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Short communication

Ghost crabs as a tool for rapid assessment of human impacts on exposed sandy beaches

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Abstract

On exposed sandy beaches, the destruction of sand dunes and intense recreational activities are often the most common anthropogenic disturbances. It was proposed that such disturbances should have important effects on animals such as ghost crabs. Numbers of burrows of ghost crabs, *Ocypode cordimana*, were compared between urban and non-urban beaches at different levels on the shore. Overall, there were more burrows at high levels near sand dunes. There were significantly fewer burrows at high levels on urban than on non-urban beaches. These differences are discussed in terms of destruction of habitat and possible changes in behaviour of crabs. This study suggests that the world-wide genus *Ocypode* may be useful as a tool in rapid assessment of human impacts on exposed sandy beaches.

Keywords: Sandy beaches; *Ocypode*; Human impact; Rapid assessment; Dunes

1. Introduction

Studies of invertebrates living on exposed sandy beaches are extremely time-consuming and there are many difficulties in sampling such physically stressed environments. For example, waves, tides and currents usually limit spatial and temporal replication. Consequently, surveys designed to detect human impacts on exposed sandy beaches are seldom found in the literature (e.g. Steiner and Leatherman, 1981; Wolcott and Wolcott, 1984; Defeo and de Alava, 1995; Jaramillo et al., 1996; Brazeiro and Defeo, 1999).

Schemes for rapid assessment using biota have been developed successfully for use in some ecosystems, especially in fresh water (Chessman, 1995; Resh et al., 1995; Reynoldson et al., 1995; Wright, 1995). They have proven to be of benefit in determining environmental quality and for the detection of different types of human impacts (e.g. in mangroves; Skilleter, 1996). However, they have not been developed for exposed sandy beaches, in spite of the fact that sandy beaches are often heavily used by humans in urban areas.

Nevertheless, human activities may have important consequences for animals and plants living in this habitat. For example, several sandy beaches in coastal cities around the world have had their dunes entirely destroyed by the construction of roads and buildings immediately above the beach (Ranwell and Boar, 1986). Other potential sources of impact on upper portions of urban sandy beaches are high levels of recreational activities (e.g. human trampling, off-road vehicles; Steiner and Leatherman, 1981; Wolcott and Wolcott, 1984; Heath, 1987; Jaramillo et al., 1996).

The ecology of sandy beaches has been studied by several researchers, particularly in the last two decades. The upper areas of exposed sandy beaches are typically inhabited by several species of amphipods, isopods, insects and ghost crabs (Brown and McLachlan, 1990). Because of their size and activity, ghost crabs are often the most obvious invertebrates on these areas.

The genus *Ocypode* is the most widespread of the Ocypodidade family, being circumglobal in the tropics and subtropics (Brown and McLachlan, 1990). They characteristically have very sophisticated behaviour (Barrass, 1963; Hughes, 1966; Rao, 1968; Jones, 1972; Vannini, 1980). More recently, there have been assessments of the physiology (Farrelly and Greenaway, 1994; Weinstein, 1998), reproductive features (Schober and

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Christy, 1993; Trott, 1998), locomotion (Blickhan et al., 1993; Weinstein, 1995), predation (Watts and Bradshaw, 1995) and taxonomy (Huang et al., 1998) of some species of this genus.

Two species of ghost crabs are found in New South Wales, Australia. *Ocypode ceratophthalma* are distributed from northern Australia to the south of New South Wales and are abundant on sandy, sheltered beaches, but rare on open, exposed beaches. *Ocypode cordimana* are found along the northern coast of western Australia, across the north of Australia, and along the east coast to southern New South Wales (Jones and Morgan, 1994).

Sandy beaches in New South Wales, particularly around Sydney, are used extensively for recreational purposes. Frequently, their sand dunes have been removed and replaced by concrete walls positioned immediately above the beach face. In contrast, beaches in surrounding national parks have lower levels of recreational activities and, typically, their vegetated sand dunes have been preserved. Preliminary observations made on sandy beaches in New South Wales suggested that, in contrast to beaches located in more pristine areas, the upper levels of the urban beaches in Sydney are rarely inhabited by ghost crabs (*O. cordimana*). If these differences are consistent, it is possible that numbers of ghost crabs may be a good indication of environment degradation. To investigate whether ghost crabs may be a good tool for rapid assessment of impact on exposed sandy beaches, I tested the hypothesis that urban beaches have smaller densities of burrows of ghost crabs than are found on non-urban beaches.

2. Materials and methods

Several replicate 'urban' and 'non-urban' beaches were sampled in New South Wales (Fig. 1). The urban beaches were located around Sydney and each had a concrete wall above the beach face and was subjected to intense recreational activities. Non-urban beaches were located more than 100 km away from Sydney, close to national parks, with preserved sand dunes and low levels of recreational activities.

The three urban beaches were Coogee, Bronte and Bondi (Fig. 1B). Non-urban beaches were at the south and north of Sydney. The three northern non-urban beaches (Fig. 1A) were Elizabeth Beach, at the south of Booti Booti National Park; Hawks Nest, close to the Myall Lakes National Park and Samurai Beach, in Tomaree National Park. The three southern non-urban beaches (Fig. 1C) were Seven Mile Beach, bordered by the Seven Mile National Park; Cave Beach, in Jervis Bay National Park and Aquatic Reserve; and Bendalong Beach. Brief descriptions of the characteristics of these beaches are given by Short (1997).

All beaches were sampled early in the morning over a 5-day period (between 31 May and 4 June in 1999). At each beach, two randomly selected sites were sampled (0.5 km apart) and the number of burrows was recorded in 30 contiguous quadrats (1 m^2), aligned parallel to the shore. This was done at three different levels on the shore 0, 2 and 4 m from the dunes or concrete walls (labelled levels 1–3, respectively) at non-urban and urban beaches (Fig. 2). The three levels were chosen because preliminary observations at non-urban beaches indicated that the great majority of the burrows of ghost crabs were distributed at these levels.

Data were collected to test the prediction that urban beaches have lower densities of burrows of ghost crabs than non-urban beaches. An asymmetrical analysis of variance (ANOVA) (Underwood, 1993; Glasby, 1997) was used to test for differences in numbers of burrows between the urban beaches and the average of the two non-urban regions (north and south). All data were $\mathrm{sqrt}(x+1)$ transformed and found to be homogeneous at $P > 0.05$ using Cochran's C-test (Underwood, 1981). Multiple comparisons among the means were done using the Student–Newman–Keuls (SNK) test.

3. Results

More burrows were present on non-urban beaches than urban beaches (Fig. 3). Burrows were present at all levels on non-urban beaches at most sites. On urban beaches, there were very few burrows at level 1 (never exceeding 1 m^{-2}) and no burrows below this level. No burrows were found at Bondi. The largest mean number of burrows at low levels (2 and 3) was found at the northern non-urban beaches (Elizabeth, Hawks Nest, Samurai), and the largest mean number of burrow was found at Elizabeth beach (Fig. 3). The largest mean numbers of burrows at level 1 were found at the two sites on Seven Miles beach (Fig. 3).

At all sites (except at the urban beach Bondi where no burrows were found), there were more burrows at the highest level on the shore and the number of burrows generally decreased with decreasing height on the shore (i.e. from level 1 to 3). The mean number of burrows at each level on urban beaches was always smaller than at corresponding levels on non-urban beaches (Fig. 3).

To simplify the analyses and because most of the burrows were found at the first level (48, 83 and 100% for northern, southern and urban beaches, respectively), ANOVAs were done for this level only. All quadrats at level 1 were pooled for each site and, thus, two replicate measures of the number of burrows (i.e. one per site) were obtained for each beach. The number of burrows at level 1 was significantly smaller on urban (0.18 $m^{-2} \pm 0.04$; mean±S.E.) than on non-urban beaches (1.6 $m^{-2} \pm 0.09$; mean±S.E.) (urban vs. non-urban in Table 1). There was no significant difference in the number of burrows between non-urban regions (northern and

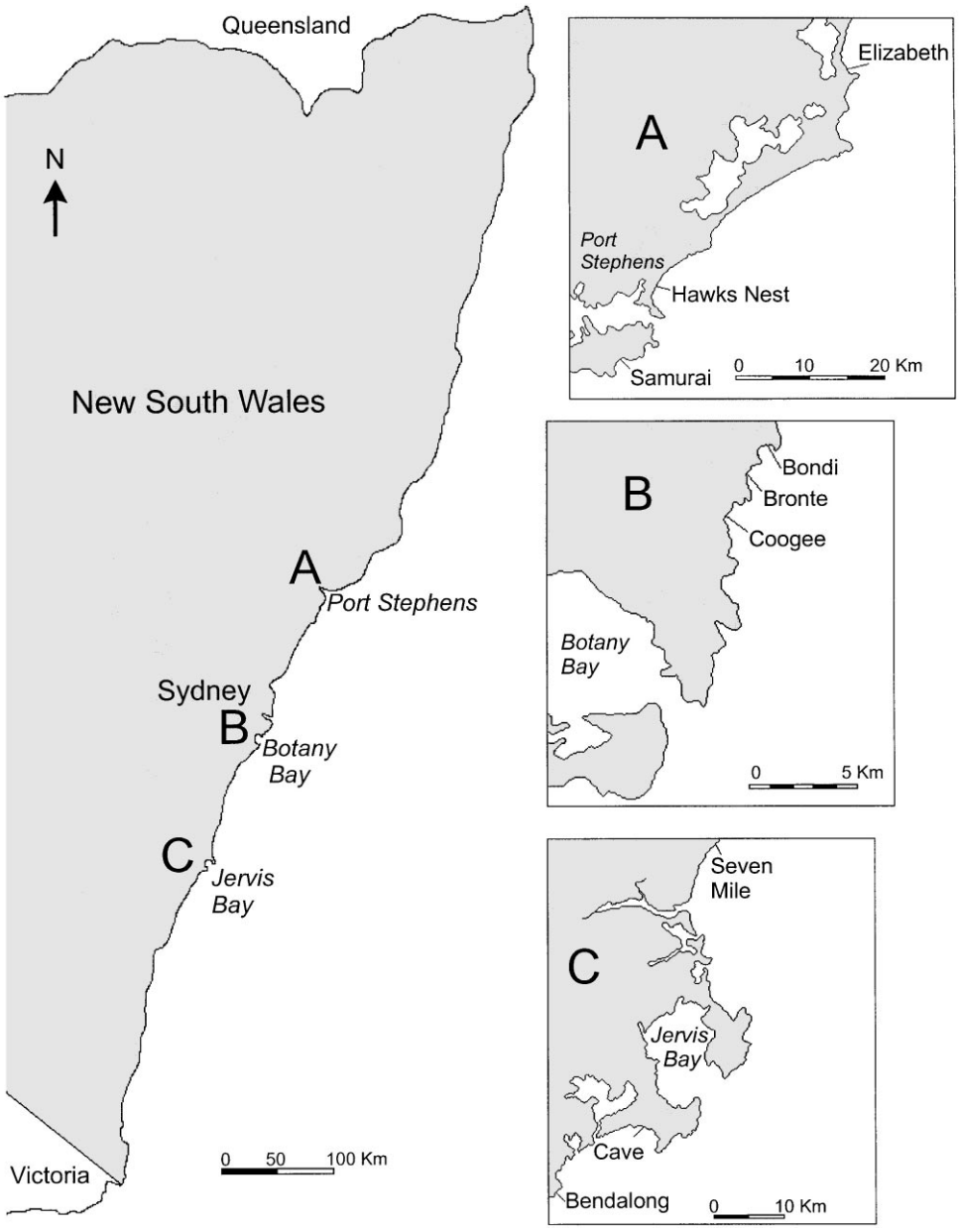

Fig. 1. Map showing the sandy beaches sampled. A = northern non-urban beaches (Elizabeth, Hawks Nest, Samurai), B = urban beaches (Bondi, Bronte, Coogee), C = southern non-urban beaches (Seven Miles, Cave, Bendalong).

southern) (non-urban regions in Table 1). However, within non-urban beaches there were significant differences (Beaches (non-urban) in Table 1). SNK tests showed that, at level 1, Seven Mile beach had significantly more burrows than any other non-urban beach ($P < 0.01$).

4. Discussion

The results clearly show that the number of ghost crab burrows was greater on non-urban beaches than on urban beaches. Therefore, human activity on beaches appears to affect ghost crabs in some way. Exactly how is not yet understood.

Studies on the effects of human trampling on beach fauna have been largely neglected (Heath, 1987) and are infrequently found in the literature. Jaramillo et al. (1996) studied the effects of human trampling on a sandy beach in Chile. They found no evidence of any impact; however, these authors did not include counts of ghost crabs. Steiner and Leatherman (1981) found that the mean density of *O. quadrata* per 0.1 ha plot was 10 on an undisturbed site, 19 on a site with pedestrians, one on a site with off-road vehicles and pedestrians and 0.3 on a site subjected to heavy use by off-road vehicles.

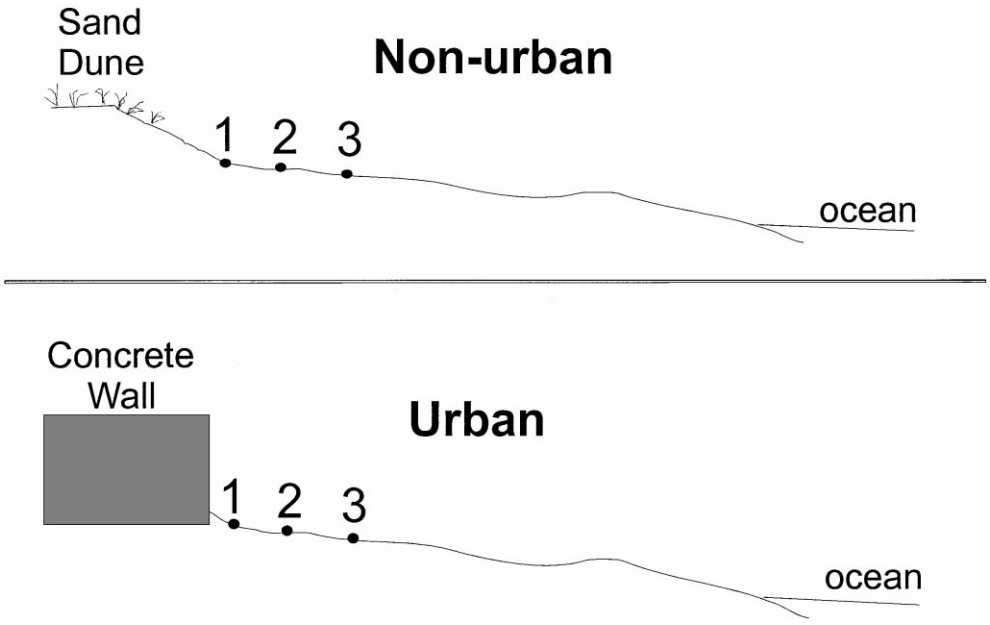

Fig. 2. Schematic diagram of the levels sampled on typical non-urban and urban beaches. The levels were: L1 = high on the beach, adjacent to the dunes or concrete wall; L2 = intermediate height, 1 m seaward from L1; L3 = low on the beach, 1 m seaward from L2.

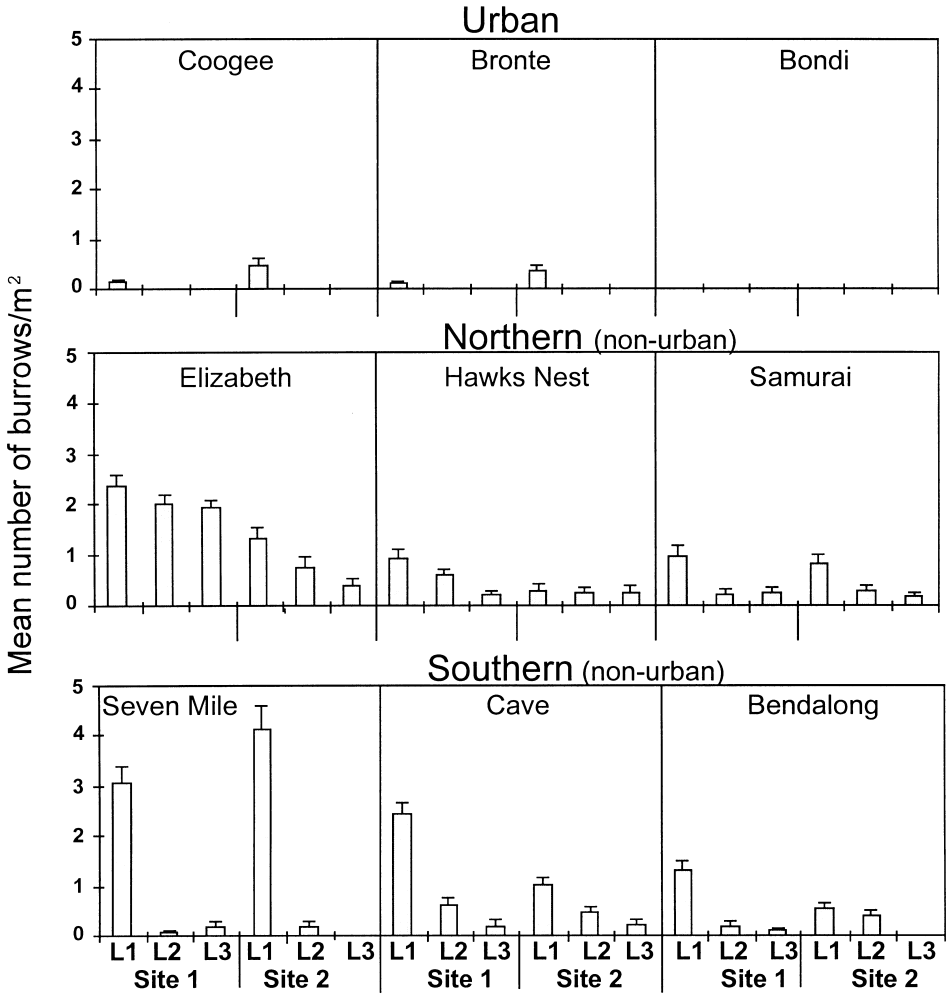

Fig. 3. Mean (+S.E.) number of burrows per square metre at each level (L1 = high, L2 = intermediate, L3 = low) at two sites on each beach ($n = 30$). Upper box = urban beaches, middle box = northern non-urban beaches, and lower box = southern non-urban beaches.

Table 1
Summary of the asymmetrical analysis of variance comparing one urban and two non-urban (southern and northern) regions[a]

Source of variation	d.f.	MS	*F*	*P*
Region	2	43.66		
Urban versus non-urban	1	76.26	9.89	0.02
Non-urban	1	11.06	1.55	0.26
Beaches (region)	6	7.15	4.27	0.03
Beaches (urban)	2	2.44	1.46	0.28
Beaches (non-urban)	4	9.51	5.68	0.01
Residual	9	1.67		

[a] There were three beaches nested within each region. The analysis was done for level 1 only. All quadrats at this level were pooled for each site and, thus, $n=2$. All data were sqrt($x+1$) transformed and found to be homogeneous at $P>0.05$ using Cochran's *C*-test.

They suggested that the densities of ghost crabs at sites used by humans were greater than at 'pristine' sites (i.e. with very few humans) due to people leaving food scraps upon which crabs feed. The conclusions of their study, however, must be considered with caution because spatial replication was minimal.

Counting the number of burrows of ghost crabs is a very simple and rapid technique that could be useful in studies investigating human impacts on sandy beaches. It is likely that the numbers of burrows do represent the real densities of the ghost crabs. For example, Warren (1990) presented a good correlation between number of burrows and number of crabs for another genus of Ocypodidae. If burrows are not a true estimate of crab abundance, then the results of the present study suggest that *O. cordimana* may be showing differences in behaviour on urban and non-urban beaches, i.e. ghost crabs inhabiting urban beaches may not construct open burrows, or may not maintain their burrows, as they do on non-urban beaches. The behaviour of ghost crabs is very complex and flexible (Barrass, 1963) and differences in habitat and diet (Jones, 1972), or the presence of the people on the beach, can affect the activity of the crabs (Hughes, 1966).

The greatest densities of the burrows of *O. cordimana* in the present study were found at the base of sand dunes, but burrows were observed to extend 10–50 m over the dune field (i.e. above level 1) in some non-urban beaches. Dakin (1987), also reported that this species may extend inland, up to 200 m from the shore. There is a vast literature on coastal dunes in human-altered systems in a managerial context (e.g. Nordstron et al., 1990). The continuing and increasing intensity of human usage of coastal areas in New South Wales has resulted in extensive and, in many cases, irreparable ecological and morphological damage to sand dunes (Chapman, 1989). Construction of roads and buildings immediately above the dunes results in modifications of the exchange and the supply of sand in the beach/dune system, and potentially can interfere with the movements of many animals, such as ghost crabs. Therefore, it is recommended that counting numbers of ghost crabs be included in ecological or morphological sand dunes surveys, because dune modification will affect part of the habitat of these animals.

5. Conclusions

In the present survey, urban beaches had significantly lower numbers of burrows of *O. cordimana* than did non-urban beaches. Thus, the number of burrows is likely to be a useful indicator for anthropogenic impacts on exposed sandy beaches.

To assess the environmental condition or health of an ecosystem, it is impossible to measure all relevant environmental variables and to appropriately integrate the large amount of information into a decision-making process. Thus, it may often be necessary to select environmental 'indicators' that should be useful to judge the degree to which specified environmental conditions have been achieved or maintained (Cairns et al., 1993).

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