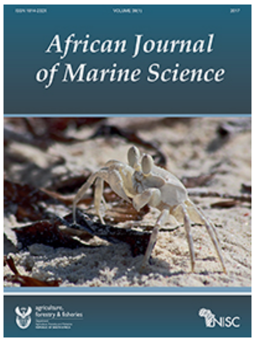


Taylor & Francis
Taylor & Francis Group

African Journal of Marine Science

ISSN: 1814-232X (Print) 1814-2338 (Online) Journal homepage: http://www.tandfonline.com/loi/tams20

Ghost crab burrow density at Watamu Marine National Park: An indicator of the impact of urbanisation and associated disturbance?

HFR Hereward, LK Gentle, ND Ray & RD Sluka

African Journal of Marine Science 2017, 39(1): 129–133
Printed in South Africa — All rights reserved

AFRICAN JOURNAL OF MARINE SCIENCE
ISSN 1814-232X EISSN 1814-2338
http://dx.doi.org/10.2989/1814232X.2017.1305990

Short communication

Ghost crab burrow density at Watamu Marine National Park: An indicator of the impact of urbanisation and associated disturbance?

HFR Hereward[1,2,3]*, LK Gentle[1], ND Ray[1] and RD Sluka[2,4]

[1] *School of Animal, Rural and Environmental Sciences, Nottingham Trent University, Southwell, UK*
[2] *A Rocha Kenya, Watamu, Kenya*
[3] *Current address: A Rocha UK, Southall, UK*
[4] *Marine and Coastal Conservation Programme, A Rocha International, London, UK*
* *Corresponding author, e-mail: hannah.hereward@gmail.com*

Ghost crab (*Ocypode* species) burrow densities have previously been used as an indicator of anthropogenic impact. This study aimed to assess the burrow density of *Ocypode* species (*O. ryderi* and *O. cordimanus*) at four sites across Watamu Marine National Park, Kenya. Two sites were in front of hotel complexes (denoting a high degree of urbanisation), and two were in front of residential housing among coastal scrub (denoting a low degree of urbanisation). The findings reveal significantly higher burrow densities at sites in front of residential housing, which was the less developed area. This provides further evidence that *Ocypode* burrow densities can be used, where other methods would be impractical, to estimate the impact of some human activities along beach fronts, such as at Watamu Marine National Park.

Keywords: anthropogenic factors, exposed sandy beach, hotel sites, marine protected area, *Ocypode*, residential environment

Introduction

Urbanisation causes an increase in developments such as the erection of hotels and residential housing complexes near sandy beaches. The impact of such developments along coastlines is varied, but includes habitat destruction, pollution and disturbance to wildlife (Nordstrom 2000). Although these impacts can be assessed using physical measures (e.g. dune profiles to monitor erosion: Andrade and Ferreira 2006), they can also be assessed biologically using indicator species as a proxy to monitor ecosystem health.

Ghost crabs (*Ocypode* species) are one of the largest invertebrates found across sandy beaches in the tropics and subtropics (Barros 2001; Lucrezi and Schlacher 2014). They inhabit burrows up to 1 m deep and feed in the intertidal zone, predominately nocturnally (Wolcott and Wolcott 1984; Jackson et al. 1991; Moss and McPhee 2006; Schlacher and Lucrezi 2010). *Ocypode* spp. are an important link in beach foodwebs as they feed on detritus, including carrion, and predate on crabs and clams (Wolcott 1978), in addition to being a prey item for other species (Lucrezi and Schlacher 2014). As such, they are a useful indicator species for sandy beach ecosystem health. Indeed, the density of *Ocypode* spp. has been used as an indicator of anthropogenic impact on beaches across their range, and has been found to decrease as a result of human impacts (Wolcott and Wolcott 1984; Barros 2001; Moss and McPhee 2006; Neves and Bemvenuti 2006; Lucrezi et al. 2009b; Schlacher and Lucrezi 2010; Aheto et al. 2011; Jonah et al. 2015; but see Schlacher et al. 2016). The density of *Ocypode* populations can be measured using a variety of methods, including visual census, physical collection of specimens, and counts of the number of burrows as a proxy for the number of individual ghost crabs (Schlacher et al. 2016). Although burrow counts do not indicate the exact number of individuals, it constitutes a quick and cheap means to assess the ecological condition of beaches, with minimal disturbance (Lucrezi 2015). Nevertheless, although indicator-species counts are a simple method for assessing ecosystems, they are not without limitations, since species may be overly sensitive to certain stressors and could produce artificially low population density estimates in certain situations. For example, *Ocypode* spp. burrow entrances can be obscured or may collapse as a result of human trampling or physical conditions, such as wind, creating low population density estimates that lead to conclusions that the stressor is worse than it actually is (Lucrezi et al. 2009a). Therefore, the results of studies using indicator species to monitor ecosystem integrity should be treated with caution.

Watamu Marine National Park (WMNP), Kenya, is one of the oldest marine protected areas in Africa, being designated in 1968 (IUCN 2004). The main focus of research there has been on coral reefs, with only one article published on sandy beach ecology (Jones 1972). Jones (1972) examined the density and behavioural patterns of two species of *Ocypode* and related these factors to feeding strategy and prey availability. Tourism and development in WMNP have increased considerably since Jones' (1972) study, with a number of new hotels having been erected in the past 40 years (HFRH pers. obs.), but no research has been undertaken to determine the extent of the impacts on the beach ecosystem.

This study aimed to assess the density of *Ocypode* burrows at four beach sites in WMNP (including one used by Jones in 1972) which differed in the scope of human use. Specifically, we tested the hypothesis that *Ocypode* burrow density would differ in relation to the degree of development (hotel or residential housing) adjoining these sites.

Methods

Site descriptions

Four beach sites were selected (Figure 1): two sites in front of hotels (high degree of urbanisation), and two sites in front of residential housing among coastal scrub, and which had a minimal amount of development and associated disturbance (low degree of urbanisation). The sites were otherwise chosen to be as similar as possible in terms of beach profile and wave action.

The first hotel site (Turtle Bay Hotel) corresponded to a location in front of the same hotel where Jones (1972) undertook fieldwork. The Turtle Bay Hotel site is situated close to the centre of Watamu town and is surrounded by three other hotels plus residential housing. In addition, there are intertidal rock pools, measuring about 40 m in width, in front of the hotel. The second hotel site was Garoda on Watamu's peninsula, which is surrounded by one other hotel, residential housing, and rocky outcrops plus a number of rock pools smaller than those at the first site. The two hotels encourage their guests to utilise the beaches through arranging outdoor sporting and commercial activities. Furthermore, both hotels regularly clean the beach fronts, and also remove washed up seagrass *Thalassodendron ciliatum* through sand raking.

The first residential housing site was Mwamba, in front of A Rocha Kenya's Field Study Centre and guesthouse. This site has a substantial amount of scrub between the housing and the beach, but no rock pools are present. The second residential housing site was Plot 34, which has a similar amount of scrub between the residential house and the beach, and about 65 m of intertidal rock pools between the sandy beach and the sea; however, these were exposed only at extreme low tides, below 0.5 m.

Field methods

Beach profiles were measured at all four sites using the method proposed by Andrade and Ferreira (2006). The largest beach width was 85 m (Garoda) and the smallest 65 m (Turtle Bay) (Figure 2). Wind came from the northeast, causing the wave action to be in a southwesterly direction, although the direction changes seasonally.

Each site was surveyed twice during November 2013, which produced 40 transects in total (see next paragraph). When possible, the four sites were surveyed on consecutive days in order to be within the same tidal cycle and hence to avoid tidal movement variation (Jones 1972). The surveys took place when low tide fell between 08:00 and 10:00 (cf. Jones 1972; Barros 2001; Lucrezi et al. 2009a) to allow the longest possible time for night-burrowing activity by the ghost crabs across the whole beach width and to ensure the least amount of burrow disturbance due to people using the beach in the mornings (Lucrezi et al. 2009a, 2009b; Lucrezi and Schlacher 2014). Surveys at the hotel sites occurred prior to sand raking. This methodology can be expected to produce the most realistic estimates of burrow density (Lucrezi et al. 2009a).

Five transect lines were laid at each site, from the edge of the scrub or hotel to the ocean edge, perpendicular to the shoreline. Transect surveys were repeated twice in the same month, creating a total of 40 transect surveys (or 10 per site). At each site the five transect lines were initially placed 3, 5 or 10 m apart to ascertain the optimal distance between transect lines, in accordance with studies by Jones (1972) and Barros (2001); the final transects were placed 10 m apart. Following the same methods as Jones (1972), and to allow for a direct comparison of data, seven 10-m^2 circular plots (quadrats) were drawn out along each transect using a 1.78-m piece of string. This was centred on the transect tape every 8 m starting at 1.78 m (as in Barros 2001). Within each plot, the size and number of all *Ocypode* burrows were noted, as was the total length of the transect to determine the full width of the beach (following Jones 1972; Barros 2001). We assumed, in line with previous researchers, that the number of ghost crab burrows was directly related to the number of individuals (Barrass 1963; Jackson et al. 1991; Lucrezi et al. 2009b; Pombo and Turra 2013). *Ocypode* species were identified when seen, using photographic identification and Richmond's (2011) criteria when necessary. However, burrows were identified to genus level only; therefore, the measure of burrow density included burrows of all *Ocypode* species present.

Statistical analysis

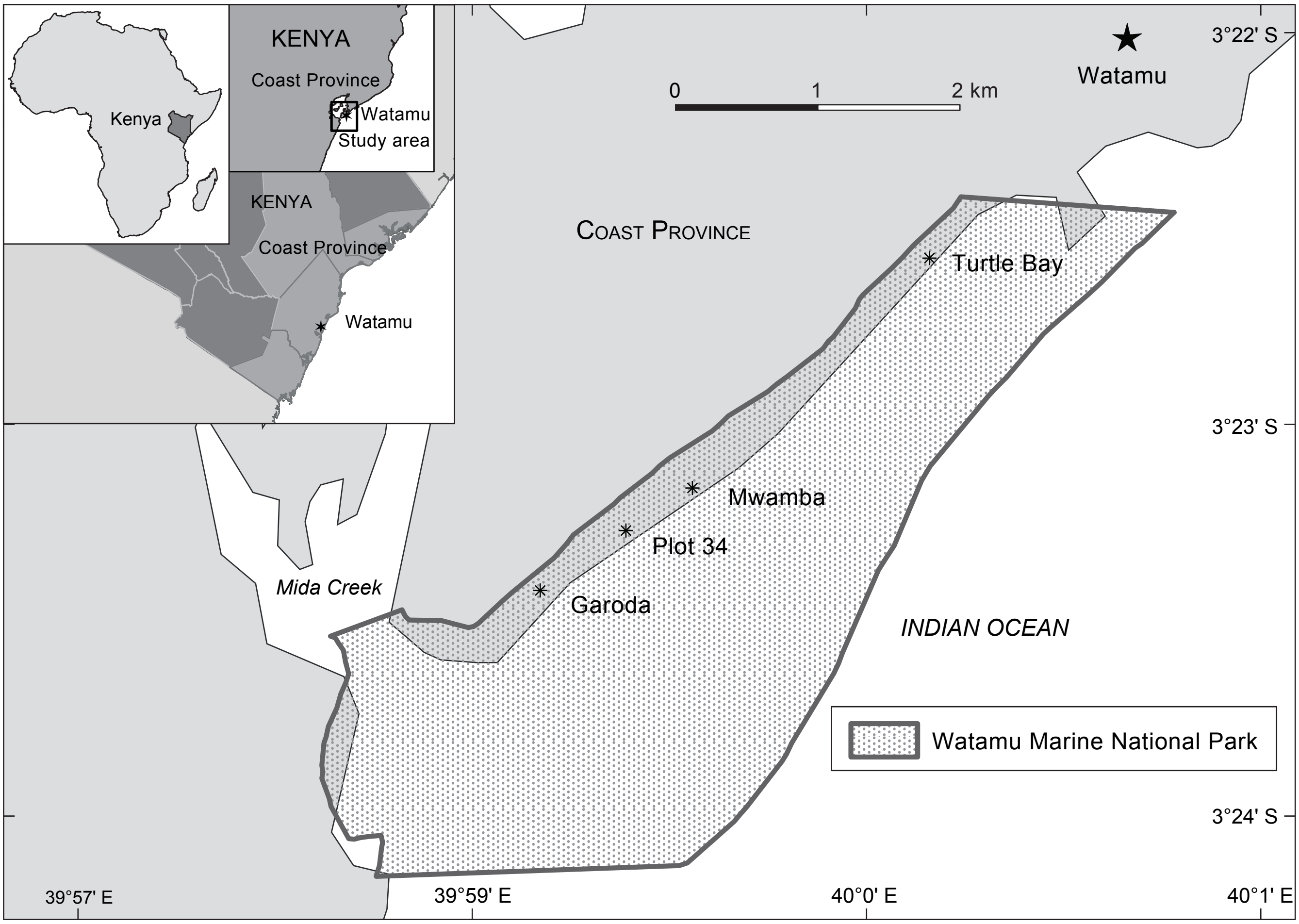
A nested ANOVA was used to assess the difference in *Ocypode* burrow density in response to the adjoining housing type (hotel or residential housing) and the site (Turtle Bay, Garoda, Mwamba or Plot 34) nested within housing. The statistical analysis was run with Minitab 17 software.

Results

Observations showed that *Ocypode ryderi* and *O. cordimanus* were found at all four beach sites. In addition, *O. cordimanus* were observed with a variety of colour morphs. There was no significant effect of site nested within housing type ($F_{2,36} = 1.41$, $p = 0.256$), but residential housing had a significantly higher *Ocypode* burrow density than hotels ($F_{1,36} = 29.02$, $p < 0.001$) (Figure 3). Furthermore, a crude comparison of the *Ocypode* burrow density reported in Jones' (1972) study at Turtle Bay (1.7 burrows m^{-2}) and the current data for the same site (0.12 burrows m^{-2}) revealed a 92.94% decline.

Discussion

The significantly lower *Ocypode* burrow density found at beaches adjoining the hotel sites compared to the residential



Map Created: 05/06/2015. Imagery Sources: whole of Africa, arcgis.com, 2014, Kenyan Counties arcgis.com: 2011.

Figure 1: Map of Watamu, Kenya (3°22°41.4° S, 39°59°20.3° E), with insets showing its location in the Coast Province. The four study sites were: Garoda (3°23°08.8° S, 39°58°46.9° E), Plot 34 (3°22°55.2° S, 39°59°06.4° E), Mwamba (3°22°45.1° S, 39°59°21.7° E) and Turtle Bay (3°21°50.3° S, 40°00°16.6° E)

housing sites confirms previous findings that showed a negative impact of various types of human disturbance on ghost crab density (i.e. Barros 2001; Moss and McPhee 2006; Lucrezi et al. 2009b; Aheto et al. 2011; Lucrezi and Schlacher 2014; Jonah et al. 2015). Hotel sites undoubtedly have a greater negative impact on coastal sites than residential housing due to the increased number of people attracted to the beach sites, with consequential increases in habitat disturbance, such as through destruction, fragmentation or modification (including beach cleaning), trampling and pollution (Reyes-Martínez et al. 2015).

The lowest *Ocypode* burrow density, at Turtle Bay, could be attributed to the site having buildings erected up to the sand-dune edge (cf. Barros 2001; Aheto et al. 2011; Noriega et al. 2012). As recognised by previous authors (Barros 2001; Aheto et al. 2011; Noriega et al. 2012), construction could have caused a lesser, but similar, reduction in *Ocypode* burrows on beaches with concrete walls. In addition, Reyes-Martínez et al. (2015) determined that increased urbanisation on beach fronts could lead to a loss of diversity and density of coastal species, and negatively impact macrofaunal communities, such as through local extinctions or changes in relative abundance of species (cf. Noriega et al. 2012). Furthermore, the Turtle Bay site had three additional hotel complexes surrounding it, whereas Garoda had only one other hotel nearby. In contrast, Mwamba and Plot 34 both had only houses situated more inland and more dispersed human activity. Consequently, human impacts such as trampling and habitat destruction would more likely have impacted the *Ocypode* burrow density at the hotel sites (cf. Wolcott and Wolcott 1984; Barros 2001; Moss and McPhee 2006; Schlacher and Lucrezi 2010; Noriega et al. 2012).

When the *Ocypode* burrow density at the Turtle Bay site was compared to that recorded by Jones (1972), a 92.94% reduction was found. The beach profile at Turtle Bay as recorded in this study remained comparable to that described by Jones (1972), although the landscape around the hotel has changed. For example, two additional hotels were built nearby in the 1990s and another was completed in 2013. This building activity could have negatively impacted the natural beach ecology, resulting in a decline of the *Ocypode* population and reduction in burrow density over the last 40 years (Wolcott and Wolcott 1984; Barros 2001; Moss and

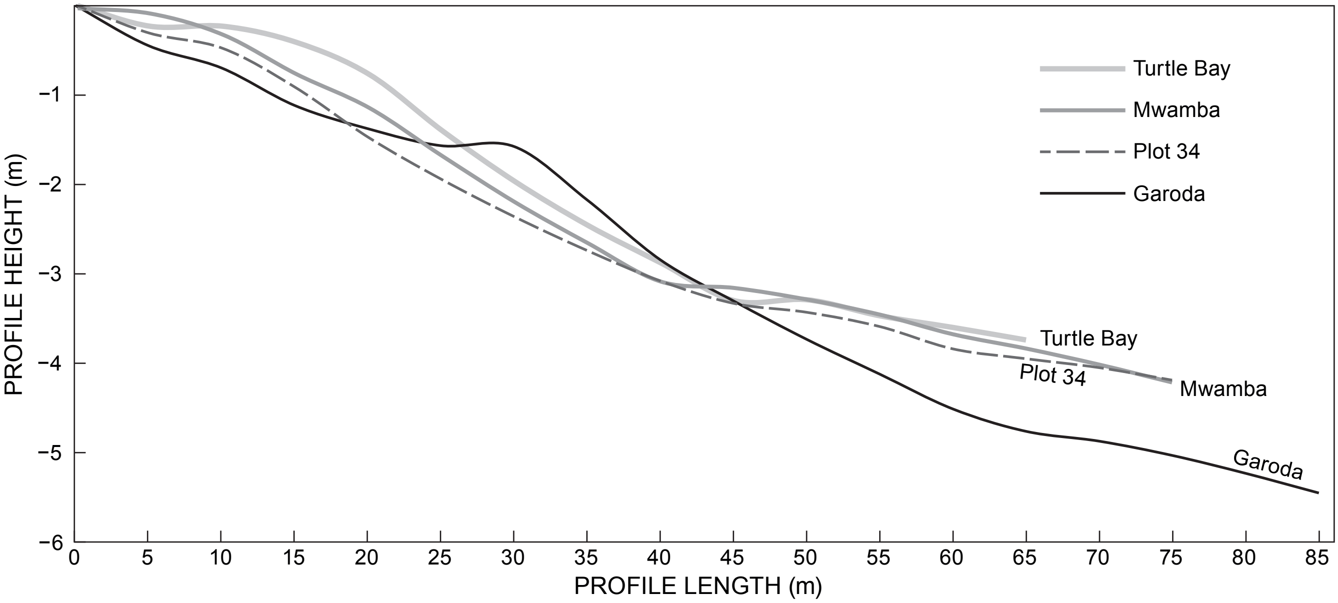


Figure 2: Beach profiles for each site using the method of Andrade and Ferreira (2006). Site locations are provided in Figure 1

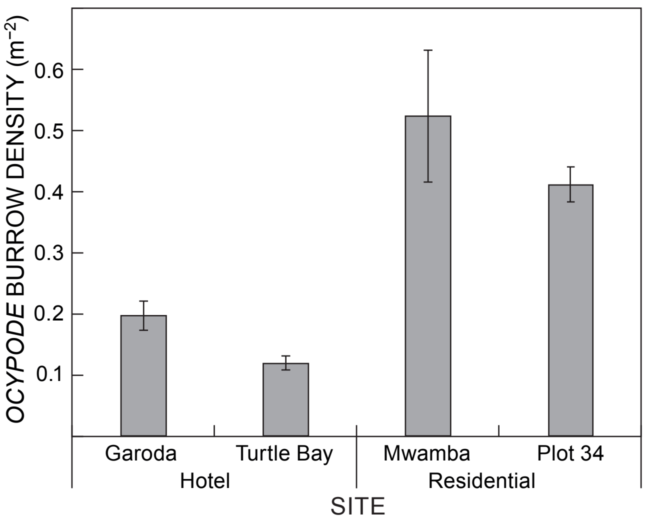


Figure 3: Mean *Ocypode* burrow density (burrows m^{-2} ± SE) was significantly lower at hotel sites than at residential housing sites ($F_{1,36}$ = 29.02, p < 0.001), but there was no effect of site nested within housing ($F_{2,36}$ = 1.41, p = 0.256)

McPhee 2006; Schlacher and Lucrezi 2010; Reyes-Martínez et al. 2015). However, the comparison of burrow density was relatively crude, and thus should not be used as a reliable indicator of actual change in the *Ocypode* population (Schlacher et al. 2016). Additional research, utilising other sites that were also selected by Jones (1972), could provide further comparisons of ghost crab density over time. This would establish whether different coastal locations have been similarly affected, or whether Turtle Bay is unique.

This East African study extends the use of *Ocypode* species as indicators of beach disturbance caused by adjoining urbanisation, such as through habitat destruction, fragmentation or modification, trampling and pollution. Moreover, this study suggests the utility of the survey method for examining impacts before and after management interventions in designated areas like WMNP (as well as other types of landscapes within the range of *Ocypode* species), especially to determine if the exclusion of a particular human activity (such as outdoor sporting activities) is needed to protect the beach ecosystem.

Conclusions

This study provides additional evidence that *Ocypode* species appear sensitive to increased urbanisation, whereby the number of burrows decreases in relation to increased levels of development and human use. Furthermore, it demonstrates that *Ocypode* burrow density can be used to estimate negative impacts to beaches, such as within marine protected areas and other coastal reserves, where other assessment methods might be impractical. We demonstrate that for one East African site, where a basic comparison of *Ocypode* burrow density was performed using studies separated by a 40-year interval, there has been a dramatic decrease in *Ocypode* burrow density. We suggest that it is likely that urbanisation has already negatively impacted the beach fauna of Watamu Marine National Park and that this ecosystem should be actively reconsidered for management intervention.

Acknowledgements — Many thanks to A Rocha Kenya for providing the fieldwork equipment and to Kenya Wildlife Service for their generous support and for permission to conduct the fieldwork within Watamu Marine National Park. Thanks also to Benjamin Cowburn, Peter Musembi, Jaap Gijsbertsen, Cassie Raker and Dorothea Kohlmeier for their help, support and guidance in data collection. Thank you to Sally Freeman and Jane Richards for support during writing of the manuscript. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

Aheto D, Asare C, Mensah E, Aggrey-Fynn J. 2011. Rapid assessment of anthropogenic impacts of exposed sandy beaches in Ghana, using ghost crabs (*Ocypode* spp.) as ecological indicators. *Momona Ethiopian Journal of Science* 3: 93–103.

Andrade F, Ferreira MA. 2006. A simple method of measuring beach profiles. *Journal of Coastal Research* 22: 995–999.

Barrass R. 1963. The burrows of *Ocypode ceratophthalmus* (Pallas) (Crustacea, Ocypodidae) on a tidal-wave beach at Inhaca Island, Mozambique. *Journal of Animal Ecology* 32: 73–85.

Barros F. 2001. Ghost crabs as a tool for rapid assessment of human impacts on exposed sandy beaches. *Biological Conservation* 97: 399–404.

IUCN (International Union for the Conservation of Nature). 2004. *Managing marine protected areas: a toolkit for the Western Indian Ocean*. Nairobi, Kenya: IUCN.

Jackson L, Smale M, Berry P. 1991. Ghost crabs of the genus *Ocypode* (Decapoda, Brachyura, Ocypodidae) of the east coast of South Africa. *Crustaceana* 61: 280–286.

Jonah FE, Agbo NW, Agbeti W, Adjei-Boateng D, Shimba MJ. 2015. The ecological effects of beach sand mining in Ghana using ghost crabs (*Ocypode* species) as biological indicators. *Ocean & Coastal Management* 112: 18–24.

Jones DA. 1972. Aspects of the ecology and behaviour of *Ocypode ceratophthalmus* (Pallas) and *O. kuhlii* de Haan (Crustacea: Ocypodidae). *Journal of Experimental Marine Biology & Ecology* 8: 31–43.

Lucrezi S. 2015. Ghost crab populations respond to changing morphodynamic and habitat properties on sandy beaches. *Acta Oecologica* 62: 18–31.

Lucrezi S, Schlacher TA. 2014. The ecology of ghost crabs. *Oceanography and Marine Biology: An Annual Review* 2: 201–256.

Lucrezi S, Schlacher TA, Robinson W. 2009a. Human disturbance as a cause of bias in ecological indicators for sandy beaches: experimental evidence for the effects of human trampling on ghost crabs (*Ocypode* spp.). *Ecological Indicators* 9: 913–921.

Lucrezi S, Schlacher TA, Walker S. 2009b. Monitoring human impacts on sandy shore ecosystems: a test of ghost crabs (*Ocypode* spp.) as biological indicators on an urban beach. *Environmental Monitoring and Assessment* 152: 413–424.

Moss D, McPhee DP. 2006. The impacts of recreational four-wheel driving on the abundance of the ghost crab (*Ocypode cordimanus*) on a subtropical sandy beach in SE Queensland. *Coastal Management* 34: 133–140.

Neves FM, Bemvenuti CE. 2006. The ghost crab *Ocypode quadrata* (Fabricius, 1787) as a potential indicator of anthropic impact along the Rio Grande do Sul coast, Brazil. *Biological Conservation* 133: 431–435.

Nordstrom KF. 2000. *Beaches and dunes on developed coasts*. Cambridge, UK: Cambridge University Press.

Noriega R, Schlacher TA, Smeuninx B. 2012. Reductions in ghost crab populations reflect urbanization of beaches and dunes. *Journal of Coastal Research* 28: 123–131.

Pombo M, Turra A. 2013. Issues to be considered in counting burrows as a measure of Atlantic ghost crab populations, an important bio-indicator of sandy beaches. *PLoS ONE* 8: e83792.

Reyes-Martínez MJ, Ruíz-Delgado MC, Sánchez-Moyano JE, García-García FJ. 2015. Response of intertidal sandy-beach macrofauna to human trampling: an urban vs natural beach system approach. *Marine Environmental Research* 103: 36–45.

Richmond MD. 2011. *A field guide to the seashores of Eastern Africa and the Western Indian Ocean islands*. Dar es Salaam, Tanzania: Sida/Western Indian Ocean Marine Sciences Association.

Schlacher TA, Lucrezi S. 2010. Compression of home ranges in ghost crabs on sandy beaches impacted by vehicle traffic. *Marine Biology* 157: 2467–2474.

Schlacher TA, Lucrezi S, Peterson CH, Connolly RM, Olds AD et al. 2016. Estimating animal populations and body sizes from burrows: marine ecologists have their heads buried in the sand. *Journal of Sea Research* 112: 55–64.

Wolcott TG. 1978. Ecological role of ghost crabs, *Ocypode quadrata* (Fabricius) on an ocean beach: Scavengers or predators? *Journal of Experimental Marine Biology & Ecology* 31: 67–82.

Wolcott TG, Wolcott DL. 1984. Impact of off-road vehicles on macroinvertebrates of a mid-Atlantic beach. *Biological Conservation* 29: 217–240.

Manuscript received November 2016 / revised January 2017 / accepted January 2017