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Considerations on the Ecological Role of Wrack Accumulations on Sandy Beaches in the Maltese Islands and Recommendations for Their Conservation Management

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ABSTRACT

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Beaches in the Maltese Islands, as in others along the Mediterranean coast, receive copious annual inputs of *Posidonia oceanica* wrack. A seasonal survey of macrofaunal communities colonising the wrack beached on three groomed and three ungroomed Maltese beaches was made with the principal aim of identifying any significant community differences between the two types of beaches and, consequently, to make recommendations for the conservation management of the wrack resource. Beaches were sampled during the winter and summer of 2002 and 2003 using pitfall traps and coring. The macrofauna collected by coring belonged to fourteen main taxa; Gastropoda and Isopoda were the most represented in terms of individual abundance, and Coleoptera (mainly the families Staphylinidae and Histeridae) were the most species-diverse. Some taxa, such as Staphylinidae, as well as some species, such as the gastropod *Truncatella subcylindrica*, were only recorded from the wrack on the ungroomed beaches. NMDS ordination and analysis of dominance patterns showed that macrofaunal communities in aged wrack on ungroomed beaches were distinct from those in 'young' wrack accumulations on the regularly groomed beaches, with differences being attributed mainly to the conduction of grooming activities or otherwise, rather than to differences in substratum type.

ADDITIONAL INDEX WORDS: *Posidonia oceanica*, macrofauna, pitfall traps, coring, groomed beaches

INTRODUCTION

Storms, wave action and heavy swells remove huge amounts of seagrass material and deposit it along shores to form large wrack banks (Lenanton *et al.*, 1982). Due to the relative lack of *in situ* production on sandy beaches, the input of such drift material may represent a major source of carbon to macrofaunal communities of exposed sandy beaches and other coastal habitats (reviewed by Dugan *et al.*, 2003) and this process has been implicated as a potentially important factor in structuring invertebrate assemblages on sandy beaches (Olabarria *et al.*, 2007).

Mediterranean coastlines receive copious amounts of dead *Posidonia oceanica* and other seagrass debris, which forms accumulations known as 'banquettes'. The Maltese Islands are no exception and according to the Malta Tourism Authority (MTA), the local agency responsible for the grooming of beaches, 53 coastal areas on the island of Malta and over 15 on the island of Gozo are groomed regularly, with some 19,000 tons of waste (including seagrass debris, for which separate statistics are not kept) being removed annually.

Judicious management of the wrack resource requires information on the total amounts of wrack deposited along a

particular coastline, the total organic material inputted as a result, and on the rate of decomposition of the wrack. The aims of the present study were to (i) monitor seasonal variations in individual abundance and species composition of the banquette macrofaunal assemblage; and (ii) identify any possible differences in wrack macrofaunal assemblages between groomed and ungroomed beaches. On the basis of the results obtained, management recommendations are made in an attempt to achieve a compromise between public enjoyment of beaches and conservation concerns.

MATERIALS AND METHODS

Three ungroomed (Xatt l-Ahmar in Gozo, and Selmun and Salini in Malta) and three groomed (Qarraba, Fomm ir-Rih and White Tower Bay, all in Malta) beaches were sampled for macrofauna by quadrat sampling in the spring, summer and winter seasons of 2002 and 2003. Pitfall traps were deployed only during the 2002 seasons. The six beaches sampled presented different substratum types: Xatt l-Ahmar, Qarraba and White Tower Bay are sandy beaches, Fomm ir-Rih and

Selmun are shingle beaches, whilst Salini is a brackish, muddy channel at the mouth of a valley system. Figure 1 gives the location of the beaches sampled in the present study.

Motile, nocturnal, surface-active wrack macrofauna were sampled using pitfall traps, which were deployed in the evening, left overnight, and were then emptied in the morning. The traps consisted of 25cm high 10cm-diameter plastic cups inserted in the banquette and half-filled with a glycerol-water mixture (1:9) to prevent collected animals from escaping or damaging each other. The quadrat sampling consisted of collecting wrack from a 20cm x 20cm quadrat to a depth of 10 cm (in effect collecting a 0.004m³ core sample), and repeating the procedure at 10cm depth intervals until the bottom of the wrack accumulation was reached. The material was then washed over a 1mm-mesh and sorted by hand for macrofauna. Groomed beaches were only sampled during the winter months since deposited wrack was removed by beach cleaners in summer.

Non-metric multidimensional scaling (nMDS) ordination plots were generated based on the Jaccard coefficient of resemblance. Substratum (sand or shingle) and condition (groomed/ungroomed) were used as overlays on the nMDS ordination plots to assess the relative importance of these two factors in shaping the wrack macrofaunal assemblage.

The DOMDIS procedure (Clarke & Gorley, 2006) was used to compare k-dominance curves generated from the biotic data recorded for the groomed beaches with those for the ungroomed beaches. This procedure calculates separately for each sample the cumulative relative abundances of species, ranked in decreasing order, with distance between every pair of cumulative samples using the Manhattan distance metric. The resultant dissimilarity matrix generated was then used to generate an nMDS ordination plot. Statistical analyses were made using the Primer 6 (Clarke & Gorley, 2006), SPSS (Norris, 1993) and QED (Henderson & Seaby, 2007) software packages.

RESULTS

Table 1 reports the seasonal total macrofaunal individual abundances and species richness values for the six beaches sampled. The macrofauna collected from the ungroomed beaches by coring belonged to fourteen main taxa (Coleoptera, Diptera, Hymenoptera, Orthoptera, Thysanoptera, Araneae, Isopoda, Amphipoda, Decapoda, Gastropoda, Polychaeta, Oligochaeta, Chilopoda and Sipuncula). Gastropoda and Isopoda were the most represented in terms of individual abundance, whilst the Coleoptera (mainly the families Staphylinidae and Histeridae) was the most species-diverse. Some taxa, such as Staphylinidae, as well as some species, such as the gastropod *Truncatella subcylindrica*, were recorded from wrack on the ungroomed beaches only. The latter species reached very high densities in some cases, as at Salina in winter 2003, when 68,070 individuals m⁻³ were recorded, which constitutes 83.1% of the entire macrofaunal catch during the winter 2003 season from all three ungroomed beaches.

Diptera, Isopoda (mainly *Spelaeoniscus vallettai* and *Chaetophiloscia elongata*), Coleoptera larvae and the polychaete *Ophelia bicornis*, although present on groomed beaches, were much more abundant on the ungroomed beaches; for example, a total of 43 Coleoptera larvae were collected from the two ungroomed beaches over two sampling years, as compared to 10 larvae collected from the three groomed beaches during the same period.

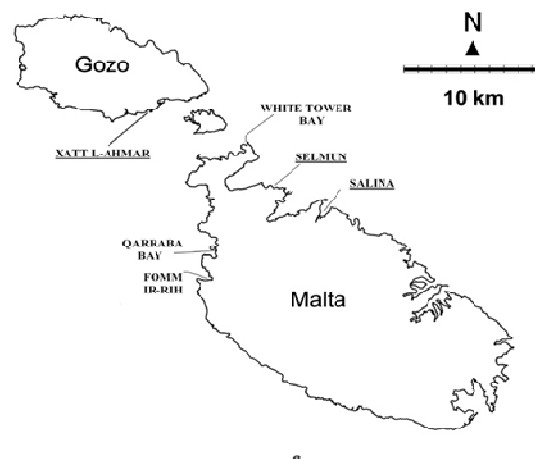


Figure 1. Map of the Maltese Islands showing the location of the beaches sampled: ungroomed beaches are underlined.

Similar individual abundances for the amphipod *Orchestia stephenseni* were recorded on groomed and ungroomed beaches, whilst few species (e.g. the isopod *Idotea* sp. and the tenebrionid beetle *Phaleria acuminata*), were recorded exclusively from groomed beaches.

A total of 2634 macrofaunal individuals belonging to 18 species from all six beaches collectively were collected by the pitfall traps during the 2002 sampling seasons. Of these species, nine were not collected by coring. On the ungroomed beach of Xatt l-Ahmar, there was a marked seasonal difference in the relative abundance of the major taxa: Isopoda dominated (in terms of individual abundance) all wrack depth strata during the winter season (with relative abundance increasing also with depth, from 40% of total abundance in the 0-10cm stratum to over 99% in the 40-50cm stratum), whilst Gastropoda dominated the summer collections (with relative abundance also increasing with depth, from 41% of total abundance in the 0-10cm stratum to over 85% in the 30-40cm stratum). The relative abundance of adult Coleoptera increased with depth during the winter seasons and decreased during the summer seasons. Amphipoda were only found during the winter in the 0-10cm stratum, whilst Oligochaeta and Polychaeta were also only recorded during the winter seasons, but were restricted to the 20-30cm stratum.

On the ungroomed beach at Selmun, Gastropoda were much less important in terms of individual abundance; the relative abundance of Isopoda increased with depth during the winter months, reaching a maximum of 47% in the 30-40cm stratum, but this taxon was also abundant during the summer seasons, with a relative abundance of 59% in the upper 0-10cm stratum. Oligochaeta were collected from all the depth strata; Amphipoda and Arachnida were collected from the 0-10cm stratum only (with Arachnida occurring only during the winter seasons), and Sipuncula were only collected from the 0-10cm and 10-20cm strata during the winter. No clear vertical distribution pattern for Coleoptera emerged for this beach. On the ungroomed beach of Selmun, the highest total macrofaunal

individual abundance was recorded at 10m and at 6m landward of the strandline during the winter and summer seasons respectively, whilst the corresponding distances on the ungroomed beach of Xatt l-Ahmar were 4m and 1m.

Diptera larvae were always collected in the uppermost wrack stratum on all the beaches sampled but Coleoptera larvae were recorded in deeper wrack strata during the winter months than during the summer months, to a maximum depth of 30cm (Selmun, winter 2003). Staphylinid beetles also showed an increase in individual abundance during the winter months; for example, on the ungroomed beach at Selmun, the combined staphylinid abundance in winter and summer was 645 and 48inds m⁻³ respectively, whilst the corresponding figures for the other two ungroomed beaches at Xatt l-Ahmar and Salini were 100 and 40inds m⁻³ and 67 and 42inds m⁻³, respectively.

In the nMDS ordination plot based on the DOMDIS-generated dissimilarity matrix, the winter 2003 samples from the ungroomed beach at Selmun separated out very strongly from the rest. In fact, winter core samples from this beach showed a homogenous dominance pattern, with 13 species recorded in comparable

individual abundances. The highest number of species collected by coring from a single season from the groomed beaches was five.

When the same analysis was repeated without the Selmun Winter 2003 assemblage, all the samples from the ungroomed beach at Xatt l-Ahmar separated out from the remaining samples in the ordination plot. This was attributed to the high individual densities of the gastropod *Truncatella subcylindrica*, the amphipod *Orchestia stephensi* and the isopod *Spelaeoniscus vallettai*, and the presence of species (opilionids, pseudoscorpions and cryptophagid and histerid beetles) at Xatt l-Ahmar.

Figure 2 gives the NMDS plots generated using the Jaccard coefficient, with substratum type (sand or shingle) and condition (groomed/ungroomed) as overlays. Gauci *et al.* (2005) report significant differences in the macrofaunal assemblages from Maltese sandy and shingle beaches and hence substratum is putatively a discriminating factor. In the present study, the nMDS analyses separated the beaches mainly in terms of condition (groomed/ungroomed), rather than on differences in substratum type.

Table 1 Species and total individual abundance of macrofauna as recorded through the core sampling technique on the groomed and ungroomed beaches during the 2002-2003 sampling period. The same number of cores was taken from each beach during every sampling season – hence, totals, rather than means, are reported in the table.

BEACH	Summer (S) and Winter (W) 2002				Summer (S) and Winter (W) 2003				Both years			
	Total individual abundance m ⁻³		Species richness		Total individual abundance m ⁻³		Species richness		Total individual abundance m ⁻³		Species richness	
	S	W	S	W	S	W	S	W	S	W	S	W
<i>Ungroomed beaches</i>												
Xatt l-Ahmar	4250	6945	7	7	3926	10092	9	12				
Selmun	2250	2611	5	5	1096	2231	5	11				
Salini	2646	375	5	5	2827	69615	16	8				
TOTAL	9146	9931	10	12	7849	81938	24	21	16995	91869	27	24
<i>Groomed beaches</i>												
Fomm ir-Rih	764	167	1	2	813	175	1	2				
Qarraba	1278	1084	2	1	950	980	3	2				
White Tower Bay	167	306	3	4	780	1111	3	4				
TOTAL	2209	1557	4	4	2543	2266	4	4	4752	3823	5	5

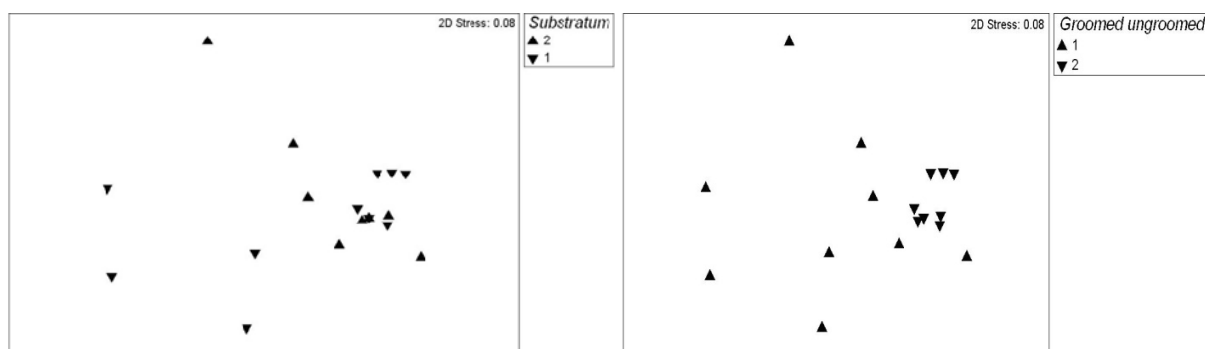


Figure 2. nMDS ordination plot for samples collected by coring from all the beaches sampled during the different seasons, using substratum type and condition (groomed/ungroomed) as overlays. In the left plot, shingle and sand as substrata are designated 1 and 2, respectively, whilst in the right plot, ungroomed and groomed beaches are designated 1 and 2, respectively.

DISCUSSION

The inter-beach differences in macrofaunal zonation patterns observed on the ungroomed beaches can be attributed primarily to differences in exposure to wave action and to the position of a beach on the reflective-dissipative spectrum, with macrofauna being displaced further inland under wave-exposed, reflective conditions. The high macrofaunal individual abundances recorded for mid-shore areas (4-10m away from the strandline) are consistent with findings by Urban-Malinga *et al.* (2008) who report highest organic weight losses (and highest organic matter availability) mid-shore.

A number of species were collected exclusively by pitfall traps but not by coring. These included carabids (*Dichrotrichus obsoletus*, *Scarites planus* and *Harpalus attenuatus*), isopods (*Porcellio laevis* and *Armadillidium vulgare*), the chilopod *Scutigera coleoptrata*, the orthopteran *Mogoplistes squamiger* and some spiders (*Arctosa* sp., *Drassodes* sp. and *Oecobinus annulipes*). These are all predatory species which are non-residents of wrack and which invade the wrack at night to prey on amphipods and isopods. Species collected exclusively by coring include all the staphylinids (e.g. *Remus filum*, *Remus pruinosus*, *Myrmecopora* spp., *Carpelimus pusillus*) and gastropods (*Truncatella subcylindrica*, *Ovatella myosotis* and *Gibbula adansonii*), the chilopod *Tuoba poseidonis* and the oligochaete *Enchytraeus albidus*. These can be considered to be wrack-specific, psammatoophilous species.

In terms of number of individuals, beached wrack is generally dominated by Coleoptera and Diptera (e.g. Ince *et al.*, 2007). The numerical dominance of gastropods and isopods in the present study is due to just a few species – the gastropod *Truncatella subcylindrica* and the isopods *Spelaeoniscus vallettai* and *Chaetophiloscia elongata*. Beetles were the most species-diverse group (20 species, of which 12 were Staphylinidae). The presence of three live individuals of *Aspidosiphon* sp. (Sipuncula) in aged banquettes at Selmun in winter 2003 is an interesting find as no previous published records of live sipunculans from banquettes exist. Additionally, species of scientific and conservation importance occur on beached wrack in Malta; for example, although not recorded in the present study, the endemic species

Chersodromia anisopyga and *Chersodromia suda* (both Diptera - Plant, 1995), and the sub-endemic species *Rachispoda caudatula* (Diptera - Gatt, 2000) have been recorded from banquettes.

The results of the present study have important management implications:

1. The macrofaunal assemblages associated with aged banquettes on non-groomed beaches are distinct from those of 'young' banquettes on the regularly groomed beaches; the former have higher individual abundance values for isopods, coleopteran larvae and for the polychaete *Ophelia bicornis*, whilst being the exclusive refuges for dipteran larvae and staphylinid beetles.

2. Some species are only found (or are only common) on aged wrack; therefore, the continued existence of such species depends on the long-term availability of this habitat. One example are the staphylinid beetles recorded exclusively from aged banquettes on the ungroomed beaches.

3. The fauna associated with beach-cast material can alter through succession (Colombini & Chelazzi, 2003). In the present study, amphipods were recorded only during the winter months, as expected of these early wrack colonizers; amphipods are normally followed by dipterans and beetles (Colombini *et al.*, 2008). Coleoptera were found deeper in the wrack banks during the summer months than in winter, which might be attributed to their preference for moister, older wrack (Griffiths & Stenton-Dozen, 1981). Hence, if beaches are groomed, the successional series will always be truncated in its early several stages. In addition, aged banquettes exhibited more homogenous macrofaunal dominance patterns than freshly-deposited banquettes, due to higher species richness and evenness values. Deidun *et al.* (2007), in their study of bare-sand macrofaunal assemblages, also report higher Shannon-Wiener diversity and Pielou evenness values from ungroomed Maltese beaches when compared to groomed ones, whilst Ince *et al.* (2007) report much higher macrofaunal individual abundance values from beaches receiving large wrack inputs when compared with beaches receiving smaller inputs.

4. Aged wrack is of importance to some species as a foraging and spawning ground; for example, the gastropod *Truncatella subcylindrica* was completely absent from the groomed beaches, whereas this species was recorded in very high densities from the

ungroomed beaches (reaching a maximum of 68,070 inds m⁻³ in winter 2003). In addition, non-resident carabid and some spider species exploit wrack resources at night to prey on amphipods and isopods found therein.

These results lead to a number of management recommendations:

1. Grooming during the winter and spring seasons should be discouraged on the more frequented and popular beaches in order to minimise shore erosion after heavy storms; this is especially relevant in the Maltese Islands where just 2.4% of the coastline is sand or shingle (Mallia *et al.*, 1999) and where the vast majority of back-beach communities have been extirpated or are severely degraded (Cassar & Stevens, 2002).

2. Beaches that are not so popular with bathers should not be groomed at all, to allow 'aged' banquettes to form and the unique macrofaunal communities that are associated with them to develop. A first step in this direction was taken by the Maltese authorities in the summer of 2007 when the beach at Selmun was not groomed, even during the tourist season.

3. Beach grooming should be conducted manually where possible, to minimise the associated removal of the surface sediment as much as possible. Guala *et al.* (2006) estimate that a mean mass of 68.1kg/m³ of sediment was inadvertently removed along with banquettes during grooming of Sardinian beaches.

4. In Malta, most of the seagrass debris removed is dumped in disused quarries. Studies should be made to identify a number of suitable back-beach locations as alternative repositories for the collected wrack. In such locations, the wrack would not negatively affect the bathing amenities of the beach while it could act as a refuge for wrack-specific species as well as a source of nutrients to the surrounding sediment, and to stabilize dune fringes.

5. Coastal managers should implement public educational campaigns aimed at dispelling the perception that seagrass debris on a beach is symptomatic of poor hygienic standards and that such accumulations are unaesthetic. An 'eco-beach' approach should be piloted on selected beaches whereby the ecological benefits of non-grooming are championed and a distinction is made between seagrass debris and anthropogenic litter.

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