Is faunal diversity on Maltese sandy beaches related to intensity of human use?

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Abstract

Sandy beaches are rare in the Maltese Islands where only some 2.4% of the ca 271km coastline is sedimentary; yet such beaches are much sought after for their amenity value by tourists and locals alike. Carrying capacity studies conducted by the Malta tourism authorities have shown that most beaches are under very heavy use while a study by Deidun et al. (2003) has indicated that the fauna of Maltese sandy beaches tends to be impoverished compared to other Mediterranean beaches and has hinted that this may be a result of lack of recruitment due to the relative isolation of these beaches. Therefore human use of Maltese sandy beaches may potentially be a key factor affecting faunal diversity of these beaches.

We explored this hypothesis by sampling the faunal assemblages of four Maltese beaches (Gnejna and White Tower Bay on Malta, and Xatt l-Ahmar and Ramla l-Hamra on Gozo) using pitfall traps set up in the wet and dry zones of each beach during the summer, when human use is expected to be highest. Human use of these beaches was assessed by estimating human occupancy of the beaches from standardised photographs. Beach occupancy values of 2400, 5700, 6700, and 12300 persons per square km were estimated for Ramla, White Tower Bay, Xatt l-Ahmar and Gnejna, respectively, establishing a gradient of anthropogenic impact with Gnejna as the most impacted beach and Ramla the least.

Three components of faunal diversity were considered: population size (number of individuals), species richness, and taxonomic composition. Faunal population size ranged from 7 individuals/trap/hour for Xatt l-Ahmar to 199 individuals/trap/hour for Ramla in the wet zone, and from 22 individuals/trap/hour for White Tower Bay to 87.33 individuals/trap/hour for Gnejna in the dry zone. The species richness ranged from 7 species (Xatt l-Ahmar) to 17 species (White Tower Bay). Between them, Amphipoda, Isopoda, Coleoptera Dermaptera and Hymenoptera accounted for the bulk of both species and individuals collected. There were no statistically significant correlations between population size, species richness and taxonomic composition.

The species collected from the four beaches was categorized into psammophiles, coastal species (occurring in coastal habitats but not restricted to sandy beaches) and euryoecious (ubiquitous) species. Ramla exhibited the highest proportion of psammophiles (98.4% of all species collected at Ramla) and the lowest proportion of ubiquitous ones (1.5% of all species), whilst for Xatt L-Ahmar the equivalent figures were 31.8% and 61.8% for ubiquitous and psammophilic species respectively

From the present study it results that there is no trend between any of the three components of faunal diversity analysed and the degree of human occupancy of the beaches, and the only tangible human impact was related to faunal habitat–use specificity. This suggests that human use of the beaches has no direct impact on the faunal assemblages of the mediolittoral and supralittoral zone of the beaches studied but that high levels of human disturbance result in generalists displacing specialist psammophilic species.

In spite of these results, intense human use of Maltese sandy beaches is of conservation concern since previous work has indicated a high degree of 'compartmentalisation' with different beaches harbouring distinct faunal assemblages either due to natural inter-beach barriers to dispersal, or due to unique environmental conditions present on the different beaches, including the nature and intensity of anthropogenic pressures. In addition, the present study addresses only the direct effect of trampling by beach visitors; indirect negative impacts, such as those of beach cleaning, have been well documented in other studies.

Keywords: sandy beaches, visitor impact, trampling, faunal diversity.

Introduction

Although roughly two-thirds of the world's coastline consists of sedimentary (mud, sand and shingle) shores (Reise, 2000), such coastlines are rare in the Maltese Islands, where just 2.4% of the coast is considered 'sandy'. Consequently, human pressure on local sandy beaches is intense and results from both the needs of the indigenous population as well as from tourism. With a total surface area of just 316 km^2, the Maltese Islands are among the smallest islands in the Mediterranean, however, they also have one of the highest population densities in the world (1194 individuals/km^2), and the local population is further inflated by over 1.2 million tourist arrivals each year (Mallia *et al.*, 2002) giving the islands the highest tourist intensity in the Mediterranean region (3171tourists/km^2 – GFANC, 1997). Most tourist arrivals are concentrated in the summer months; for example, in 2000, 65.2% of all tourist arrivals occurred in the period April-September (Mallia *et al.*, 2002). This greatly exacerbates human impact on local sandy beaches since some 58% of all beach visitors are non-locals (MECO, 2000) and some 85% of tourists spend time on local beaches (Mangion, 2001). Tourism accounts for 24.29% of the country's GNP, the highest tourism-GNP contribution of any Mediterranean country (Mangion, 2001). Tourism is therefore of vital importance to the Maltese economy and any tourism-related amenities, including local sandy beaches, are considered valuable economic assets.

There is at present a growing body of information on the morphodynamics, management, stability and visitor preferences of local beaches (Micallef, 1995, 1997, 2003; Morgan *et al*., 1996; Micallef *et al.*, 1999, 2001; Blakemore *et al.*, 2002; Micallef & Williams, 2002), however, biological studies are still very limited (Deidun *et al*., 2003 a, b) and none exist on visitor-impact on beach ecology.

This study aims to provide preliminary information on one aspect of human impact on the ecology of Maltese beaches, by investigating if there is any relationship between the intensity of human use and faunal diversity on Maltese sandy beaches.

Materials and Methods

Macrofauna (animals >0.5mm) were collected from four beaches – Gnejna and White Tower Bay on Malta, and Ramla l-Hamra and Xatt l-Ahmar on Gozo (**Figure 1**) – by pitfall trapping, coring and through standard searches.

Pitfall traps were used to collect fauna that burrows during the day and only emerges at night. The traps consisted of five 7.5cm-diameter plastic cups inserted into the sand such that their mouth was flush with the sand surface. The cups where arranged one at the centre and the other four in a cross pattern, and the peripheral traps were connected to the central one by thin strips of wood resting on the sand, which served as walk-ways; the use of such walk-ways greatly enhances sampling efficiency (Dr Lorenzo Chelazzi, personal communication). Constellations of five cups were placed in the dry and wet zones of the beaches after midnight (to reduce disturbance by human beach users) and were emptied in the morning, five hours later. Faunal abundances from pitfall trap data were standardised to individuals/trap/hour.

Figure 1: Location of the four sandy beaches sampled

A 24cm-diameter circular corer was used to collect infauna from the wet and dry zones of the beaches studied. The corer was pushed into the sand and the top 10cm of sand were transferred to a 0.5mm-

mesh sieve and wet sieved. The organisms retained on the sieve were collected. The same procedure was then repeated for the sand fractions between 10cm and 20cm and between 20cm and 30cm below the beach surface.

In order to collect motile fauna, standard searches were made within 5m x 3m rectangles marked out on the sand.

All fauna collected were identified to the lowest taxon possible and were classified according to habitat specificity as psammophiles (species restricted to sandy habitats), littoral (occurring in coastal habitats but not restricted to sandy beaches) and euryoecious (ubiquitous species occurring in many different habitats). Quantitative analyses on the fauna was only made for the pitfall data, as coring and searches resulted in too few individuals; however, data from the latter two techniques were used qualitatively.

For each beach, slope, exposure to wave action, median grain size, sediment salinity, and percentage organic content were also measured. Beach slope was measured by the 'rules and spirit-level' method described by Eifion Jones (1980). Exposure was calculated using the method devised by Thomas (1986). Sediment salinity, and median grain size were measured as described in Buchanan (1984). The percentage organic content of the sediment was determined using the Walkley and Black titration method following wet-oxidation by potassium dichromate, as described in Morgans (1956) and Buchanan (1984). Determinations were made separately for the wet and dry zones of the beaches studied, using the upper strandline limit as the border between the two, since Pérès & Picard (1964) consider these two zones to harbour different biocoenoses on soft substratum Mediterranean shores.

Human use of the beaches was assessed by estimating human occupancy using a standardised photographic technique. Photographs were taken daily from the same vantage point at the same peak time (13.00h) for the four beaches, and the number of people occupying defined areas of beach were counted from the images made.

Correlations between the faunal data and beach physical parameters, and ANOVA were run using SPSS v. 9 (Statistical Package for Social Sciences; SPSS Inc.), whilst NMDS analyses were made using the PRIMER 5 statistical package (Clarke & Warwick, 1994). For the NMDS, the faunal data were log transformed to reduce the contribution of large species densities relative to small values whilst conserving their rates of change, whilst no data truncation was made, due to the small number of faunal individuals collected.

Results

Beach occupancy values of 2400, 5700, 6700, and 12300 persons per square km were estimated for Ramla l-Hamra, White Tower Bay, Xatt l-Ahmar and Gnejna, respectively, establishing a gradient of anthropogenic impact with Gnejna as the most impacted beach and Ramla l-Hamra the least.

A total of 1474 individual animals were collected by pitfall trapping, but only 39 individuals and 74 individuals were collected by coring and in the standard searches, respectively. For the pitfall data, population size ranged from 7 individuals/trap/hour (for Xatt l-Ahmar) to 199 individuals/trap/hour (for Ramla) in the wet zone, and from 22 individuals/trap/hour (for White Tower Bay) to 87.33 individuals/trap/hour (for Gnejna) in the dry zone. The species richness ranged from 7 species (Xatt l-Ahmar) to 17 species (White Tower Bay). Most species collected belonged to the Amphipoda, Isopoda, Coleoptera, Dermaptera and Hymenoptera. The first four of these five major taxa were represented by a similar number of species on the four beaches and only Hymenoptera showed large differences between the beaches in terms of number of species, with just one species collected from Ramla l-Hamra (12% of all species and 0.1% of all individuals collected from this beach), and three species from Gnejna (27% of all species and 18.5% of all individuals collected from here).

No significant correlations were observed between beach occupancy values and any of the three faunal diversity components analysed and neither between beach occupancy and any of the physical parameters measured. However, a positive correlation between exposure to wave action and faunal population size was observed ($r = 0.998$; $P<0.05$), as well as a negative correlation between pitfall trap faunal abundances and salinity ($r = -1.000$, $P<0.05$).

ANOVA revealed significant differences (P>0.05) between the standardized abundances of fauna collected by pitfall trapping in the wet zone at Ramla and those for the wet zone of the three other beaches. No such statistically significant differences were revealed by ANOVA in the number of faunal species collected in the wet zones and neither in abundance and species richness of the fauna collected in the dry zones of the beaches considered.

Table 1 gives abiotic parameters for the four beaches studied. Slope varied from 0.09° to 0.38°, whilst exposure to wave action ranged between 2.17 and 6.24 which is considered low (Thomas exposure index <6.5; Thomas, 1986). The sand at White Tower Bay was classified as fine, whilst the sand at the three other beaches was classified as medium. The organic carbon content in the dry zone varied between 0.007% and 0.128%, whilst for the wet zone, it ranged from 0.026% to 0.140%.

Physical Parameter	BEACH			
	Gnejna	White Tower Bay	Ramla	Xatt l-Ahmar
Slope(°)	0.22	0.21	5.92	0.25
Exposure to wave action	2.17	4.86	6.24	2.76
Median grain size(phi)	W 1.05 D 1.43	W 2.56 D 2.36	W 1.42 D 1.71	W 1.23 D 1.5
Salinity(psu)	W 0.88 D 0.51	W 1.89 D 1.81	W 1.00 D 0.20	W 1.94 D 1.20
Percentage organic content	W 12.9 D 1.25	W 13.5 D 1.12	W 0.05 D 0.02	W 28.83 D 28.83
Human occupancy (individuals/km^2)	12,300	5,700	2,400	6,700

Table 1: Physical parameters for the four beaches sampled
(W = Wet zone; D = Dry zone)

Figure 2 shows the taxonomic composition and the relative distribution of species in the different habitat-use categories defined, for the four beaches studied. Ramla l-Hamra had the highest proportion of psammophilic species (98.4% of all species collected at Ramla) and the lowest proportion of euryoecious ones (1.5% of all species), whilst the equivalent figures for Xatt L-Ahmar, the second most frequented beach, were 61.8% and 31.8% for psammophilic and euryoecious species respectively.

Figure 2: (A) Habitat use classification of faunal individuals collected
(B) Taxonomic classification of faunal individuals collected
(Human occupancy levels included on top of every histogram)

Figure 3 shows NMDS plots for the faunal abundances with different physical parameters as overlays.

Figure 3: NMDS plots of faunal abundances with beach occupancy levels and slope as overlays

Discussion

This study indicates that human use of sandy beaches in the summer months does not seem to have any very large impact on any of the three components of faunal diversity analysed, i.e. population size, species richness and taxonomic composition. However, although not statistically significant, there was some correlation between occupancy levels and taxonomic composition, with a general increase in the number of Hymenoptera species in conditions of increased human disturbance. The beach at Ramla l-Hamra, which had the lowest human occupancy levels, exhibited the highest proportions of psammophiles and the lowest proportions of euryoecious/ubiquitous species, as would be expected for species that have narrow habitat requirements and presumably therefore, are more susceptible to disturbance. The only statistically significant correlations that the three faunal diversity components exhibited were with physical factors: salinity and exposure to wave action.

Results from the present study suggest that beach morphodynamic factors are more important in shaping faunal communities than human disturbance due to direct beach use. Brown & McLachlan (1990) list sediment grain size, slope and exposure to wave action as the three most important factors shaping the faunal assemblages on beaches worldwide, and suggest that the lower beach 'bare sand' faunal communities are more resilient to disturbance than the upper beach 'vegetated zone' ones; these authors therefore earmark beaches for recreation and dunes for conservation. A similar conclusion has been reached by Jaramillo *et al.* (1996) who showed that destruction of the fabric of the substratum and of mound formation by beach gamers, walkers and sunbathers did not affect the abundance of sandy beach fauna.

One reason for such reduced impact of trampling might be the suite of behavioural adaptations possessed by sandy beach fauna, such as the ability to rapidly burrow in the sand during the day to escape from predators and to seek refuge from high surface temperatures, and to emerge to forage only during darkness (Little, 2000). The Maltese beaches studied also have a predominantly nocturnal fauna; almost 93% of all individuals collected by the three sampling techniques combined were collected using pitfall traps, which were operated overnight.

The NMDS plots indicate that in terms of faunal assemblages, the beach at Ramla is different from the other three. Although no statistically significant correlation between any of the faunal diversity components and beach occupancy levels were found, nonetheless, the observed NMDS pattern could be best explained by using slope and beach occupancy as overlays

Although for the beaches studied, human impact, in the form of trampling, does not seem to impinge directly on faunal assemblages, other activities associated with beach use may have more important impacts. One such is clearing of wrack, mainly seagrass debris, from beaches prior to the holiday season. This wrack, and the sand underneath, supports a suite of species, many of which are psammatophiles (restricted to the strandline of sandy beaches); on local beaches staphylinid beetles and dipteran predominate (unpublished results). Additionally, Mayer (1995) reports that *Posidonia* banquettes are important for the structure and construction of the beach itself and that these banquettes are an important factor in dune formation. The removal of seagrass banquettes and pebbles from the beach at Paradise Bay (northern Malta)is indicated by Micallef (2003) as enhancing sand erosion at this site. Other indirect impacts result from accommodation and recreational facilities that abut on beaches and which may interfere with beach-related sediment transport (Bird, 1996). For the Maltese Islands, Micallef (2003) lists 15 beach-related service facilities that in 1996 were sited on the beach itself, as well as the removal of the entire small beach at Anchor Bay during the construction of a tourist attraction there.

The dearth of ecological studies on local sandy beaches is of concern especially since there is evidence of 'compartmentalisation', where each beach is ecologically isolated and harbours a more or less unique faunal assemblage, making the conservation of every single beach a priority (Deidun *et al.*, 2003).

Evidence of compartmentalisation is also provided by the present study, where certain psammophilic species were recorded from just a single beach. For example, the isopod *Tylos europaeus* was only collected from Ramla l-Hamra and the tenebrionid beetle *Phaleria bimaculata* only from White Tower Bay. Micallef (2003) states that Maltese pocket beaches may be considered as 'sediment-tight' systems due to headland obstruction and wave diffraction by beach headlands, both of which restrict sediment transport to and from individual beaches. Such a lack of inter-beach sediment transport suggests a similar lack of inter-beach larval dispersal for beach fauna that disperse their larvae in the water. For fauna with do not disperse larvae or whose larvae are terrestrial, the 'island' nature local beaches, which are all small pocket beaches, effectively limits dispersal from one beach to another. This isolation due to both terrestrial and marine barriers to dispersal effectively leads to isolated and unique beach faunal assemblages.

One major shortcoming of the present study is the lack of multi-seasonal sampling, since the beaches studied were only sampled in the summer of 2001. Additionally, no reference site (that is, a local beach that has a very low human occupancy) was found as all local beaches have a high human visitor density. The seasonal aspect is being addressed in a long-term study that is presently in progress.

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