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

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## HIGHLIGHTS

- The study assessed the response of ghost crabs to human stressors.
- Beaches were categorized into high use, medium use and low use beaches.
- Burrow sizes and densities were significantly higher at the low use beaches.
- Several human uses are attributed to low crab numbers recorded on impacted beaches.
- There is the need to pursue direct ecological beach management policy in Ghana.

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## ABSTRACT

The increasing urbanization of much of the world's coasts threatens irreversible damages to beach ecosystems, if unchecked. Unfortunately, beach monitoring programmes for remediation actions are uncommon, especially for less developed nations where infrastructural development and socio-economic goals are regarded 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. The study tested a 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 intense trampling levels 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 is limited to a safe distance from the shoreline. There should also be consideration of natural vegetation barriers between development and the beach to enhance natural beach–dune ecosystem interaction.

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## 1. Introduction

Beaches and associated dunes serve as essential habitats 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 well sought after by people for recreational, tourism and residential purposes (Klein et al., 2004; Noriega et al., 2012). These multiple competing uses have contributed to the ever-increasing human pressure on beaches and dunes especially 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). It is confirmed that over 70% of the world's beaches are experiencing coastline retreat because of coastal erosion, largely due to human-

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induced impacts (Bird, 1985; Anthony, 2005). The competing multiplicity of demand for beach and dune resources has severely modified them around the world (Nordstrom, 2000; Coombes et al., 2008). Indeed, beaches are not just piles of sand; they support a wide range of biodiversity that play key ecological roles and hence require conservation and management.

All the world over, limited management interest have been traditionally directed towards ecological damage of 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 the 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 et al., 2009a,b). 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 resulting from human use of beaches and dunes.

Ghost crabs (Fam. Ocypodidae, Gen. *Ocypode*), are one of the most efficient biological indicators used to monitor human disturbances on sandy beaches (Barros, 2001; Lucrezi et al., 2009a,b; 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 et al., 2007), shore armouring (Barros, 2001; Aheto et al., 2011), beach nourishment and bulldozing (Peterson et al., 2000), tourism (Schlacher et al., 2011) and urbanization (Noriega et al., 2012). In these studies, ghost crabs densities were reported to be lower at human affected areas. Most coastal ecologists have accepted ghost crabs as useful biological indicators because they occur at both unvegetated beach and dunes (Noriega et al., 2012) and they are the top invertebrate predator living on beaches (Barrass, 1963; Schlacher et al., 2007). Changes in their density and population structure are also easy to estimate by counting and measuring the burrow openings (Barros, 2001; Schlacher et al., 2007) and indeed, they are widespread and abundant on tropical to warm-temperate beaches (Quijon et al., 2001; Noriega et al., 2012).

This paper uses ghost crabs as bio-indicators to estimate beach health conditions. This approach is often perceived by coastal authorities in developing countries as expensive due to the labour-intensive nature of estimating beach biodiversity. 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 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 purpose, with a combination of other human stressors leading to severe transformations of beach and dune systems. Beach ecological studies are particularly important in the context of sea level rise resulting from climate change and poor land use in coastal areas of the country (Adotey et al., in press). Other human pressures include urbanization in the active coastal strip, sand mining on 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 to conduct studies on these beaches to gauge the ecological change resulting from these multiple human use and stressors to inform beach management decisions at the municipal and national levels.

During the past 40 years, beaches near Cape Coast in the Central Region of Ghana have undergone significant changes due to increased human activities within the active coastal zone (Jonah, 2015; Adotey et al., in press). In recent years, there has been an increasing demand for coastal lands for tourism activities, with infrastructure constructed on land previously occupied by dune vegetation. Beach sand mining is also widely practised on most sandy beaches at varying scales, to feed the local construction industry (Mensah, 1997; Jonah et al., 2015a). 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 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 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. Study sites were selected based on field observations made by Jonah (2014) and preliminary field surveys carried out in October 2012. Six beach sites were selected based on level of human activities (Figs. 1 and 2). The selected sites were qualitatively classified as 'low use', 'medium use' and 'high use' based on 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 were 1 km apart, 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).

### 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, some physical environmental parameters that affect ghost crabs distribution were measured. Surveys were done at approximately the same tidal period using standard tide tables from the Ghana Ports and Harbours Authority (GHAPOHA, 2013). During each survey period, all surveys took place 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 et al., 2009b; Moss and McPhee, 2006).

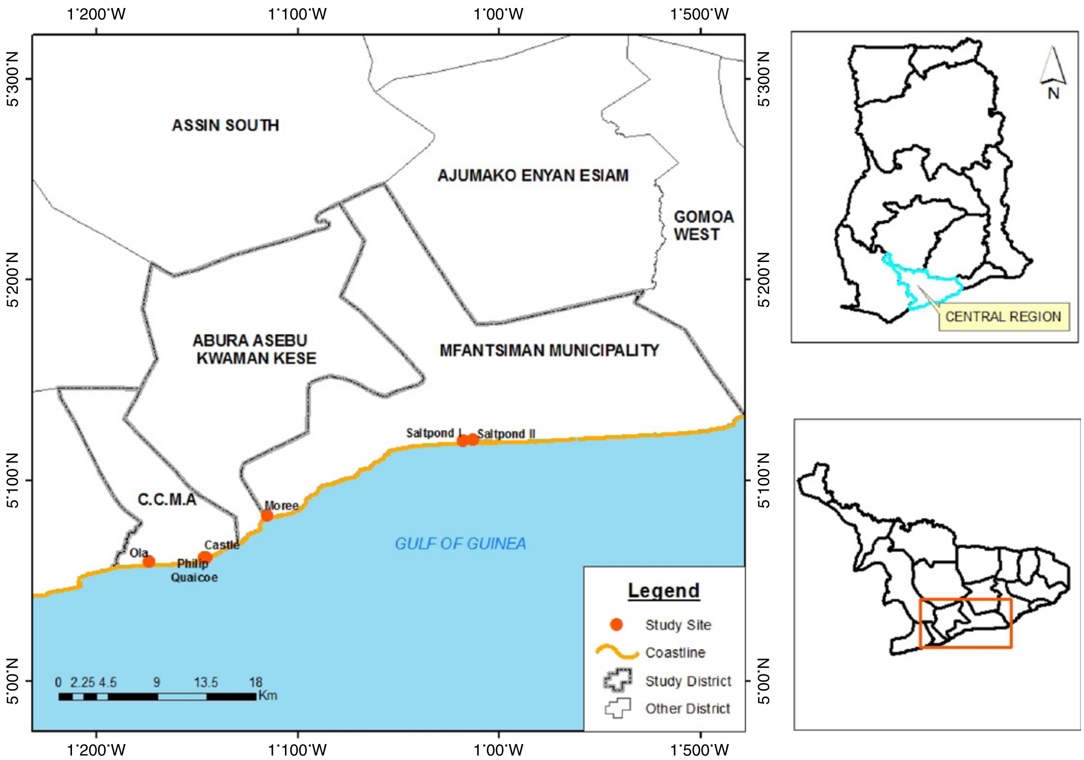


**Fig. 1.** Map showing surveyed beaches in the Central Region of Ghana.

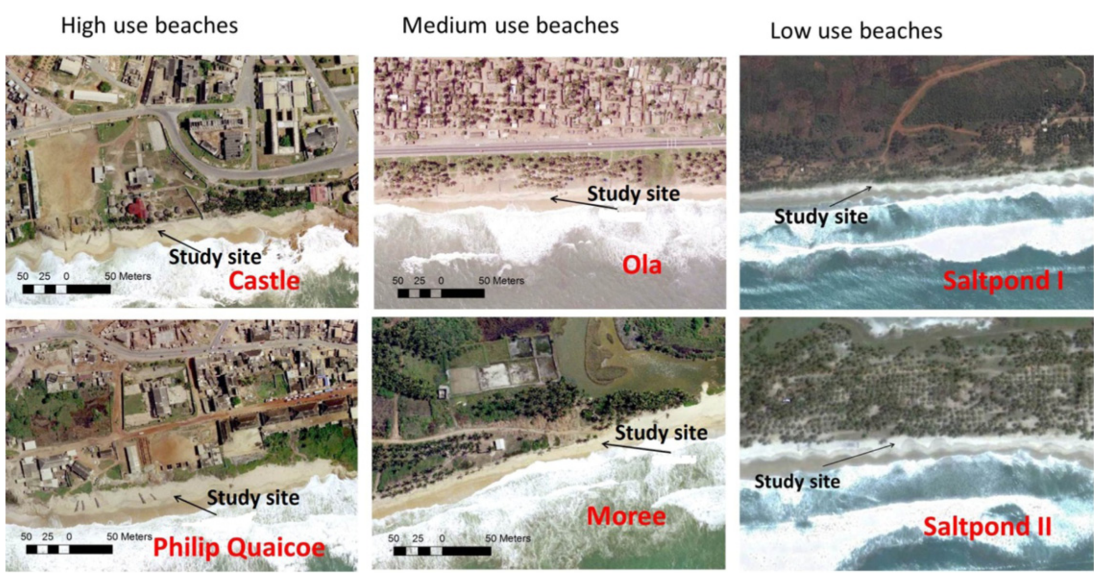


**Fig. 2.** Aerial photographs of surveyed beaches in the Central Region of Ghana.

Estimates of the population density of ghost crabs were achieved by counting the number of burrow openings occurring within 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). Burrows need to be maintained daily or they collapse, thus it is reasonable to assume that the presence of a burrow corresponds to the presence of a ghost crab (Valero-Pacheco et al., 2007; Noriega et al., 2012) and therefore useful in estimating the number of crabs present on particular beaches. Preliminary surveys identified that the intertidal zone of all the surveyed beaches varied between 17 and 31 m, depending on tidal conditions, with about 20–25 m of the beach berm inhabited by ghost crabs on the individual beaches. On each beach, five replicate samples were taken along three line transects oriented perpendicular to the direction of the shoreline at 50 m intervals. Surveys on each transect was initiated by casting quadrats at 1–2 m above the low water mark line. On each transect, five different sampling using quadrats of 1 $m^2$ dimension was done at 4.5 m line interval. Burrow diameters were also measured using a vernier calliper within quadrats to estimate sizes (carapace length) of crabs. This methodology 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 within all quadrats were taken during three surveys.

Additional data on physical environmental conditions including sediment and air temperatures were taken and analysed as key environmental and habitat metric of the beaches. Sediment

**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 | 5° 12′ 2.77″N | 5° 12′ 4.20″N |
| Longitude | 1° 14′ 34.08″W | 1° 14′ 37.97″W | 1° 17′ 23.81″W | 1° 11′ 30.66″W | 1° 1′ 46.75″W | 1° 1′ 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 min ($n = 8$) | 79.38 | 28.38 | 10.38 | 26.25 | 1.5 | 0.75 |

samplings were done using sediment corers (15 mm diameter, 300 mm deep) to collect samples to a depth of 200 mm from the five quadrats. Five replicate sediment cores were taken within each quadrat and analysed 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 analysed 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 (4750, 2000, 1000, 710, 600, 425, 300, 200, 75 μm). The heights of beach scarps were also measured once during the study at 20 m intervals 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 et al., 2002). Sand and air temperatures were taken at all the beaches during each survey using a mercury thermometer. Sediment temperature were taken at a depth of 200 mm. Wave period for each beach was also determined by counting the number of waves breaking in the surf zone during a 3-min period. In addition to these, the number of beach users was recorded over 30 min time interval, on each Saturday afternoon before Sunday morning ghost crab surveys and used as a proxy to human trampling. This procedure was achieved with the assistance of enumerators placed concurrently on each beach.

### 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 and 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 periodicity was relatively constant at all sites with values ranging from 5.1 to 5.3/min. All six surveyed beaches had 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 25° to 39 °C 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 24° to 33 °C. 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. Sediment grain sizes did not vary significantly among the six beaches (ANOVA, $p > 0.01$).

Data pooled for all sites showed no correlation between sediment grain size and ghost crab burrow density (Spearman's $\rho,\ r = -0.741,\ p = 0.092$). Erosion scarp height was found not to have an effect on burrow density at all sites (Spearman's $\rho,\ r = -0.429,\ p = 0.397$). The number of beach users varied significantly amongst the categories of beaches (ANOVA, $F_{5,42} = 16.65,\ p < 0.0001$).

### 3.2. Burrow density and size variation

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

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 occurred at Saltpond II ($56.53 \pm 13.01$ burrow $m^{-2}$, mean ± S.E) in February, whereas the lowest monthly abundance was recorded in Moree ($7.56 \pm 2.48$ burrow $m^{-2}$, mean ± S.E) also in February (Fig. 4).

Mean diameters of burrows differed significantly among sites (ANOVA, Table 4). Mean ghost crab burrow diameters were also significantly higher at the low-used beaches compared to mean

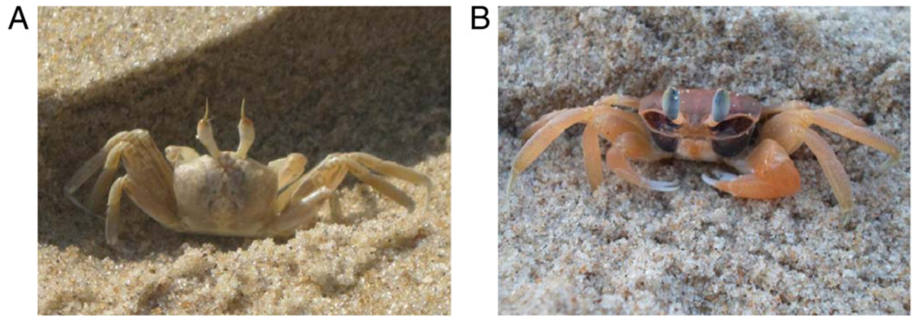


**Fig. 3.** Ghost crab species found in Ghana: (A) *O. cursor* and (B) *O. africana*. (Photos by F.E. Jonah.)

**Table 2**
Summary of mean burrow densities and mean burrow diameters at six 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) |

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

| ANOVA table | *df* | *MS* | *F* | *P* | *Fcrit* |
|---|---|---|---|---|---|
| Treatment (between sites) | 5 | 18 830 | 12.81 | <0.0001 | 3.04 |
| Residual (within sites) | 714 | 1 470 | | | |
| Total | 719 | | | | |

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

| ANOVA table | *df* | *MS* | *F* | *P* | *Fcrit* |
|---|---|---|---|---|---|
| Treatment (between sites) | 5 | 1646 | 11.02 | <0.0001 | 3.15 |
| Residual (within sites) | 264 | 149.3 | | | |
| Total | 269 | | | | |

burrow diameters recorded at both the medium-used and high-used beaches (Bonferroni, $p < 0.0001$). However, no significant differences were observed between the means of burrow diameters at the medium-used and low-used beaches (Bonferroni, $p > 0.05$).

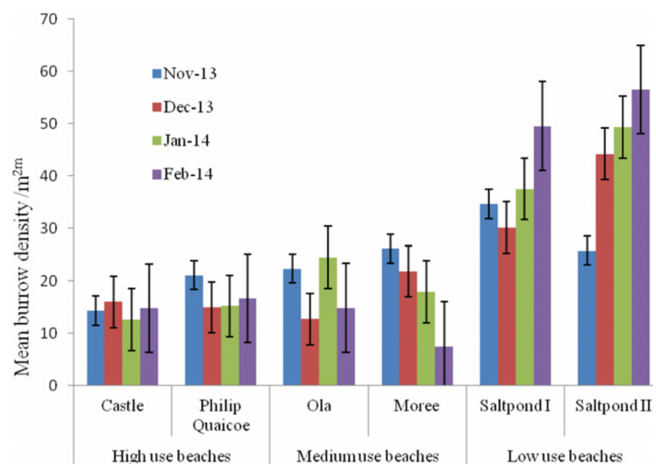


**Fig. 4.** Temporal variation (mean ± S.E) in ghost crab burrow densities recorded at the six study beaches in the Central Region of Ghana.

## 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 activity on sandy beaches at selected sites in the Central Region of Ghana as a case study. Ghost crab burrow density and sizes were used as the main indicating factor coupled with other relevant physical environmental conditions. Three different categories of beaches were investigated: high-used, medium-used and low-used, based on the intensity of identified human activities. Results showed that ghost crab burrow densities at the low-used beaches were twice or more times higher than those recorded at the medium-used and high-used beaches. Similar patterns were observed in the mean burrow diameters, where mean diameters recorded at the low-used beaches were almost twice or more the diameters recorded at the medium-used and high-used 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.

Along this study area, human modifications of beaches have been carried out by residents (for residential facilities), investors (for tourism activities) and the municipal authorities (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 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-Martínez 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 et al., 2009b; 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-Martínez et al., 2015).

In this study, we found a strong negative correlation between the number of beach users and ghost crab density. Trampling resulting from beach users is known to cause the clogging of ghost crabs burrows, the direct and indirect crushing of ghost crabs (Defeo et al., 2009). In Ghana, most urban beaches are open to visitors. However, poor accessibility is a major reason for the low usage of certain beaches such as the beaches classified as 'low use' in this study. Urban beach patronage is especially high 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 used beaches may therefore be partly associated with the high levels of trampling that occurred on the preceding day. Burrows of ghost crabs need to be maintained daily and especially at night when they are most active (Wolcott, 1978). Hence, 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 et al., 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 of 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 remove the stranded material, which can be utilized by lower trophic levels.

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 et al., 2009a; Aheto et al., 2011) and urbanization (Xiang and Jingming, 2002; Souza et al., 2008; Magalhaes et al., 2009; Noriega et al., 2012). Undertaking coastal urban projects, such as construction of beachfront 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 et al., 2009b). 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 beachfront 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 property as well as enhancing the recreational and aesthetic value of the beaches for tourism, with little or no attention given to beach living organisms such as the ghost crabs. Such programmes have caused severe impacts on the factors that support the survival of many living organisms that use the beach environment as habitat, nesting or spawning grounds in both developed and developing countries (Nordstrom, 2005; Cartwright, 2014). This could lead to a possible loss of coastal and marine organisms that depend on the beach either as habitat or as spawning grounds (e.g. ghost crabs and sea turtles). There is the need therefore, to reduce the negative effects of human activities and the impacts of beach management programmes on beach living 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 ad hoc beach development and siting of unapproved infrastructure for recreational purpose. The unregulated recreational use of beaches and "ad hoc" infrastructure development may cause 'unacceptable' changes to natural systems and thus influencing negatively on ghost crabs and other living organisms on the beach.

Apart from scavenging scraps and dead organisms on the beach, ghost crabs contribute significantly to the ecological functioning of the beach. Schlacher et al. (2011) identified a strong correlation between higher ghost crab abundance at sites with higher vegetation. It is assumed that the ghost crabs borrows facilitate soil aeration and percolation and thus enhance the growth of vegetation. Therefore, the reduction in ghost crab population may affect beach vegetation. Vegetation is an important habitat component for ghost crabs for reasons such as; plants provide more shade, which protect the ghost crab from harsh physical conditions caused by high temperature and high evaporation rates, and taller vegetation may provide better camouflage from predators such as birds and foxes. Furthermore, leaf litter from plants influences the abundance and distribution of invertebrates in coastal dunes.

There is the need to pursue direct ecological beach management policies 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 habitats. The following direct beach ecological management programmes 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. The size of a beach sanctuary will depend on the beach size and the conservation needs. However, we assume that a minimum of 100 m to a maximum of 1 km of undisturbed beach and adjoining backshore maintained at various locations along the shoreline depending on conservation needs can be useful. In addition, there is the need to control the destruction of sand dunes and regulate human activities, particularly, sand mining and other 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 activities are the most likely cause of the observed differences in burrow size and abundance of ghost crabs. Continued unregulated anthropogenic use of beaches in Ghana may lead to increased negative effects on habitat conditions; compromising the survival of beach fauna and resulting in wider implications for local marine and coastal resources conservation.

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