Human use and modification of beaches and dunes are linked to ghost crab (*Ocypode spp*) population decline in Ghana

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Abstract

The increasing urbanization of many of the world's coasts threatens irreversible damages to beach ecosystems, if unchecked. However, beach monitoring programmes for immediate remediation is uncommon, especially for several less developed nations where infrastructural development and socio-economic goals are regarded as more important than environmental goals. This study aimed at obtaining information about the effects of the modification and use of beaches and dunes on beach biota using ghost crab burrow density and size as variables. This study tested the hypothesis that the mean densities and sizes of ghost crab burrows on six beaches under three categories of human use in the Central Region of Ghana are different. Results indicated that low use beaches had significantly higher numbers of burrows and larger burrow sizes compared to medium use and high use beaches. Since physical and environmental parameters were consistently the same amongst the six surveyed beaches, the paper concluded that the differences in the observed beach use and dune modifications were responsible for the observed differences in ghost crab abundance and sizes. Major beach use such as high level trampling and clearing of dune vegetation for infrastructural developments are most likely responsible for the observed differences. On account of ecological considerations, it is recommended that beach land use reforms by coastal Municipal authorities in Ghana should ensure that infrastructure development along undeveloped sections of the coast consider natural vegetation barriers between development and the beach to enhance natural beach-dune ecosystem interaction.

Keywords: human impacts; beach management; beach ecology; ghost crab populations; Ghana

1. Introduction

Beaches and associated dunes provide essential habitat for plants and invertebrates, as well as feeding and nesting sites for birds and sea turtles (Baird and Dann, 2003; Lastra *et al.*, 2010). Beaches are also well sought-after by people for recreational, tourism and residential purposes (Klein, Osleeb and Viola, 2004; Noriega *et al.*, 2012). These multiple competing uses have contributed to the escalating pressures on beaches and dunes from increased demands for recreational access and development of coastal lands (Defeo *et al.*, 2009). Indeed, the degradation of beaches has been a matter of global concern in recent years (Ramsay and Cooper, 2002; Payet *et al*., 2009). It is also confirmed that 70 % of the world's beaches are experiencing coastline retreat as a result of coastal erosion due largely to human-induced impacts (Anthony, 2005). The multiplicity of users lead to competing demands for beach and dunes resources, which has ultimately made most coastal dunes and beaches around the world severely modified (Nordstrom, 2000; Coombes *et al.*, 2008). People worldwide use sandy beaches than any other type of coastal shore. However beaches are not just piles of sand, they support a wide range of biodiversity that require conservation, management and for the ecological roles they play.

Limited management interest has traditionally been directed towards ecological damage to beaches and dunes caused by human development and over-exploitation of sandy coastlines

(Nordstrom *et al.*, 2000; Noriega *et al.*, 2012). However, more attention has been given to shoreline stabilization, erosion management and maintaining aesthetic appeal of beaches over the years (Schlacher *et al.,* 2008). Environmental monitoring and assessments of sandy beach ecosystems is rare across the globe despite the great social, economic and environmental importance of sandy shores (Lucrezi, Schlacher and Walker, 2009). The effects of the massive trampling that metropolitan beaches may endure either seasonally or year-round remain largely unexamined (James, 2000). Poor management of coastal ecology is even more evident along the coastlines of developing nations, where there are often trade-offs between development goals and environmental protection. However, development and implementation of monitoring programmes on coastal systems may aid in the timely detection and remedy of possible irreversible ecological damages as a result of human use of beaches and dunes.

Ghost crabs (Fam. Ocypodidae, Gen. *Ocypode*), are one of the biological indicators that can be used to monitor human disturbances on sandy beaches (Barros, 2001; Lucrezi, Schlacher, and Walker, 2009; Aheto *et al.*, 2011). It has been applied to measure the effects of various human disturbances on sandy beach ecology, including off-road vehicles (Blankensteyn, 2006; Moss and McPhee, 2006; Schlacher, Thomson and Price, 2007), shore armouring (Barros 2001; Aheto *et al.*, 2011), beach nourishment and bulldozing (Peterson *et al.*, 2000), tourism (Schlacher, de Jager, Nielsen, 2011) and urbanization (Noriega *et al.*, 2012). In all these studies, ghost crabs densities were reported to be lower at human affected areas. Most researchers have accepted ghost crabs as useful bio-indicators because they occur at both unvegetated beach and dunes (Noriega *et al.*, 2012), they are the top invertebrate predator leaving on beaches (Barrass 1963; Schlacher, Thompson and Price, 2007), changes in their density and population structure are easy to estimate by counting and measuring the burrow openings (Barros, 2001; Schlacher, Thompson, and Price, 2007) and indeed, they are widespread and abundant on tropical to warm–temperate beaches (Quijon, Jaramillo, and Contreras, 2001; Noriega *et al.*, 2012).

This paper uses ghost crabs as bio-indicators to measure beach health. This approach may be perceived to be expensive due to the labour-intensive nature of estimating beach biodiversity by coastal authorities in developing countries. However, recent studies such as Aheto *et al.* (2011) and Jonah *et al.* (2015b) have established this technique to be inexpensive, simple to undertake and could be easily funded by coastal authorities in developing nations taking cognisance of the useful ecological benefits of such programmes.

In Ghana, beaches of the Central Region are the most sought-after for tourism, with a combination of other human stressors leading to severe transformations of beach and dune systems. This is particularly important also in the context of sea level rise resulting from climate change and poor land use in coastal areas of the country (Adotey *et al*., 2015). Other human pressures include urbanization in the active coastal strip, sand mining on a commercial scale, destruction of beach vegetation, fishing activities, waste disposal and beach nourishment. Unfortunately, the environmental impacts of these activities have received little considerations in the past (Armah, 1991; Appeaning-Addo, 2009). This makes it essential for studies to be conducted on these beaches to gauge the ecological change resulting from these multiple human use and stressors to inform beach management decisions at the district and national levels.

During the past 40 years, beaches in the vicinity of Cape Coast in the Central Region of Ghana have undergone significant changes as a result of increased human activities within the active coastal zone (Jonah, 2015; Adotey *et al.*, 2015). In the past few years, there has been an increasing demand for coastal lands for tourism activities, with infrastructure being constructed on land previously occupied by dune vegetation. Beach sand mining is also widely practiced on most sandy beaches at varying scales, to feed the local construction industry (Jonah *et al.*, 2015a; Mensah 1997). These have contributed to accelerated beach and dune erosion, making facilities along the zone vulnerable to sea waves. In response, the central government has constructed a nearly 1.5 km rock revetment sea defence and several gabions to protect communities and road infrastructure, whilst property owners have also undertaken several small scale projects to protect their investments. In addition, most beaches show signs of several human impacts including campfires, trampling, litter and 'bush toilets'.

The objective of this paper is to contribute to existing knowledge on the ecological conditions, habitat properties and human use of selected beaches in the Central Region of Ghana using Ghost crab burrow densities and size variations, intensity of beach trampling and other physical environmental conditions such as sediment temperatures as primary data sources.

2. Materials and Methods

2.1 Study sites

This study was conducted on beaches in the mid-portion of the Central Region coast of Ghana from October 2013 to February 2014. Sites for the study were selected based on field observations made by Jonah (2014) and preliminary sampling surveys carried out in October 2012. Six beach sites were selected based on level of human activities (Figure 1, 2). The selected sites were qualitatively classified as 'low use', 'medium use' and 'high use' according to levels of human disturbances (Table 1). Two sites (Saltpond I and Saltpond II) located on the same beach stretch in the Mfantseman District and southeast of the town of Saltpond were selected as the 'low use' beaches. These two sites are 1 km apart and situated about 2 km from the nearest community in Saltpond and receive very low levels of visitors. The term 'medium use' was associated with beaches that support moderate levels of trampling, sand mining and infrastructure development. The term 'high use' was used for beaches that support small to medium scale beach sand mining activities, high levels of trampling, cleared dune vegetation and high levels of infrastructure development on the adjoining dune (Table 1).

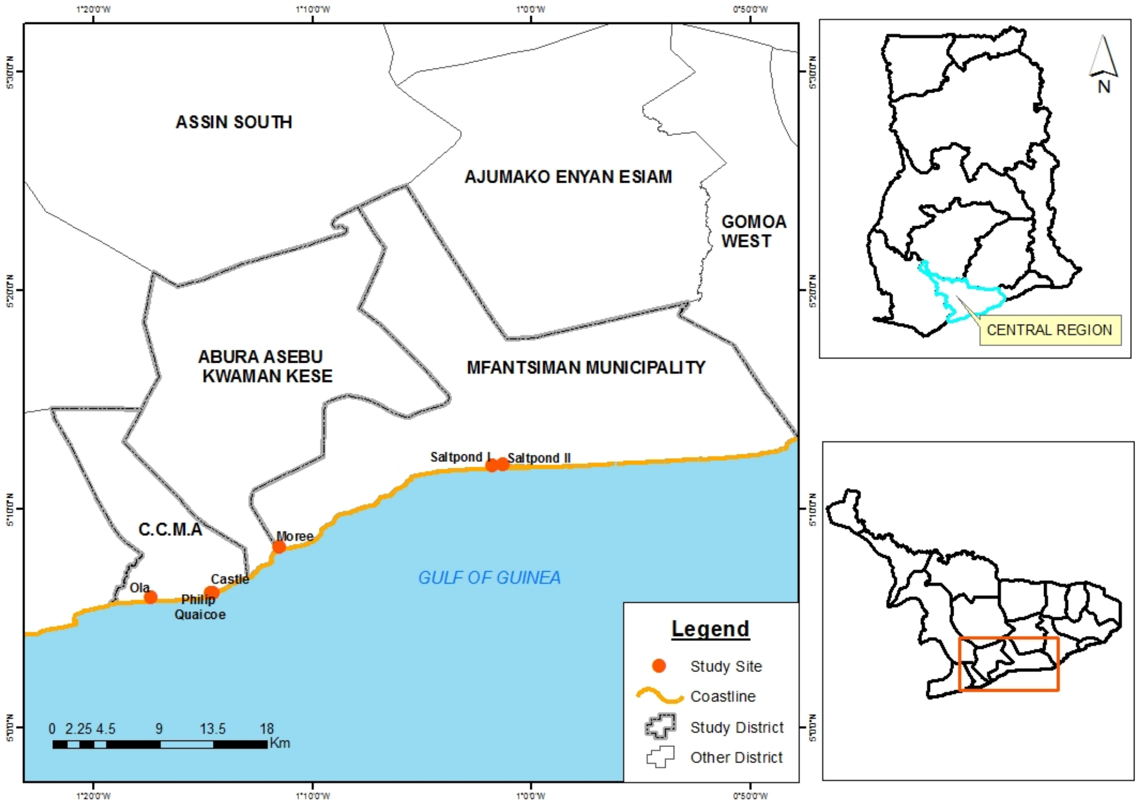

Figure 1: Map of Ghana showing the surveyed sites

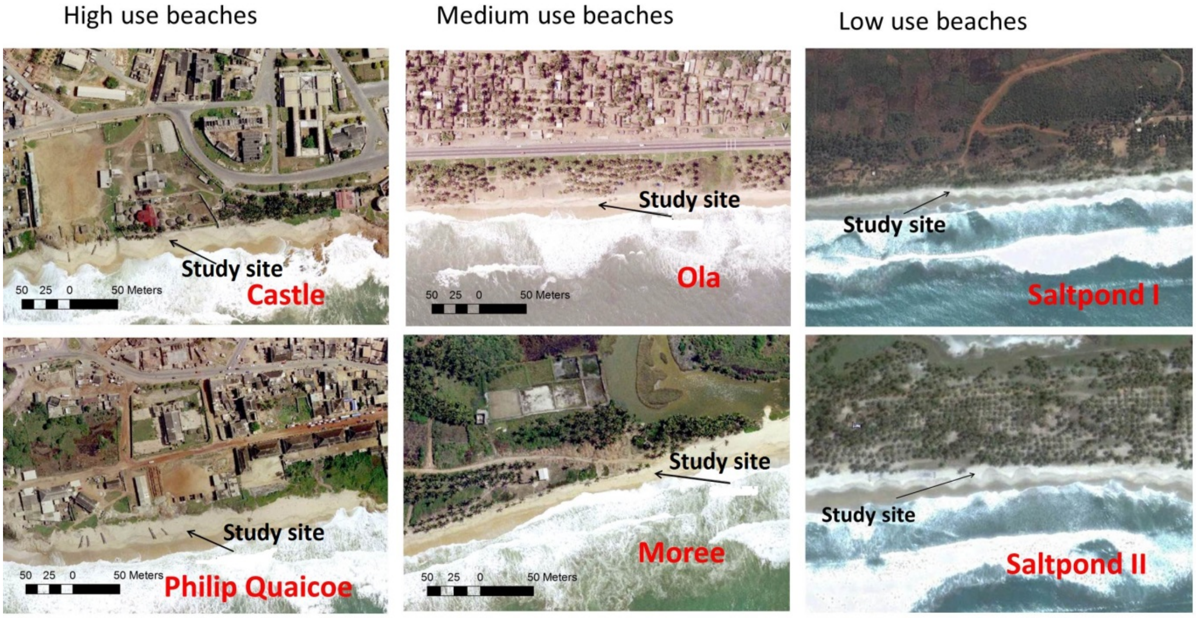

Figure 2: Aerial photographs of surveyed beaches in the Central Region of Ghana

2.2 Data Collection

Two species of ghost crabs, *Ocypode cursor and Ocypode africana,* are found on sandy beaches in Ghana (Aheto *et al.,* 2011). This study assessed the differences in densities and sizes of the ghost crabs burrows across the six selected beaches. In addition, several physical environmental parameters that affect ghost crabs distribution were measured. Surveys were started before sunrise at approximately the same tidal period using standard tide tables from the Ghana Ports and Harbours (GHAPOHA, 2013). During each survey period, all surveys were done very early in the morning to ensure consistency and minimize variation in environmental conditions. Early morning sampling helps to reduce and eliminate the effect of overlooking burrow openings due to ghost crabs plugging the openings during the heat of the day (Lucrezi, Schlacher and Walker, 2009; Moss and McPhee, 2006).

Estimates of the population density of ghost crabs were achieved by counting the number of burrow openings in 1 m^2 quadrats (Aheto *et al.,* 2011). This follows the assumption that the presence of a burrow on the beach corresponds to the presence of the crab (Wolcott, 1978). On each beach, five replicated samples were taken on three line transects cast perpendicular to the general direction of the shoreline at 50m intervals. Surveys on each transect was initiated by casting quadrats at 1-2 m above the low water mark line. On each transect, five replicated quadrats (1 m^2) were sampled at 4.5 m intervals. Burrow diameters were also measured using a vernier caliper within quadrats to estimate sizes (carapace length) of crabs. This follows the findings of Strachan *et al.* (1999) and Tureli *et al.* (2009), that there is a strong positive correlation between carapace length of ghost crab and burrow diameter. Diameters of all encountered burrows were taken during three surveys.

Additional data on physical environmental conditions were also taken and analyzed as key environmental and habitat metric of the beaches. Sediment sampling was done using sediment corers (15 mm diameter, 300 mm deep) to collect samples to a depth of 200 mm from five quadrat levels. Five replicate sediment cores were taken within each quadrat and analyzed separately to obtain the variability in grain sizes across the entire beach. Sediment cores were used wholly to ensure that the variability in sediment sizes up to a depth of 200 mm was captured. Samples were analyzed using the ‘sieve method’. In the laboratory, sediment granulometry was determined by dry-sieving samples through a nested series of nine sieves arranged in decreasing order of mesh aperture (4,750, 2,000, 1,000, 710, 600, 425, 300, 200, 75 µm). The heights of beach scarps were also measured once during the study at 20 m interval over a distance of 200 m on each beach. Scarp heights have been identified as being the consequence of human use of beaches and dunes (Mensah, 1997; Esteves, 2002). Sand and air temperatures were also taken at all the beaches during each survey using a mercury thermometer. Sediment temperature was taken at a depth of 20 cm. Wave period for each beach was also determined by counting the number of waves breaking in the surf zone during a 3-minute period. In addition to these, the number of beach users was recorded over 30 minute periods during each survey, as a proxy to trampling.

2.3 Data Analysis

A one-way analysis of variance, followed by a *post hoc* Bonferroni's test was used to compare burrow densities and diameters among sites. Mean sediment grain was calculated with the GRADISTAT software, using the Folk and Ward method (Blott & Pye, 2001). Spearman's rank correlation was used to assess the relationships between physical and environmental factors and burrow density of ghost crabs.

3. Results

3.1 Environmental conditions, habitat properties and human use

Wave period was relatively constant at all sites with values ranging from 5.1 to 5.3/minute. All six surveyed beaches have medium energy waves with an average height of 1 m breaking in the surf zone (GHAPOHA, 2013). Mean scarp heights ranged from 0.048 m at Saltpond I to 1.096 m at Ola (Table 1). The weather conditions that prevailed during the study period were mostly warm and dry. Sediment temperature ranged from 25º-39ºC during surveys, but did not vary significantly among sites (Anova, $p > 0.05$). Sediment temperature was positively correlated with air temperature (Pearson's $r = 0.716$, $p < 0.0001$). Air temperature at the time of survey (0500 – 0800) ranged from 24º-33ºC. Sand from all sites fell in the medium sand category and ranged from a mean grain size of 0.4783 µm at three sites (Ola, Saltpond I and Saltpond II) to 0.7117 µm at Moree.

Data pooled for all sites indicated a strong negative correlation between sediment grain size and ghost crab burrow density (Spearman's ρ, $r = -0.741$, $p = 0.092$). Erosion scarp height was also found to be negatively correlated to burrow densities (Spearman's ρ, $r = -0.429$, $p = 0.397$). The number of beach users varied significantly amongst the categories of beaches (Anova, $F_{5,\,42} = 16.65$, $p < 0.0001$). There was also a strong negative correlation between number of beach users and ghost crab densities (Pearsons $r = -0.698$, $p > 0.123$).

Table 1: Summary of classification of human uses and habitat parameters of surveyed beaches

Parameter	High use		Medium use		Low use	
	Castle	Philip Quaicoe	Ola	Moree	Saltpond I	Saltpond II
Latitude	5° 6'11.80"N	5° 6'11.15"N	5° 5'59.61"N	5° 8'19.38"N	5º12'2.77" N	5º12'4.20" N
Longitude	1°14'34.08"W	1°14'37.97"W	1°17'23.81"W	1°11'30.66"W	1º1'46.75"W	1º1'17.75"W
Manual beach cleaning	Weekly	Daily-weekly	Monthly	Occasional	Never	Never
Dune vegetation	Cleared	Moderately modified	Strongly modified/cleared	Cleared	Intact	Intact
Trampling	Very high	Moderate to high	Moderate	Moderate	Very low	Very low

Sand mining	Small to medium scale commercial	Small to medium scale	Small scale	Small to large scale	None	None
Sea defence (seawall, wire mesh revetment)	Present	Present	Absent	Absent	Absent	Absent
Infrastructure development	High	High	Moderate	Low	None	None
All-terrain vehicle (ATV) use	Yes	No	No	No	No	No
Scarp height, m (S.E)	0.682 (0.14657)	0.256 (0.10595)	1.096 (0.07916)	0.874 (0.05026)	0.048 (0.02396)	0.056 (0.02731)
Mean grain size, µm (S.E)	0.5783 (0.03186)	0.5783 (0.02909)	0.4783 (0.03624)	0.7117 (0.05871)	0.4783 (0.02519)	0.4783 (0.02693)
Mean beach users per 30 minutes (n = 8)	79.38	28.38	10.38	26.25	1.5	0.75

3.2 Burrow density and size variation

A total of 960 quadrats were surveyed during this study. *O. africana* and *O. cursor* were observed to co-habit all surveyed beaches (Figure 3). Ghost crabs were observed to occur 1-3 m from the low water line, across the beach into dune vegetation. Mean burrow density was highest at the low use beaches, with values of 44 m^{-2}±5.05 burrow.m^{-2} and 38±5.35 burrow.m^{-2} for Saltpond II and Saltpond I respectively, followed by the medium use and high use beaches (Table 2).

Figure 3: Ghost crab species found in Ghana: (A) *O. cursor* and (B) *O. africana*. (Photos by F.E. Jonah).

Table 2: Summary of mean burrow densities and mean burrow diameters at eight sites with standard error

	Castle	Philip Quaicoe	Ola	Moree	Saltpond I	Saltpond II
Mean burrow density (±S.E)	14.48 (1.80)	17 (1.98)	19 (2.34)	18.38 (2.59)	38 (5.35)	44 (5.05)
Burrow diameter means (±S.E)	6.23 (0.82)	8.43 (0.84)	9.28 (1.59)	10.09 (1.89)	19 (2.41)	20.8 (2.58)

Mean burrows densities were found to be significantly different between sites (Table 3). Mean burrow densities were significantly higher at low use beaches (Saltpond I and Saltpond II) compared with medium use beaches (Ola and Moree) and high use beaches (Castle and Philip Quaicoe) (Bonferroni, $p < 0.0001$). No significant differences were found between burrow densities at the medium use and high use beaches (Bonferroni, $p > 0.01$), though recorded burrow density means were slightly higher at the medium use beaches. The highest monthly ghost crab abundance was recorded at Saltpond II (56.53±13.01 burrow.m^{-2}, mean±S.E) in February, whereas the lowest monthly abundance was recorded in Moree (7.56±2.48 burrow.m^{-2}, mean±S.E) also in February (Figure 4).

Table 3: Summary of one way ANOVA of ghost crab population densities at eight beaches

ANOVA Table	*df*	*MS*	*F*	*P*	*F crit*
Treatment (between sites)	5	18830	12.81	<0.0001	3.04
Residual (within sites)	714	1470			
Total	719				

Mean diameters of burrows differed significantly among sites (Anova, Table 4). Mean ghost crab burrow diameters were also significantly higher at less use beaches compared to mean burrow diameters recorded at medium use and high use beaches (Bonferroni, $p < 0.0001$). There were no significant differences between the means of burrow diameters recorded at the medium use and low use beaches (Bonferroni, $p > 0.05$).

Table 4: Summary of one way ANOVA of ghost crab burrow sizes from eight surveyed beaches

ANOVA Table	*df*	*MS*	*F*	*P*	*F crit*
Treatment (between sites)	5	1646	11.02	<0.0001	3.15
Residual (within sites)	264	149.3			
Total	269				

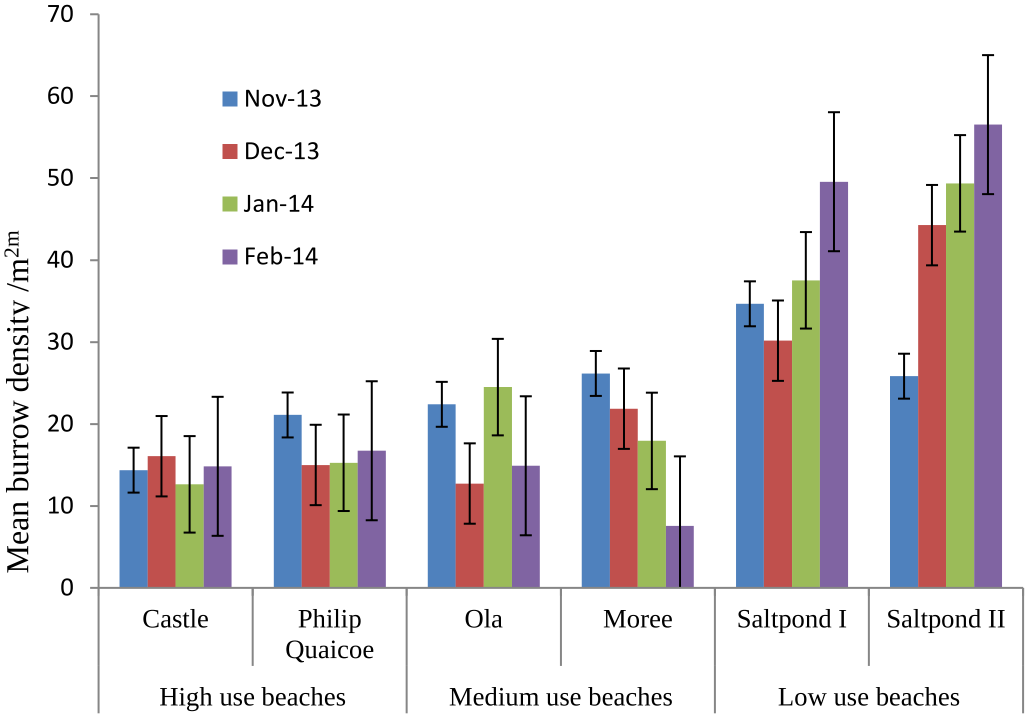

Figure 4: Temporal variation (mean ± S.E) in ghost crab burrow densities recorded at the six study beaches in the Central Region of Ghana.

4 Discussion

4.1 Effect of human use and modification of beaches and dunes on ghost crabs

The objective of this study was to determine the ecological impacts of human use of sandy beaches at selected sites in the Central Region of Ghana as a case study. Ghost crab burrow density and sizes was used as the main indicating factor coupled with other relevant physical environmental conditions. Three different categories of beaches were investigated: high use, medium use and low use, based on the intensity of identified human activities. Results showed that ghost crab burrow densities at the low use beaches were twice or more times higher than those recorded at the medium use and high use beaches. Similar patterns were observed in the mean burrow diameters, where mean diameters recorded at the low use beaches were almost twice or more the diameters recorded at the medium and high use beaches. The results indicate that physical variables were very consistent and did not vary statistically among the different categories of beaches and hence appeared unlikely that physical environmental factors are the main causes of the observed differences in mean burrow densities and burrow diameter among sites. It is however more likely that these spatial differences in ghost crab burrow densities and diameters are as a result of the varying human disturbances identified on the sites.

Beaches are the most visited part of the marine coastal ecosystem (Marshall and Banks, 2013). Several studies have identified that such high level of beach visits and human activities along this area have significantly negative impacts on the densities and distribution of resident biota (Noriega *et al.*, 2012; Lucrezi *et al.*, 2014; Reyes-Martinez *et al.*, 2015). Along this study area, human modifications of beaches have been carried out by residents (for residential facilities), investors (for tourism activities) and the local government (for social infrastructure development). These have resulted in the conversion of sandy beaches and dunes into highly utilized urbanized areas patronized by both local residents and tourists. Such simultaneous multiple urban uses of sandy beaches also present a major challenge to coastal managers when trying to distinguish which one may be responsible for the decrease or loss of biodiversity (Veloso *et al.*, 2009).

In this study, beaches with the highest human use and modification had the lowest ghost crab populations. Similar observations of the effects of various human activities on *Ocypode spp* have been documented in several recent studies, such as trampling (Noriega *et al*, 2012; Reyes-Martinez *et al.*, 2015), beach sand mining (Jonah *et al.*, 2015b), off-road vehicles (Lucrezi and Schlacher, 2010; Schlacher and Lucrezi, 2010), beach sweeping (Yong and Lim, 2009) and dune modification and shoreline armouring (Lucrezi, Schlacher and Walker, 2009; Hubbard *et al.*, 2013). Such activities cause direct changes to the habitat, destroy the dune systems, change the natural physical characteristics of the beaches, eliminate food sources, and reduce habitats and shelter areas (Reyes-Martinez *et al.*, 2015).

In this study we found a strong negative correlation between the number of beach users and ghost crab density. Trampling as a result of beach users is known to cause the clogging of ghost crabs, the direct and indirect crushing of ghost crabs (Defeo *et al.*, 2009). In Ghana, most urban beaches are open to visitors with poor accessibility being the only major reason for the low usage of certain beaches such as the beaches classified as ‘low use’ in this study. Urban beaches are especially patronized during weekends and on national holidays. Large numbers of individuals patronize the area to engage in recreational activities. Field surveys for this study were carried out on early Sunday mornings; following recreational activities on urban beaches on Saturdays. The low densities of ghost crab burrows encountered at the high and medium use beaches may therefore be partly associated with the high levels of trampling that occurred in the previous day. Moreover, since burrows of ghost crabs need to be maintained daily and especially at night when they are most active (Wolcott, 1978), it is reasonable to assume that low records of burrows at the ‘high use’ beaches during early morning surveys following the previous day’s recreational activities directly corresponds to the actual densities of ghost crabs present on those beaches (Valero-Pacheco *et al*,. 2007). Similar observations have been made in other studies including Neves and Bemvenuti (2006) and Noriega *et al.* (2012).

The two species of ghost crabs found in Ghana are *Ocypode africana* and *Ocypode cursor*. The former is known to inhabit the supratidal zone and the latter both the intertidal and supratidal zones (Lucrezi and Schlacher, 2014). In all, the surveys found ghost crab burrows were located across the beach face, from the low tide line to the base of erosion scarp, shore armour or vegetation line on the beach. However, at the Castle and Philip Quaicoe beaches, there were no records of ghost crab burrows at sections with signs of intense trampling but not affected by tidal swash. Burrows were found to occur at other sections of the same beaches with signs of equally intense trampling, but influenced by tidal actions and also at sections not influenced by tides and had very low signs of trampling. It is likely that trampled areas not influenced by wave run-up are less suitable for ghost crab burrow construction since soils from those areas are less compact (less stability for burrow construction). It is also possible that the effect of trampling may be reduced by periodic wave run-up, which may increase the compactness of sediment and consequent stability of burrows.

Driving of all-terrain vehicles (ATV) was occasionally observed at the Castle beach. The use of these vehicles is likely to have contributed to some direct and indirect mortality of ghost crabs. The use of ATVs and other off-road four wheel vehicles have been identified in several studies to negatively affect the population of ghost crabs and other invertebrates in the intertidal area (Moss and McPhee, 2006; Schlacher and Morrison, 2008; Thompson and Schlacher, 2008). Ghost crabs may also be vulnerable to crushing whilst in their burrows by such four wheel drive vehicles (Hobbs *et al.,* 2008) even though such crab mortalities may be strongly dependent on burrow depth (Schlacher, Thompson and Price, 2007).

Similarly, ghost crab burrow densities were observed to be significantly low at the beaches that receive more frequent beach cleaning with brooms (Castle and Philip Quaicoe). These are done to make beaches more appealing to visitors. Beach sweeping to remove rubbish, natural debris and to improve the aesthetic appeal of the beach can cause disruption in the natural ecological process and modify beach ecosystems (Gheskiere *et al.,* 2005; Davenport and Davenport, 2006). At the study sites, beach cleaning took the form of litter picking and sweeping the shoreline and adjacent dunes. Similar beach cleaning activities were observed by Yong and Lim (2009) in their study of beaches in Singapore. They observed that while litter picking may not be damaging to the shore, sweeping can disturb the sand surface and cover up the ghost crab burrows, or destroy the sand piles made by the crabs. In addition, Yong and Lim (2009) observed that beach sweeping removes sea wrack and other marine debris that can serve as food sources for ghost crabs and other strandline species that in turn may be fed on by ghost crabs. Veloso *et al.* (2009) observed that beach cleaning not only directly compromise the survival of *Atlantorchestoidea brasiliensis* by reducing its population abundance, but also indirectly by removing the stranded material, which can be utilized by lower trophic levels. Along our study area, remnants of burnt rubbish and camp fires were occasionally encountered on urban beaches, also possibly contributing to mortalities to ghost crabs.

The effects of various aspect of beach and dune modifications on ghost crab populations have been studied, including nourishment and bulldozing (Peterson *et al.*, 2000), shoreline armouring (Barros, 2001; Lucrezi, Schlacher and Robinson, 2009; Aheto *et al.*, 2011) and urbanization (Xiang & Jingming, 2002; Souza *et al.,* 2008; Magalhaes *et al.,* 2009; Noriega *et al.,* 2012). Undertaking coastal urban projects, such as construction of beach front tourist facilities and residential infrastructure usually involves clearing or modification of dune vegetation. With time, most of such facilities become threatened by sea erosion needing additional engineering interventions such as nourishment, bulldozing and shoreline armouring (Nordstrom, 2000). Such coastal developments and interventions may directly affect the habitat size and range of ghost crabs which become trapped between coastal development on the terrestrial side and tidal actions on the other side.

Ghost crabs are known to construct their burrows with respect to the level of the drift line (Noriega *et al.,* 2012). On beaches with significant human modifications, such as shoreline armours and urbanized dunes, the flexibility of ghost crabs to migrate up and down the beach in response to changing tidal levels may become limited. Ghost crabs may only have the option of migrating across the beach face to find more suitable habitats (Lucrezi, Schlacher, and Walker, 2009). Seawalls, clearing of dune vegetation and construction on dunes may prevent access or limit the mobility of ghost crabs to food sources. At the Ola beach where part of the original dune vegetation had been cleared and a wooden beach front tourist facility installed, burrows were found up to about 18 m inland from the base of the erosion scarp. Here, ghost crabs were observed to inhabit very shallow burrows; such as a 3 cm burrow occupied by a crab with carapace width of about 1.10 cm at almost 7 m inland of the erosion scarp line. Ghost crabs in this area may however receive a trophic subsidy from food scraps left by visitors. Along several beaches of the Central Region where vegetation are intact, ghost crabs burrows have been found as far back as 40 m from the beach vegetation line and thus demonstrating the ability of ghost crabs to migrate up the beach vegetation in search of food. Other studies such as Jones and Morgan (2002) have also observed ghost crabs constructing burrows some distance of the actual beach, up to 200 m from the water's edge.

4.2 Beach management and ecology

Beach management programmes in many developing nations including Ghana have largely focused on protecting life and properties as well as enhancing the recreational and aesthetic value of the beaches for tourism. Such programmes have caused severe impacts on the biophysical environment of the beaches because less attention is given to the influence of human activities and the management programmes on beach organisms.

Management interventions to issues of human use of beaches, and regulation in Ghana have been reactive rather than strategic (Boateng, 2006). Most often beach management regulations seek to control commercial activities such as sand-mining, but regulation on recreational use is less strict. The limited control on the recreational use of beaches has led to the increasing amounts of ad hoc beach development and the provision of infrastructure for recreational purpose. The unregulated recreational use of beaches and "ad hoc" infrastructure development may cause 'unacceptable' changes to natural systems. This study has clearly shown that unregulated recreational use and management of beaches have negative effects on biodiversity of beaches.

There is the need to pursue direct ecological beach management policy and interventions to protect the ecosystems of recreational beaches. Direct management of the ecological resources of beaches is less prominent in developing countries such as Ghana. The authors recommend that coastal authorities should develop plans for recovery and protection of beach species and their habitat. The following direct beach ecological management programme is therefore suggested: protection of birds nesting grounds on beaches, creation of small pockets of sanctuary and habitats on recreational beaches to protect ghost crabs and other beach organisms, control the destruction of sand-dunes, and regulate human activities, particularly, the "ad hoc" recreational infrastructure development along the coast.

5. Conclusion

In this study, beaches and dunes with low human use and modification recorded significantly higher ghost crab densities and burrow sizes compared to beaches with medium to high human use. Since, physical and environmental parameters were similar across the sites, human impacts are the most likely cause of the observed differences in size and abundance of ghost crabs. In limiting the impacts of human use on beach biota in Ghana, coastal authorities should modify beach land use regulations to include limiting the modification of beach vegetation. A dune vegetation strip could be left intact along newly developing beaches to ensure a semblance of the natural beach-dune ecosystem interaction. Furthermore, major developments along the beaches could be limited to some distance behind the dune to ensure that future erosion and engineering interventions are minimized.

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