values of V were calculated using wind data records obtained from the local Meteorological Office (Malta International Airport) for the three years prior to the study to obtain mean values over an appropriately long period (see FONSECA & BELL, 1998). Wind velocities that exceeded 95% of the recorded velocities (> 10 m s^{-1}; 'exceedance winds', KEDDY, 1982) were removed from the data set, and the remaining values used to calculate V, which was therefore the grand mean (mean of monthly means of daily maximum wind speeds). Fetch was taken as the distance from the particular site under consideration (taken at the centre of the bay/inlet) to land along a given compass heading (SHORE PROTECTION MANUAL, 1977). Effective fetch was estimated by measuring fetch along 4 lines radiating out from either side of the *i*th compass heading with a spacing of 11.25°, and along the *i*th heading (n = 9), and then averaging the product of each of the nine lines multiplied by the cosine of the angle of departure from the *i*th heading (SHORE PROTECTION MANUAL, 1977).

Data on the distribution of *P. oceanica* at each of the four locations were pooled with those from a number of other surveys (namely BORG & SCHEMBRI, 2003) to produce a map showing the large-scale distribution of the seagrass around the Maltese Islands.

Results

The mapping surveys established a set of four maps showing the small-scale distribution of *P. oceanica* beds at the four study locations (Figs 2 – 5). Overall, there was very good agreement between the distribution of *P. oceanica* determined from the aerial photographs and data collected from the ground-truthing surveys. At each of the four locations, the general pattern of *P. oceanica* distribution was as follows: in shallow waters (2 – 4 m), *P. oceanica* occurred as small patches of varying size (< 1 m to several metres across) on a rocky substratum. In deeper waters (5 – 10 m), the patchy stands were often replaced by reticulate beds consisting of *P. oceanica* growing on a soft sediment bottom and interspersed with bare sand. Further offshore and at deeper depths (11 – 13 m), there was a transition from reticulate to continuous beds, with both reticulate and continuous beds occurring on a thick 'matte'. Continuous beds extended to water depths of between 25 m and 30 m, and eventually formed reticulate or patchy beds in deeper waters. Therefore, the sequence of occurrence of the different *P. oceanica* bed types, moving away from the shore, was: patchy – reticulate – continuous – reticulate – patchy (Figs 2 - 5).

Overall, the state of health of *P. oceanica* at each of the four locations surveyed was good (see BORG *et al.*, 2005), however, the seagrass at White Rocks and St Thomas Bay supported a higher epiphyte load than at Ramla Bay and Mellieha Bay. In Mellieha Bay, patches of naturally occurring dead *P. oceanica* matte interspersed amongst living matte were encountered in various places, at depths ranging between 5 m and 13 m. These patches of dead matte varied in size from < 1 m^2 to around 100m^2.

The GIS analyses (Table 1) indicated a progressive increase in values of total seagrass percentage cover, and a concordant decrease in values of the fragmented:continuous (F:C) bed ratio on moving southwards (Ramla Bay to St Thomas Bay) along the north-eastern coast of the Maltese Islands. The estimated values of Relative Exposure Index for the four study locations

Table 1

Values of total area surveyed at each of the four study locations, total seagrass cover at each location, and cover of fragmented and continuous *Posidonia oceanica* beds recorded from each location.

Locality	Total area surveyed (m^2)	Total seagrass cover (%)	Fragmented bed cover (F) (%)	Continuous bed cover (C) (%)	Cover ratio F/C
Ramla Bay	437,745	21.91	46.82	53.18	0.88
Mellieha Bay	391,966	78.30	40.70	59.29	0.69
White Rocks	393,987	92.70	35.99	64.01	0.56
St Thomas Bay	394,692	97.84	22.61	77.39	0.29

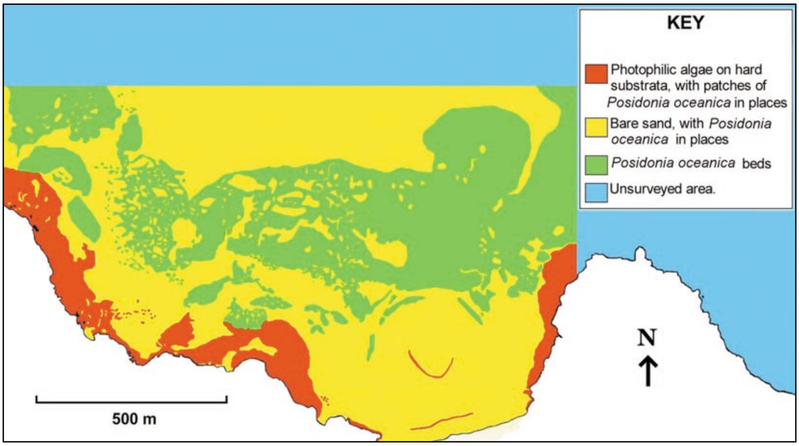

Fig. 2: Map showing the small-scale distribution of main benthic habitat types in Ramla Bay.

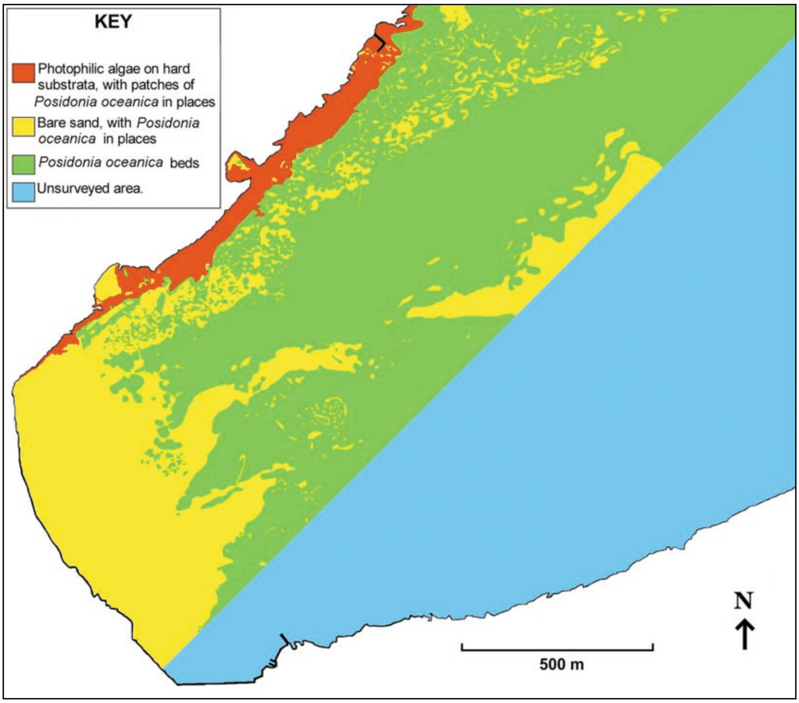

Fig. 3: Map showing the small-scale distribution of main benthic habitat types in the north-western sector of Mellieha Bay.

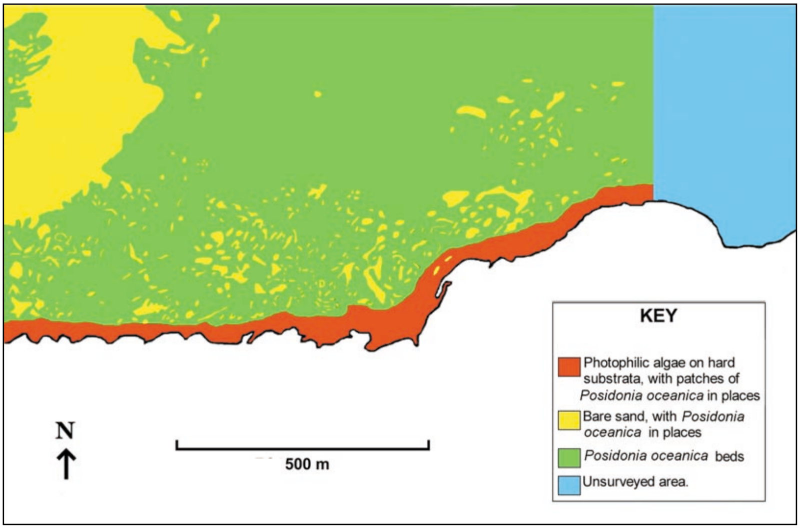

Fig. 4: Map showing the small-scale distribution of the main benthic habitat types at White Rocks.

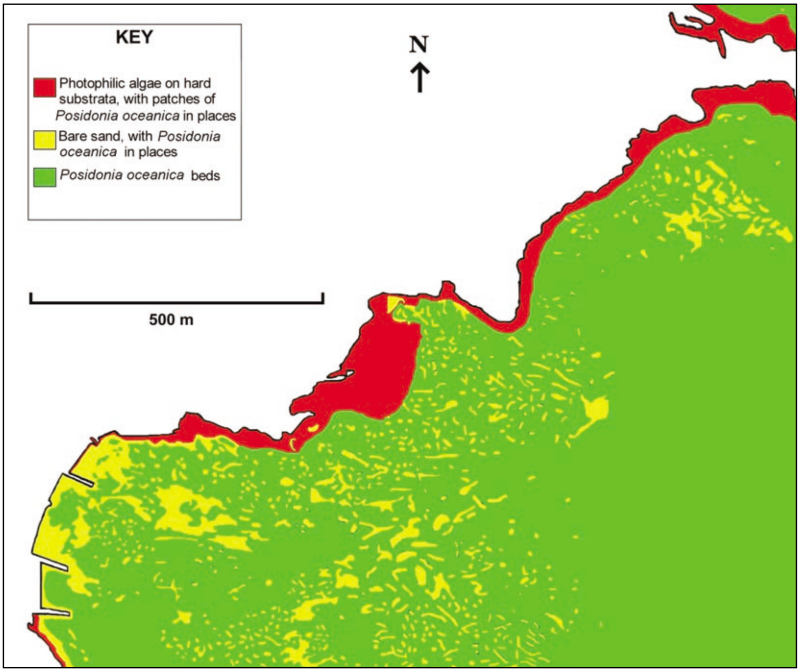

Fig. 5: Map showing the small-scale distribution of the main benthic habitat types in the north-western sector of St Thomas Bay.

are given in Table 2. St Thomas Bay and Ramla Bay had the highest exposure, followed by White Rocks, while Mellieha Bay had the lowest exposure.

The outcome of pooling the distribution data for *P. oceanica* collected from the four study locations with that from BORG & SCHEMBRI's (2003) surveys is a map showing the large-scale distribution for the Maltese Islands (Fig. 6). *P. oceanica* occurs mainly on the north-eastern coasts of the Maltese Islands from Xwejni on the northern tip of Gozo to Marsaxlokk Bay on the southern tip of mainland Malta; a distance of 40.5 km. The only break in the occurrence of *P. oceanica* is in the coastal area between the Valletta Harbours and Xghajra; a distance of 5.4 km. The distribution of *P. oceanica* is much less extensive on the western coasts of the islands; the seagrass mainly occurs between Mgarr ix-Xini on the southern coast of Gozo and Fomm ir-Rih on the western coast of Malta; a distance of 12.8 km. However, some meadows and patches of the seagrass also occur in the smaller inlets present on the western coasts of the islands (Fig. 6).

Table 2
Values of the Relative Exposure Index (REI) estimated for each of the four study locations.

Locality	REI value
Ramla Bay	3.22×10^6
Mellieha Bay	1.66×10^6
White Rocks	2.46×10^6
St Thomas Bay	3.28×10^6

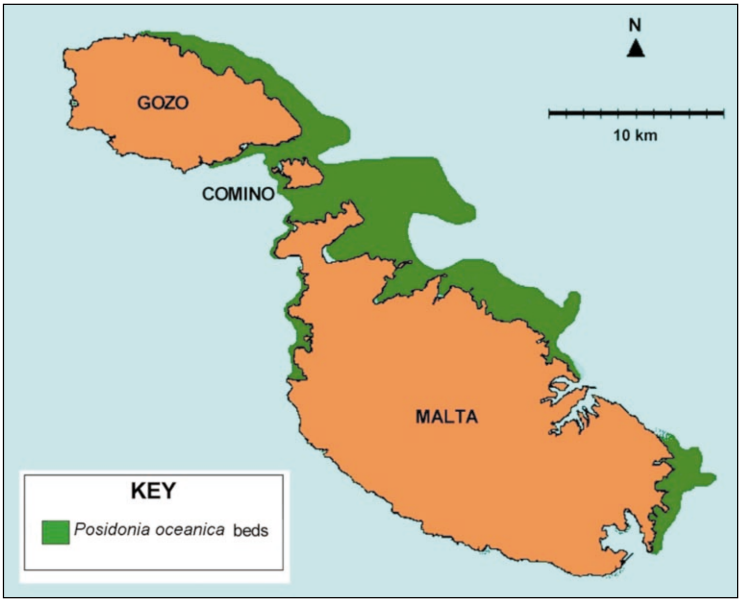

Fig. 6: Small scale map showing the large-scale distribution of *Posidonia oceanica* around the Maltese Islands.

Discussion

The results from the mapping survey indicate that three main types of *P. oceanica* beds occurred at each of the four localities surveyed: (i) patch; (ii) reticulate; and (iii) continuous. While the *P. oceanica* patches occurred mainly on bedrock in shallow waters (circa 4 m), the continuous and reticulate beds occurred adjacent to each other at similar depths (9 – 12 m). The occurrence of *P. oceanica* patch and continuous beds on rock has been reported from other areas of the Mediterranean (e.g. MAZZELLA *et al.*, 1986; GIOVANETTI *et al.*, 2008), and reticulate beds have been described by other Mediterranean workers as meadows with 'inter-matte' channels (e.g. COLANTONI *et al.*, 1982). The occurrence of adjacent zones of different *P. oceanica* bed types from the four study locations surveyed in the present study is concordant with the distribution pattern of this seagrass in other parts of the Mediterranean (e.g. COLANTONI *et al.*, 1982; MEINESZ *et al.*, 1988; BUIA *et al.*, 2000; BARBERÁ CEBRIÁN *et al.*, 2002). This pattern probably results from the interaction of a gradient of environmental factors, amongst which the sedimentation regime, sea currents, storms and exposure are major ones ((KIRKMAN, 1985; FONSECA *et al.*, 1983; FONSECA & KENWORTHY, 1987; KIRKMAN & KUO, 1990; FONSECA & BELL, 1998). The way in which these natural environmental factors influence patterns of seagrass bed structure is undoubtedly complex but they probably act by promoting or halting development, or possibly inducing regression at the bed boundaries, or by creating pockets within the seagrass beds that are devoid of living shoots (KIRKMAN, 1985).

Disturbance resulting from anthropogenic activities also affects seagrass bed morphology through direct physical damage (e.g. deployment of moorings or damage by anchors; HASTINGS *et al.*, 1995; FRANCOUR *et al.*, 1999) and through indirect degradation, such as that resulting from organic loading (e.g. DELGADO *et al.*, 1997; 1999; RUIZ *et al.*, 2001; DIMECH *et al.*, 2002). MANZANERA & ROMERO (2000) reported differences in structure of *P. oceanica* beds exposed to different degrees of environmental disturbance. Given the local absence of permanent rivers and the sporadic runoff following rainfall episodes, coastal eutrophication and turbidity resulting from runoff following precipitation are not expected to have a major influence on the distribution of *P. oceanica* beds around the Maltese Islands. On the other hand, fragmentation of *P. oceanica* beds resulting from anthropogenic disturbance has almost certainly occurred in some areas, particularly in the vicinity of the Valletta harbours, which are used heavily for commercial and recreational maritime activities, and off Xghajra where Malta's largest sewage outfall is located (AXIAK *et al.*, 2000). Coastal waters off the southern coast of the island of Malta tend to have an elevated nutrient loading (AXIAK *et al.*, 2000) resulting from a higher population density and more intense coastal use there (MALLIA *et al.*, 2002), compared to northern coast of the same island. One would expect, therefore, that *P. oceanica* beds present off the southern coast of the Maltese Islands would be stressed compared to those present off the northern coast.

GIS analysis indicated that *P. oceanica* beds had a progressively higher cover on moving north to south along the north-eastern coast of the Maltese Islands, while the ratio of fragmented/continuous (F:C) cover decreased progressively. These results are somewhat unexpected considering that the south-eastern half of the Maltese Islands is the more densely populated (MALLIA *et al.*, 2002), while the adjacent marine areas are subjected to considerable anthropogenic disturbance, which have resulted in these parts of the islands having relatively poor seawater quality (AXIAK *et al.*, 2000). Therefore, while one would expect that seagrass meadows off the south-eastern coast would be less abundant and exhibit a higher degree of habitat fragmentation compared with the north-eastern coast, the present results indicate otherwise. It is difficult, if not impossible, to relate this difference to any single environmental factor; probably, a complex set of environmental variables is involved. These include differences in the hydrodynamic regime (COLANTONI *et al.*, 1982) and in other factors such as the physico-chemical characteristics of the substratum and bottom geomorphology (see FONSECA *et al.*, 2002) between the different locations. Several studies have shown that seagrass beds tend to be more fragmented where water movement is strong, whereas in more sheltered places, beds tend to have a more continuous morphology (FONSECA *et al.*, 1983; MARBÁ and DUARTE, 1995). The Maltese Islands are very windy. On average, only 7.7 days of the year are calm and winds of between 1.8 and 39 kmh^{-1} occur during the rest of the year. The predominant winds blow from the northwest, on average, during 19% of the year (CHETCUTI *et al.*, 1992). As a result, San Dimitri Point (Fig. 1), which lies on the northwestern tip of the island of Gozo, is the most exposed coast in the Maltese Islands, while the south-eastern tip of Malta, at Marsaxlokk Bay (Fig. 1) is, on average, the most sheltered (excluding the heads of creeks and embayments). Therefore, this wind exposure regime, coupled with the predominant southeast current (HAVARD, 1978; 1979; 1980), to which there is decreased exposure from Ramla Bay to St Thomas Bay, may partly explain the decrease in the F:C cover ratio (hence decrease in fragmented bed cover) in a southeasterly direction along the northeastern coast of the Maltese Islands. On the other hand, the estimated REI values indicate a similar exposure for Ramla Bay and St Thomas Bay, while Mellieha Bay had the lowest REI value. Hence, the estimated REI values do not support a potential relationship between exposure and fragmented/nonfragmented seagrass bed cover. However, the hydrodynamic properties of a particular locality are not determined solely by wave exposure. The submarine geomorphology (e.g. FONSECA *et al.*, 2002), micro-scale currents (e.g. HAVARD, 1978; 1979) and other physical environmental factors (e.g. seiches; DRAGO, 1999) also contribute to the hydrodynamic properties of a particular locality. Therefore, more detailed aspects of the hydrodynamic and sedimentary regimes, and of the geomorphological characteristics at specific localities, need to be taken into account when assessing potential relationships between exposure and the occurrence of different bed types of *P. oceanica* and seagrass cover.

Considering that the data used by BORG and SCHEMBRI (1995) showing the large-scale distribution of *P. oceanica* around the Maltese Islands was collected exclusively using diving, the agreement between these authors' map and the one produced from the present study (Fig. 6) is good. On the other hand, there are discrepancies between the present map and the one produced by GAS/MEPA (2003) (see also MIFSUD *et al.*, 2006); particularly in areas where the seagrass is known from other surveys (see Borg and Schembri, 2003) to occur on bedrock. For example, the map produced by GAS/MEPA (2003) (see also MIFSUD *et al.*, 2006) does not indicate any *P. ocean-*

ica meadows off Qala (Gozo), Spinola Headland (St Julians), and Fond l-Ghadir (Sliema), whereas extensive areas with the seagrass are known to occur at all three localities (BORG & SCHEMBRI, 2003). Such differences are probably attributable to the surveying technique used during the GAS/MEPA's (2003) surveys (see also MIFSUD *et al.*, 2006).

In conclusion, the distribution and occurrence of *P. oceanica* bed types around the Maltese Islands appear to be similar to those recorded from other parts of the Mediterranean. The factors that determine the small-scale distribution of the habitat, and the occurrence, spatial distribution and conformation of different bed types of the seagrass are not well understood, but are undoubtedly complex. Data from the present study do not support a relationship between exposure and cover of fragmented/non-fragmented beds of *P. oceanica*. However, it should be noted that natural physical factors operating at the local scale, such as sea currents and other hydrodynamic attributes, and the geomorphological features of the seabed, were not considered in the present study. Hence, consideration of such factors in an index or an ecological model may result in a different finding. The combination of aerial photography and surveying using diving to map the distribution of *P. oceanica* down to a water depth of around 25 m appears to be satisfactory for use in clear coastal waters. However, at depths greater than 25 m, a combination of underwater videography and side-scan sonar techniques would be more appropriate. Data on the small-scale distribution of seagrass beds and other habitats in specific localities, such as those collected in the present study, are important for effective conservation and management of coastal benthic ecosystems, particularly in highly populated countries such as Malta where coastal development and other anthropogenic influences that constitute a potential threat to marine benthic habitats are high. Studies of the ecology of Maltese *P. oceanica* habitat indicate similar architectural characteristics between fragmented and continuous beds (BORG *et al.*, 2005), which would support the notion that fragmented beds do not have a lower ecological values than non-fragmented ones. Furthermore, it appears that even *P. oceanica* bare matte supports a high diversity of associated biota (BORG *et al.*, 2006). It would therefore seem appropriate to undertake further surveys, similar to the present, that are aimed at mapping the small-scale distribution of *P. oceanica* bed types, and to monitor potential changes in the large-scale distribution of the habitat that may occur with time.

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