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NOTE

Total sample area and estimates of species richness in exposed sandy beaches

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ABSTRACT: Recent studies have shown that macroinfaunal species richness of exposed sandy beaches increases from reflective to dissipative conditions. To analyse if this trend is affected by sampling strategies (primarily area sampled), we compared results from surveys carried out in different beach types of South Africa, Australia and Chile. Total area sampled in those surveys was 4.5 m^2. The percentage of species predicted for each beach increased in relation to an increase in total sampling area. Only at a total sample area of 4 m^2 were most (>95%) of the species present collected. Sampling areas of 1 m^2 and 2 m^2 result in average underestimations of nearly 40% and 20% of the species, respectively. Beaches harbouring the highest number of species (the most dissipative ones) need to be sampled more extensively to collect most of the species, as compared with beaches having lower species richness. A bibliographic survey showed that most of the studies carried out on sandy beaches have been based upon sampling areas considerably smaller than 4 to 4.5 m^2, suggesting that in many of the studies the sandy beach macrofauna was undersampled.

KEY WORDS: Sandy beach macroinfauna · Species-area relationships

Studies carried out on sandy beaches of the northwest of USA, South Africa, Australia and south-central Chile (McLachlan 1990, Jaramillo & McLachlan 1993, McLachlan et al. 1993) have shown that beaches of different morphodynamic types harbour differences in macrofaunal community attributes including species richness, abundance and biomass. Species richness increases linearly from reflective to dissipative conditions (e.g. McLachlan et al. 1993). Although changes in beach type appear to result in predictable changes in macrofaunal species richness, it is also possible that the above general trends may be affected by sampling strategies, primarily area sampled.

Materials and methods. To examine the possibility that estimates of species richness may be affected by sampling strategy (specifically, the area sampled), species-area relationships from a range of morphodynamic beach types were compared using data from macroinfaunal surveys of exposed sandy beaches on the coasts of south-central Chile, southeastern South Africa, and southern and northeastern Australia (Table 1). The beach state index calculated for each site shows that the beaches examined spanned a wide range of morphodynamic beach types. Three replicate samples of sediments (each 0.1 m^2 in area and 25 cm deep) were collected at 15 equally spaced levels along a transect extending from above the drift line to the lower limit of the swash zone (the across-shore strategy). Total area sampled was 4.5 m^2. The sediment was sieved through 1 mm mesh and the collected animals stored in 5% formalin until sorting. A program based on probability theory (Hartnoll 1983) was used to construct species-area curves for sample areas up to 5 m^2

Table 1. Beach characteristics for the sandy beaches studied at each geographic area. BSI: beach state index in which values <0.5 are for reflective beaches, 0.5 to 1.0 are for intermediate beaches, 1.0 to 1.5 for dissipative beaches and 1.5 to 2.0 for fully dissipative beaches (McLachlan et al. 1993). The Chilean beaches were sampled in September 1993, the South African one in July 1993 and those of Australia in July 1992

Site	Area	BSI	Type of beach
Chile			
Los Molinos	Temperate	0.50	Reflective, microtidal
Mehuín	Temperate	1.50	Dissipative, microtidal
South Africa			
King Beach	Warm temperate	0.95	Intermediate, microtidal
Australia			
Coorong	Temperate	1.03	Dissipative, microtidal
Goolwa	Temperate	1.28	Dissipative, microtidal
McKay	Tropical	1.42	Ultradissipative, macrotidal
Grasstree	Tropical	1.52	Ultradissipative, macrotidal
Sarina	Tropical	1.43	Ultradissipative, macrotidal
Cassuarina	Tropical	1.79	Ultradissipative, macrotidal

for each beach. A second sampling strategy (the along-shore strategy) was used on 2 beaches studied in Chile. Five samples of sediment (0.03 m^2 each) were collected at 5 equally spaced levels along 30 transects (1 m apart) extending from above the drift line to the lower limit of the swash zone. Since the five 0.03 m^2 samples of each of the 30 transects were pooled (0.15 m^2 for each transect), the total area sampled under both strategies was 4.5 m^2. The 2 sampling strategies used in Chile allowed analysis of the effect of number of beach levels sampled on estimates of species richness.

Results. Table 2 shows the results for the across-shore strategy. The percentage of species predicted for each beach increased in relation to an increase in total sampling area. The number of species at 5 m^2 sampling area was arbitrarily taken to be 100 %, recognizing that the curves never flatten out completely and thus never reach 100 % in absolute terms. Only at a total sample area of 4 m^2 were most (>95 %) of the species present collected. Sampling areas of 1 m^2 and 2 m^2 resulted in average underestimations of nearly 40 and 20 % of the species, respectively (Table 2). The curves which represent the situation for each beach (15 beach levels sampled) are shown in Fig. 1. The highest species richness was found towards more dissipative conditions (cf. Fig. 1 and Table 1). Beaches harbouring the highest number of species (Cassuarina and Serina in Australia) need to be sampled more extensively to collect most of the species, as compared with beaches having lower species richness (Fig. 1). As number of species present increases, total sampling area needs to be increased.

Fig. 2 shows the results of the comparison of sampling strategies for the Chilean beaches. Number of

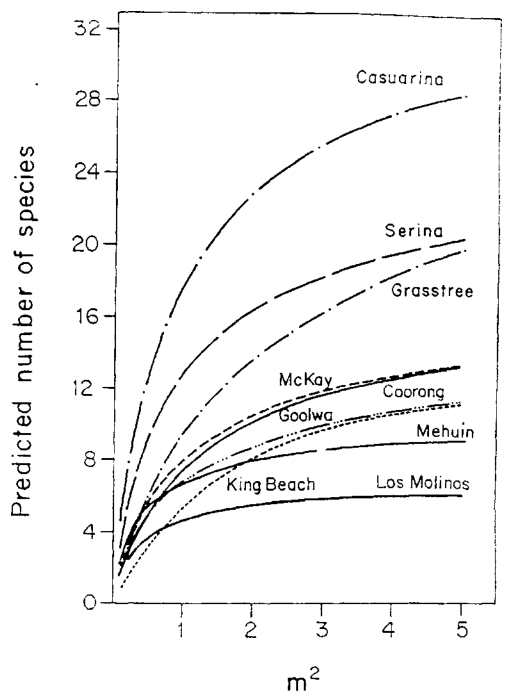

Fig. 1. Predicted number of species in relation to an increase in sampling area (15 levels sampled at each beach)

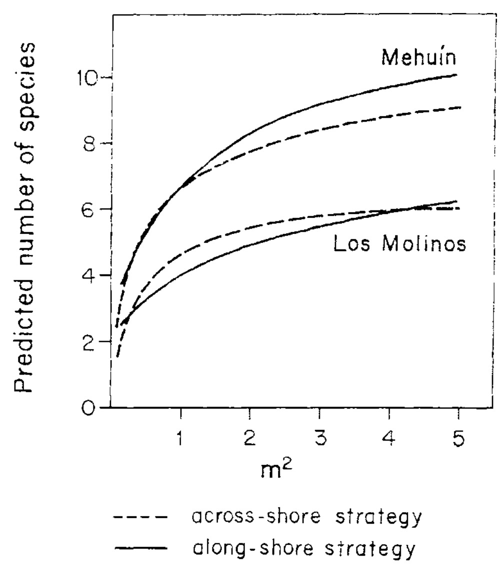

Fig. 2. Predicted number of species in relation to an increase in sampling area with the 2 sampling strategies used on the 2 beaches studied in Chile (see text)

Table 2. Total number of species recorded as a function of sampling area on sandy beaches: total number of species collected (n) and predicted percentage of species with increase in sampling area

Sites	n	1 m^2	2 m^2	3 m^2	4 m^2	5 m^2
Chile						
Los Molinos	6	76.8	90.3	96.0	98.8	100
Mehuín	9	73.7	86.3	93.2	97.7	100
South Africa						
King Beach	11	48.5	72.9	86.7	95.4	100
Australia						
Coorong	11	61.4	78.3	89.0	96.8	100
Goolwa	13	56.9	77.3	89.0	96.7	100
McKay	13	60.8	79.7	90.2	96.9	100
Grasstree	19	49.4	70.7	84.9	95.6	100
Serina	20	64.0	81.2	90.7	96.9	100
Cassuarina	28	63.1	81.5	91.3	97.2	100
Average %:		61.6	79.8	90.1	96.9	100

beach levels sampled does not affect the estimates of species richness, since both strategies produced a similar trend; i.e. a larger area of the dissipative beach of Mehuín needs to be sampled to collect most of the species, as compared with the reflective beach of Los Molinos which had a lower species richness.

Discussion. The overall results of these analyses have profound implications for sandy beach ecology and biodiversity of sandy beach macrofauna. Most of the surveys carried out on sandy beaches have been based upon sampling areas considerably smaller than 4.5 m^2. This assertion is based upon a survey we carried out about sampling methodologies reported in 31 published studies from which clear information on sampling areas could be collected (Table 3). We do not claim that this survey is a complete one; however, it clearly shows that in many of the studies the sandy beach macrofauna was undersampled; i.e. the areas sampled were ≤1 m^2. Only in 2 of these studies, the authors sampled a total area of 4 to 4.5 m^2 (or more) (Bally 1983, Donn & Cockcroft 1989), the area that our analysis demonstrated as necessary to obtain >95% of the macrofaunal species living on exposed sandy beaches of a variety of morphodynamic types. In 4 of the studies, the authors sampled as much as 4 m^2 (or more), but only in 1 or some of the studied sites (Gauld & Buchanan 1956, Dexter 1974, 1976, Defeo et al. 1992).

Table 3. Total area sampled (m^2) in sandy beach surveys around the world. Ranges are given when different total areas were sampled in the same study

Source	Location	Area sampled
Gauld & Buchanan (1956)	Ghana	3.50–5.00
Wood (1968)	New Zealand	2.00
Seed & Lowry (1973)	Ireland	1.88–2.50
Dexter (1974)	Costa Rica, Colombia	1.20–4.80
Croker et al. (1975)	USA	0.60–0.72
Dauer & Simon (1975)	USA	2.40
Dexter (1976)	Mexico	2.00–4.00
Croker (1977)	USA	0.60–0.72
McLachlan (1977)	South Africa	3.00
Jaramillo (1978)	Chile	0.90–1.44
Dexter (1979)	Panama	3.00
Wooldridge et al. (1981)	South Africa	2.00–3.25
Koop & Griffiths (1982)	South Africa	2.50
Sánchez et al. (1982)	Chile	1.70–2.50
Bally (1983)	South Africa	4.00
Knott et al. (1983)	USA	1.35
Dexter (1984)	Australia	1.20
Wendt & McLachlan (1985)	South Africa	2.00–2.50
Ismail (1986)	Red Sea	0.15
Dexter (1986/1987)	Israel, Egypt	0.30–0.40
Jaramillo (1987)	Chile	0.60–1.30
Jaramillo et al. (1987)	USA	0.48–0.60
Clarke & Peña (1988)	Chile	0.72
Dexter (1989)	Egypt	0.64
Donn & Cockcroft (1989)	Namibia	6.00–8.40
Dexter (1990)	Portugal	0.16
Larsen & Doggett (1990)	USA	0.50
Jaramillo & González (1991)	Chile	0.54–0.60
Perez Edrosa & Junoy (1991)	Spain	1.92–2.08
Defeo et al. (1992)	Uruguay	1.65–4.29
Jaramillo & McLachlan (1993)	Chile	1.20

The total area needed to be sampled in macrofauna surveys targeted to find out estimates of species richness depends on beach type and tide range. The slope of curves presented in Fig. 1 suggests that for microtidal beaches (Los Molinos, Mehuín, King Beach, Coorong, Goolwa) a sample area of 3 to 4 m^2 reaches the point where the curves start flattening. However, for the macrotidal beaches greater sampling effort is required, probably at least 5 m^2.

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