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COMPOSITION OF THE NOCTURNAL MOTILE FAUNA FROM THE UPPER INFRALITTORAL FRINGE OF SANDY BEACHES IN THE MALTESE ISLANDS: ARE THERE ANY IMPLICATIONS FOR CONSERVATION?

COMPOSIZIONE DELLA FAUNA VAGILE NOTTURNA DELLA FRANGIA INFRALITORALE DELLE SPIAGGE SABBIOSE DELLE ISOLE MALTESI: POSSIBILI IMPLICAZIONI PER LA CONSERVAZIONE

Abstract

Samples of nocturnal, shallow-water (<1 m), motile fauna were collected using a 1 mm-mesh handnet during each season between autumn of 2001 and summer of 2003 from four sandy beaches in the Maltese Islands. Beaches on Lampedusa, Favignana and Pozzallo were also sampled during one season only for qualitative comparison with the Maltese beaches. Mysids and amphipods were the most abundant taxa, whilst omnivores/scavengers were the most abundant feeding types. Beaches on the Maltese Islands were faunistically distinct from each other, an observation that has important implications for conservation.

Key-words: *motile fauna, infralittoral fringe, Malta.*

Introduction

The major exchanges of organic materials and nutrients between sandy beaches and the sea take place in the surf zone (Brown & McLachlan, 1990), defined as that part of the beach extending from the waterline to the most seaward point at which waves approaching the coastline commence breaking (Barros *et al.*, 2002). The surf zone is described as lying in the uppermost infralittoral in the coastal biocoenoses classification scheme of Pérès (1967).

Surf zone biota form an important link in shallow water food chains, and consumers feedin on these assemblages include larvae of commercially exploited fish (see reviews by Viherluoto, 2001 and Munilla & San Vicente, 2005). Despite their ecological importance, surf zones have received little scientific attention, possibly due to the difficulties associated with working in these high-energy environments (Munilla & San Vicente, 2005).

Deidun *et al.* (2003) made night-time collections in the surf zone of five Maltese beaches during one season (summer 2000) and recorded only 92 individuals belonging to 12 different species, with abundances ranging from 0.6 to 21 individuals/m^2, suggesting a very impoverished biota both in terms of species richness and abundance. Other studies on Maltese beaches (Deidun & Schembri, 2004; Borg *et al.*, 2003; Gauci *et al.*, 2005) have hinted at 'compartmentalisation' of beach fauna, where distinct upper shore faunal assemblages were identified on different beaches, despite geographical proximity.

The present study aimed to characterise the surf zone assemblages of a number of Maltese beaches, to study seasonal and inter-annual variability in these assemblages, and to discover if the compartmentalisation demonstrated for upper shore

beach assemblages is also shown by those of the surf zone. Finally, it compared qualitatively the surf zone assemblages of the Maltese beaches studied with those of other central Mediterranean islands.

Materials and methods

Shallow water faunal assemblages were sampled using standardised nocturnal towing of a 0.5 mm-mesh net of mouth area 0.1 m² through the water column to cover an area of seabed *ca* 25 m². Each haul was made parallel to the shore in water less than 1 metre deep and lasted for 20 minutes. These hauls were designed to collect upper infralittoral infauna that emerged to swim in the water column at night.

Beaches sampled were on the central Mediterranean islands of Malta (Golden Bay, White Tower Bay), Gozo (Ramla and Xatt l-Ahmar), Lampedusa (Conigli Beach), Sicily (Pozzallo) and Favignana (Porto and Lido Burrone). Beaches on Malta and Gozo were sampled from autumn 2001 to summer 2003, whilst the other beaches were sampled in either spring 2002 (Conigli Beach) or spring 2003 (the rest). Since data from the non-Maltese beaches were not seasonal, these were not included in the statistical analyses and were used only for qualitative comparisons with data from the Maltese beaches.

Tab. 1 - Physical parameters measured on the different beaches sampled. Maltese beaches were sampled seasonally in 2002 and 2003 while all the other beaches were sampled in spring 2003 except Conigli beach, which was sampled in spring 2002.
Key: A = Autumn; W = Winter; Sp = Spring; Su = Summer.

Parametri fisici misurati sulle spiagge campionate. Le spiagge maltesi sono state campionate stagionalmente nel 2002 e nel 2003 mentre le altre spiagge sono state campionante nella primavera del 2003, tranne la spiaggia dei Conigli, campionata nella primavera del 2002.
A = autunno; W = inverno, Sp = primavera, Su = estate.

BEACH/YEAR or SEASON	PHYSICAL PARAMETER														
	Beach occupancy by humans (Ind/100m²)	Exposure value	Mean seawater POM content (×10⁻²mg l⁻¹)				Median sediment grain size (phi)				% organic content (×10⁻²)			
			A	W	Sp	Su	A	W	Sp	Su	A	W	Sp	Su
Golden Bay/2002	1.23	6.80	1.3	1.1	1.7	0.9	1.7	1.5	1.5	1.6	14	7.7	6.6	12.0
Golden Bay/2003	Not measured		8.8	1.0	1.5	1.2	1.7	1.6	1.5	1.6	15.0	8.3	6.9	12.5
White Tower Bay/2002	5.7	6.19	1.2	2.3	2.5	4.3	1.1	0.9	0.8	1.3	3.9	9.8	11.5	4.7
White Tower Bay/2003	Not measured		1.0	1.9	1.4	1.2	1.1	1.0	0.8	1.3	4.1	10.5	11.9	4.5
Ramla/2002	0.24	8.72	6.2	3.7	1.4	0.7	2.4	1.9	1.7	2.0	6.3	6.9	7.0	6.5
Ramla/2003	Not measured		1.5	4.1	1.5	2.0	2.5	2.3	2.1	2.0	6.7	7.5	8.5	6.8
Xatt l-Ahmar/2002	6.7	2.21	2.4	1.5	5.0	1.6	1.5	1.0	1.1	1.2	8.5	14.5	15.8	9.2
Xatt l-Ahmar/2003	Not measured		1.9	1.1	3.2	1.1	1.6	1.0	1.1	1.2	9.1	15.5	16.5	9.9
Conigli/spring 2002	Not measured	5.64	Not measured				2.3				7.2			
Lido Burrone/spring 2003	Not measured	5.60	Not measured				2.4				26.6			
Porto/spring 2003		1.57	Not measured				1.1				4.8			
Pozzallo/spring 2003	Not measured	7.89	Not measured				1.8				9.0			

Environmental parameters measured were: median sediment grain size (following Buchanan, 1984), percentage organic content of the upper 10 cm of the sediment - determined using the Walkley & Black titration method following wet-oxidation by potassium dichromate, as described in Morgans (1956) and Buchanan (1984) - the particulate organic material (POM) content of the water column (using suction filtration of seawater through a 0.47 μm membrane filter), the exposure to wave action of the beach (using the method described by Thomas,

1986), and beach occupancy by humans as an index of the intensity of anthropogenic use. These results are summarized in Tab. 1.

The fauna collected were sorted, identified and counted. The species were classified into six feedings types: macrophytophagous, microphytophagous, macrocarnivorous, microcarnivorous, omnivorous/scavenger and detritivore feeding modes. No observations on feeding were made but species were assigned to each category on the basis of literature reports (mysids – Viherluoto, 2001; polychaetes – Fauchald, 1977; Hamond, 1969; decapod crustaceans – Falciai & Minervini, 1992; cumaceans and tanaids – Blazewicz-Paszkowycz & Ligowsk, 2002; amphipods – Ruffo, 1998; copepods – Stella, 1984; isopods – Gutow, 2003).

Log-transformed numerical abundances were used to construct similarity matrices using the Bray-Curtis measure, which were then analysed using non-metric multidimensional scaling (NMDS) ordination and hierarchical clustering with the PRIMER 5 statistical package (Clarke & Warwick, 1994). The BIOENV procedure and regression analysis were used to examine the relationship between community structure and environmental variables (Clarke & Warwick, 1994), whilst the SIMPER technique was used to identify which species contributed most to the differences observed between beaches.

Results

A total of 1699 individuals belonging to 50 different macrofaunal species were collected from the eight beaches sampled during the two years of study: 9 polychaetes, 2 molluscs, 1 copepod, 1 cumacean, 6 mysids, 5 isopods, 1 tanaid, 10 amphipods, 9 decapod crustaceans, and 6 fish. Nineteen species (55.9% of all species collected) and 17 species (53.1% of all species collected) were only found on single beaches during a particular season in the first and second year of sampling, respectively. In addition, 30 species out of the total 50 collected were only found on a single beach during the entire two year sampling program; the majority of these were decapods and polychaetes (8 species each), followed by fish and amphipods (5 species each), mysids (2 species) and tanaids and isopods (1 species each). Only two species were collected solely from non-Maltese beaches: the decapods *Philocheras* sp. (Pozzallo) and *Palaemon elegans* (Conigli) – on the non-Maltese beaches, species richness ranged from 3 (Conigli, Lido Burrone) to 5 (Pozzallo), whilst individual abundances ranged from 0.20 inds/stroke (Lido Burrone) to 5.53 (Pozzallo). In comparison, species richness and individual abundances ranged from 0 (Ramla, Xatt L-Ahmar, spring 2002) to 7 (Golden Bay, spring 2002) and from 0 (Ramla, Xatt L-Ahmar, spring 2002) to 5.51 inds/stroke (White Tower Bay, winter 2003).

For the Maltese beaches, there was very little inter-annual variation in the total faunal abundances (615 and 728 individuals for the first and second years, respectively) and in total species richness (33 and 32 species, respectively). There was also minimal inter-annual variation in relative abundance; mysids and amphipods were the most abundant taxa in both years (33.9% and 32.8% respectively in 2002, and 37.9% and 33.9% respectively in 2003). In terms of species richness, amphipods, along with polychaetes, were the most abundant during 2002 (each constituting 17.6% of all species collected), whilst amphipods, followed by mysids, were the most abundant during 2003 (constituting 21.9% and 18.8% of all species collected, respectively). There was more inter-annual variation in species

composition; the most abundant species collected in 2002 were the amphipods *Gammarus subtypicus* (42.2% of all individuals) and *Atylus swammerdami* (12.8%), and the mysid *Siriella clausii* (12.5%); however, in 2003 the most abundant species were the mysid *Siriella clausii* (22.8% of all individuals), the amphipod *Atylus swammerdami* (16%) and the mysid *Siriella armata* (7.4%).

For Maltese beaches, temporal changes in abundance were much more pronounced for all taxa (Fig. 1) but were especially so for the mysids. During 2002, mysids varied from a maximum of 51.7% of the total individuals collected in summer to a minimum of 8.6% in spring; during 2003, mysids ranged from a maximum of 44.7% of the total individuals collected in spring to a minimum of 31.2% in winter.
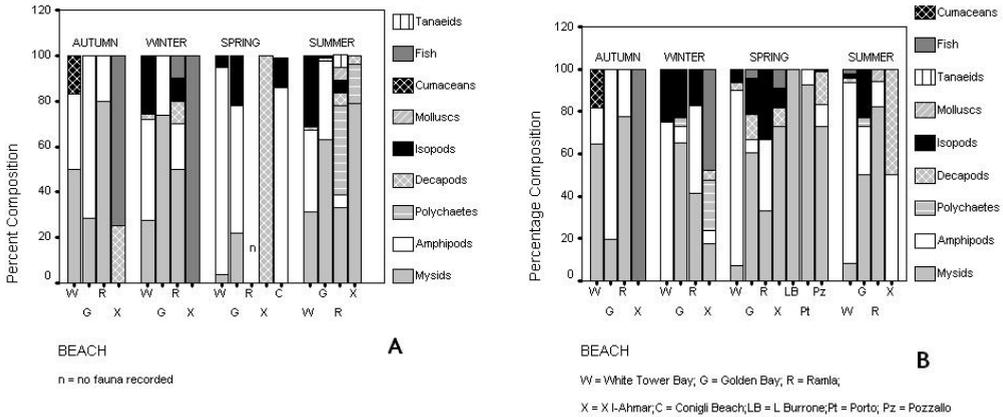

Fig. 1 - Seasonal variation in taxonomic composition of the surf zone faunal assemblages from the beaches sampled in (A) 2001 and (B) 2002.

Variazioni stagionali nella composizione tassonomica dei popolamenti faunistici della zona di surf delle spiagge campionate nel 2001 (A) e 2002 (B).
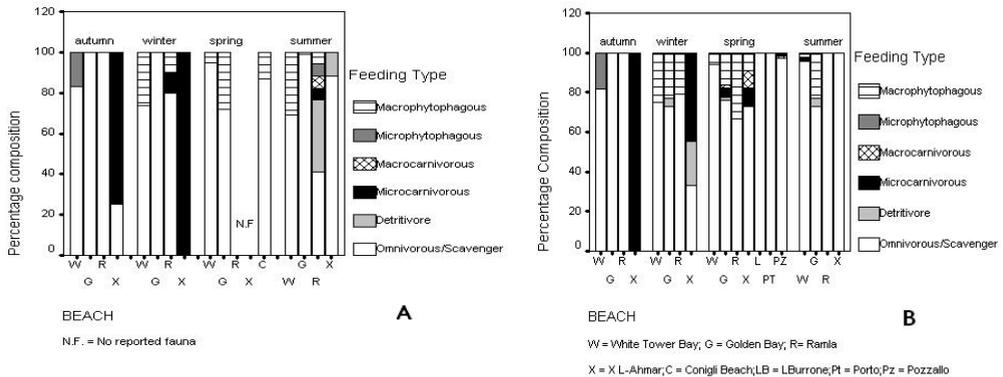

Fig. 2 - Seasonal variation in feeding functional types of the surf zone faunal assemblages from the beaches sampled in (A) 2001 and (B) 2002.

Variazioni stagionali per tipo di funzionale di alimentazione del popolamento faunistico della zona di surf delle spiagge campionate nel 2001 (A) e 2002 (B).

The majority of species collected were omnivores/scavengers (9 species – 25.7% of all species collected), followed by micro-carnivores (8 species – 22.9%) and deposit feeders/detritivores (6 species – 17.1%) (Fig. 2). There were evident seasonal changes in feeding types: macro-phytophagous species were almost exclusively collected during winter and spring for both years and micro-phytophagous species were only collected during summer and autumn for both years. In terms of abundance, micro-carnivores and omnivores/scavengers were the most represented during practically all seasons.

Fig. 3 shows a hierarchical clustering plot for all the beach collections made over the entire two year period (i.e. all seasons together). Samples separated
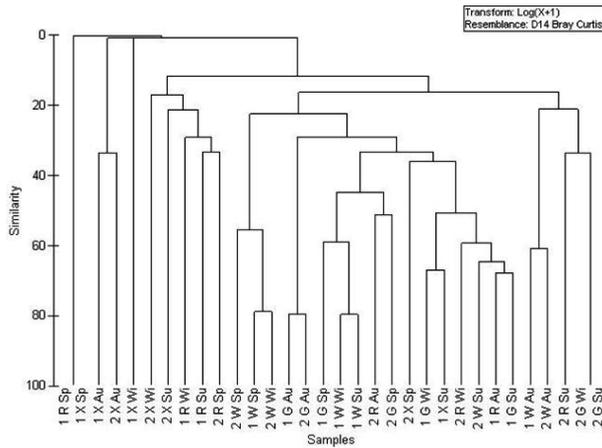

Fig. 3 - Dendrogram resulting from hierarchical clustering of abundance data based on the Bray-Curtis similarity measure for all Maltese beach collections (both years, all seasons). W = White Tower Bay; G = Golden Bay; R = Ramla; X = Xatt l-Ahmar; Au = Autumn; Wi = Winter' Sp = Spring; Su = Summer.

Dendrogramma risultante dal clustering gerarchico dei dati di abbondanza basati sulla misura della similarità di Bray-Curtis per tutti i campionamenti condotti sulle spiagge maltesi(due anni, tutte le stagioni). W = White Tower Bay; G = Golden Bay; R = Ramla; X = Xatt l-Ahmar; Au = autunno; Wi = inverno; Sp = primavera; Su = estate.

largely on spatial distribution rather than on seasonal differences, with collections from Xatt l-Ahmar, and to a lesser extent from Ramla, exhibiting least similarity with the other beaches. The equivalent NMDS plot (Fig. 4) gave two broad groups: Xatt l-Ahmar winter and autumn samples, and all the others. Of the abiotic parameters measured, none was useful in explaining the observed pattern, with the possible exception of grain size for comparisons between Maltese beaches only (Fig. 4).

For the Maltese beaches, BIO-ENV gave very poor correlations (p = 0.063 and 0.418 for first and second year samples, respectively) between exposure, median grain size, sediment organic content and POM content, and the observed biotic patterns. Similarly, there were no correlations between the same abiotic variables, excepting POM content, and biotic patterns for spring samples only (p = −0.044).

SIMPER showed that the observed differences between collections from Xatt l-Ahmar and Ramla, and the other beaches, could be attributed to the presence or absence of just a few species. Six species account for about 66% of the dissimilarity between the Xatt l-Ahmar autumn and winter collections and most of the remaining beach collections; thus, the fish *Labrus* sp. and *Atherina* sp. were mainly present at Xatt l-Ahmar and absent from the other beaches, while the mysid *Siriella clausii*, the amphipods *Gammarus subtypicus* and *Atylus swammerdami*, and the isopod *Idotea baltica*, were all absent from Xatt l-Ahmar and present on the remaining beaches. In addition, seven out of the nine polychaete species were only collected from Xatt l-Ahmar or Ramla. Six species (3 mysids, 2 amphipods and 1 isopod) also account for about 66% of the dissimilarity observed between the Ramla and Xatt l-Ahmar spring and summer collections and those of the other beaches.

Fig. 4 - NMDS plot of abundance data based on the Bray-Curtis similarity measure for collections from both years (all seasons) for the Maltese beaches only, with POM content of the water as overlay.

NMDS plot dei dati di abbondanza basati sulla misura della similarità di Bray-Curtis per campionamenti per ambedue gli anni considerati (tutte le stagioni) solo per le spiagge maltesi, sovrapposti al contenuto in POM delle acque.

Conclusions

Wave action determines energy flow in nearshore environments by distributing organic material along the coastline (McLachlan & Bate, 1984). A correlation between biotic patterns and particulate organic matter (POM) content of the water column and/or exposure to wave action might therefore expected, but only a weak correlation with POM was found and none with exposure or any of the other abiotic parameters measured in the present study.

Analysis of the total dataset showed the Xatt l-Ahmar autumn and winter samples (and to a lesser extent even the Ramla and Xatt l-Ahmar spring and summer samples) to be distinct from the rest (Fig. 3). This distinctiveness of the

Xatt l-Ahmar samples appears related to the exclusive presence of many fish species and the absence of most species of mysids in the uppermost levels of the infralittoral zone on this beach. Surf zones are often important nursery areas for fish due to their high levels of secondary production by resident crustacean populations (Brown & McLachlan, 1990) so the inverse relationship between fish and mysids at Xatt l-Ahmar may be related to this. Xatt l-Ahmar has one of the lowest exposure values of the beaches studied, which may also contribute to the high population density of fish found here in autumn and winter, when juvenile fish seek shelter from the turbulence of the open coast. The low popularity of this beach with bathers (Deidun *et al.*, 2003) might also explain the high fish densities. The surf zone sediment at Xatt L-Ahmar is relatively coarse (grain size ranging from 1.00 to 1.55 phi) when compared to that of other beaches (refer to Tab. 1) and this might explain the lack of mysids at this location. Interestingly, the beach which received the highest input of wrack (White Tower Bay) also had the highest individual abundances during both sampling years, although not the highest species richness.

The results of the feeding functional group analysis agree with expectations; McLachlan & Brown (1990) report that most surf-zone zooplankton are opportunists and omnivores, and omnivory was the most represented feeding type in the present study.

As for the Catalan beaches sampled by Munilla & San Vicente (2005), the fauna in the central Mediterranean beaches studied there was dominated by peracarid crustaceans, mainly mysids (the most abundant) and amphipods (the most species rich). The swimming behaviour of mysids, adapted to move along the beach, can explain the abundance of this group in the surf zone (Clutter, 1967).

The total number of species (50) and individuals (1699 from a total area of 900 m^2) recorded from this study are markedly lower than those from other Mediterranean beaches; thus, Munilla & San Vicente (2005) reported 145 species and 29,717 individuals (from a total area of 750 m^2) from the Catalan beaches they studied. This may be related to the different sampling strategies employed in the two studies but may also have a biological basis, perhaps related to the higher productivity of the northwestern Mediterranean coastline compared to the more oligotrophic central Mediterranean.

In spite of the overall similarity between the faunal assemblages of the beaches studied in the present work, the different beaches do not have identical suites of species; thus, 30 species (60% of the total found in the present study) were recorded from one beach only. The majority of these were decapods and polychaetes (8 species/16% of all species each), followed by amphipods and fish (5 species/10% of all species). For amphipods this is hardly surprising since these lack free-ranging larvae. The majority of the species reported from just one beach were collected from Ramla on Gozo (10 species were exclusive to this beach). Although some species occurred on the Maltese beaches only and not on those of the other islands studied, their absence from the non-Maltese beaches studied here is very likely mostly related to sampling effort and only to a lesser extent to the physical characteristics of the beaches.

For the Maltese beaches at least, the results of this study have some important implications for conservation. In the Maltese Islands, sandy beaches are an overall rare type of coast, constituting only 2.4% of the *ca* 271 km coastline of the islands; moreover, all these beaches are pocket beaches separated from each

other by rocky headlands or long stretches of rocky coast (Anderson & Schembri, 1989). Each beach is therefore very small and relatively isolated, which may explain why different beaches have different faunal assemblages, both in terms of species composition and in relative abundance. This 'compartmentalisation' has already been noted for the upper supralittoral faunal assemblages of Maltese beaches (Deidun & Schembri, 2004; Borg et al., 2003; Gauci et al., 2005). It would seem that the surf zone fauna of Maltese beaches is also compartmentalised, although to a lesser extent. It therefore follows that environmental planners and managers need to give due consideration to such beach-specific biotic features in coastal zone management plans and in assessment of the environmental impact of coastal development projects.

Riassunto

Nel periodo compreso tra l'autunno 2001 e l'estate 2003 sono state effettuate stagionalmente catture stagionali e notturne di fauna pelagica/planctonica in acque poche profonde (<1 m di profondità) di quattro spiagge delle isole Maltesi, utilizzando un retino con vuoto di maglia di 1 mm e seguendo un protocollo standard di campionamento. Singoli campionamenti sono stati effettuati nella primavera 2002 o nella primavera 2003 in quattro spiagge della Sicilia, Favignana e Lampedusa. Contemporaneamente al campionamento sono state misurate le concentrazioni di particelle organiche sospese (POM), le dimensioni medie dei granelli di sabbia sul fondale nonché il livello d'esposizione della spiaggia all'azione delle onde.

Sono state catturati 1699 individui appartenenti a 50 specie diverse. In base al numero di specie e di individui, Mysidacea e Amphipoda sono risultati i gruppi faunistici dominanti in tutte le stagioni. Sono state rilevate scarse differenze stagionali e inter-annuali tra le abbondanze dei vari gruppi faunistici. Gli individui catturati sono stati suddivisi in sei categorie sulla base del comportamento alimentare: gli onnivori sono risultati i più numerosi nelle diverse stagioni. Le maggiori differenze nelle catture sono ascrivibili alle differenze nelle particelle organiche sospese (POM) nei diversi siti di campionamento. NMDS e Clustering, hanno indicato una divergenza evidente tra le catture nelle diverse spiagge maltesi, mentre non sono stati osservati grandi divergenze tra le catture fatte su isole geograficamente lontane tra di loro. BIOENV e SIMPER sono state utilizzate per identificare i parametri fisici più rilevanti a spiegare le divergenze biotiche osservate ed a identificare le specie più importanti a spiegare tali divergenze. I risultati ottenuti possono fornire importanti indicazioni per la conservazione poiché le comunità faunistiche delle spiagge maltesi sono più o meno distinte tra di loro.

Acknowledgements

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