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HUMAN TRAMPLING EFFECT ON BENTHIC FAUNA OF SANDY BEACHES WITH DIFFERENT INTENSITIES OF USE IN RIO DE JANEIRO, BRAZIL

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Abstract: About 75% of the world's shoreline is composed of beach environments. Among them, the sandy beach is a familiar environment and used for tourism and recreation. The organisms that live in these environments, as polychaetes, crustaceans and mollusks, are almost unknown by people because they live buried. Thus, many time people could cause damage to these organisms without their own knowledge. Trampling is one of the human-induced impacts to those organisms, destroying their bodies or even dispelling them. Focused on this behavior, this research aims to simulate trampling on two sandy beaches and to observe a real scenario of recreation on weekends and during the week during summer and winter seasons in the Rio de Janeiro state, Brazil. This study verified the changes occurring mainly in the faunal density of these two beaches with different intensities of use, in the predefined situations. Samples were collected during four months, on the second half of year, using simulated treatments and in another two months simple observation of the behavior of tourists was also performed. The simulated treatments did not cause significant changes in any collection except two. One of them was possibly a sampling artifact, which may be due to a low level of impact. The samples on the winter months also did not show significant changes, but the summer samples showed a large decrease in density of organisms during the weekend compared to during the week, probably related to the high intensity of human activity. As this study aimed to verify changes or impacts in organisms at up to 20 cm of depth, we concluded that only high impact activities could affect drastically the faunal density, as observed during the summer season at weekends on the study.

Keywords: Brazilian southeast; polychaetes; restricted beach; seasonality; unrestricted beach.

INTRODUCTION

According with a world's trend, more than a quarter of the Brazilian population (about 50 million of habitants) live in coastal areas (IBGE 2011). Furthermore, less than 10% of residencies are seasonal or for vacancy, indicating a casual use. The conditions and use of beaches for recreational purposes are based on both, geomorphologic features (*i.e.*, declivity, wave strength, tide pool formations) and infrastructure (*i.e.*, bathroom facilities, public transport or presence of kiosks) (Silva *et al.* 2009). Particularly, sandy beaches are characterized for being a sandy sediment zone localized between the intertidal zone and the coastal vegetation (Garrison 2007). The water dynamic and the wind action applied to this zone provide the redistribution and deposition of sediment grains (Wright & Short 1984, Defeo *et al.* 2009).

The organisms living in the sandy beaches needs an ideal set of features, mainly related to salinity, grain size, declivity, tidal action, precipitation, tidal period, and winds (Cardoso & Veloso 1997, Veloso & Cardoso 2001). There is a classification scheme grouping sandy beaches into three categories: dissipative, intermediate and reflective (Wright & Short 1984). The first (*i.e.*, dissipative) is a less energy beach carrying a fine sandy and with weak hydrodynamics, the opposite to the other extreme (reflective), with high hydrodynamics and generally a coarser grained beach (Wright & Short 1984). The beach characteristics change with time in response to climatic changes, wave height, or even climatic events, like sea surfs (Defeo & Mclachlan 2005). Many biological indices, as species richness and abundance, or abiotic parameters, as dissolved carbon or sediment grain size, varies from reflective to dissipative beaches (Defeo & Mclachlan 2005). These indices affect the organisms and their adaptation to the environment and they could be more or less dependent of these variables (Defeo & Mclachlan 2005). In this way, we can classify them in generalists or specialists. Generalist organisms would live in environments with the most variable conditions (*e.g.*, community compositions, beach slope, salinity, exposure), while the specialist ones need a complex arrange of characteristics of environment, being restricted to places where it could find these requirements (Cardoso *et al.* 2011). In reflective beaches, the hydrodynamics and all the tough conditions leads to a selection of organisms, and in this case, we could find that crustaceans are usually dominants by being generalists (Cardoso *et al.* 2011). In other way, mollusks and polychaetes need some specific conditions due to their soft body, burrow habit and they are found in greater abundance in sheltered beaches, usually dissipative (Cardoso *et al.* 2011).

In reflective beaches from the Rio de Janeiro state, Brazil, that have sediment grains coarser, some of the common macrobenthic species resist to great wave impact, such as the decapods *Emerita brasiliensis* Schmitt 1935 and *Ocypode quadrata* (Fabricius 1787), the mollusks *Donax hanleyanus* Philippi 1847 and *Tivela mactroides* (Born 1778), and also the polychaetes *Pisionidens indica* (Aiyar & Alikunhi 1940) and *Hemipodia californiensis* (Hartman 1938) (Cardoso & Veloso 1997). On the other hand, dissipative beaches have sediment grains finer, allowing tube formation for marine worms and gallery construction for crustaceans and mollusks. These characteristics are essential for polychaetes as *Scolelepis squamata* (O. F. Müller 1806) and *Thoracophelia furcifera* Ehlers 1897, bivalves as *Donax gemmula* Morrison 1971, *D. hanleyanus*, the gastropods *Impages cinerea* (Born 1778) and *Terebra imitatrix* Aufennberg & Lee 1988, and some crustaceans as *Tholozodium rhombofrontalis* (Giambiagi 1922), *Excirolana armata* (Dana 1853) (Isopoda), *Arenaeus cribrarius* (Lamarck 1818) and *Sergio mirim* (Rodrigues 1966) (Decapoda) (Cardoso & Veloso 1997).

Schlacher (2007) verified that the number of burrows made by ghost crabs (*Ocypode* sp.) could be a good proxy for human impacts because the high-impact activities made by off-road vehicles decreased significantly the number of ghost crab burrows. Besides smashing the organisms, these vehicles lead, many times, to an excessive upkeep of burrows, forcing the animals to leave the protection during the day, becoming more susceptible to predators (Schlacher 2007). Lucrezi *et al.* (2009) has simulated footsteps on burrows, but studying only ghost crabs, their burrows size and number, aiming to check impacts on this fauna. Blankensteyn (2013) has analyzed human impact in beaches of Santa Catarina state, South of Brazil, comparing a set of them, based on urban infrastructure. Some beaches have two sectors analyzed, next to the urban core and another far from it. It noticed that, though the abundance of benthic macrofauna has increased in some beaches with high infrastructure due to the human activity, many people still leave food remains in the beach (Blankensteyn 2013). In another beach with high impact of vehicles, the total absence of organisms was registered (Blankensteyn 2013). Among the studies on the human trampling, those about simulated and controlled situations conducted by Moffett *et al.* (1998) in Eastern Cape, South Africa, verified that under natural conditions the intensity of trampling needs to be very high (about 500 footfalls) to generate some harm. In Brazil, Veloso *et al.* (2006) performed an experiment comparing high urbanized beaches with lesser urbanized ones in the Rio de Janeiro state, where the beaches were classified into two distinct seasons (summer and winter). In that study it was possible to verify a drastic change in abundance of some crustacean species, such as *Atlantorchestoidea brasiliensis* (Dana 1853), which was completely absent in the highly urbanized beach sampled (Cardoso *et al.* 2016). Machado *et al.* (2017) performed a very similar study about human trampling comparing two beaches in the Rio de Janeiro state, one highly urbanized and another non-urbanized. They verified that there is an impact only in the highly urbanized sectors, mainly in soft body organisms such as Nemertea and the polychaete *H. californiensis*, an abundant species in that region (Machado *et al.* 2017).

Although many other studies have searched the effects of vehicle trampling (*e.g.*, Schlacher 2007) or people stepfoots (*e.g.*, Lucrezi *et al.* 2009) on the benthic macrofauna, they have used different methods, like simulate a volleyball game or counting burrows and their diameter. The method used in the present study, i.e. the march over the sand column, have not been found in another study, thus it is a new approach. The present study aimed to compare the composition and density of the benthic macrofauna in two reflective sandy beaches in the Rio de Janeiro state, one of them with restricted access and another one with free access, both under effects of a simulated trample treatment and the differences between weekend or week days, in addition to the differences on two temporal situations, named here as summer and winter.

MATERIAL AND METHODS

Study area

The study area was composed of two sandy beaches located in the Rio de Janeiro state, Brazil, one of unrestricted use and another one that is a fort of exclusive use of the Navy. Urca Beach (22°56'51.9" S; 43°09'47.7" W) has almost 100 m of extension, and was considered here as the unrestricted beach (UB), because of the unlimited access to anyone. This beach receives great amounts of people during the summer months and vacations. In addition, it has been affected by the Guanabara Bay, that does not receive proper water treatment (INEA 2012). Fora Beach (22º56'40.5" S; 43º09'21.0" W) is in the same bay, being localized in the open sea side, and used as a restricted beach (RB), because of its limited access, which allows access only to military people and their relatives. These two geomorphologically similar beaches are in a close proximity but having different patterns of use gave us an opportunity to observe the effects of trample in the different taxa found.

Sampling of benthic fauna

The samples were collected using a cylindrical sampler "Corer" type, with 10 cm in diameter and 20 cm in height. It was designed a transect parallel to the water for both beach, with three strata. Each stratum had three replicates (yielding nine replicates per transect) and they were located 3 m apart from each other. For the simulated treatment, two subsample categories were created: Trampled (Tr) and without trample (Wt). Each treatment was applied in a transect with the same design previously explained, but each transect was distanced 9 m away from each other, in the same beach. The samples for the seasonal study (summer and winter) did not receive a simulated treatment, being sampled after a simple observation, with footfall count, in a half hour period. The area for this study was the same previously mentioned. In this way, we aimed to observe the behavior patterns of the benthic community in a normal situation in both seasons designated here.

The collected samples were preserved in 4% formalin and stored in the Zoology Laboratory of Rio de Janeiro State University (UERJ). They were washed through sieves with 1 and 0.5 mm openings. All retained organisms were identified to the lowest possible taxonomic level.

Experimental Design (Winter x Summer)

An area of 2 x 6 m parallel to the water line was designated for both beaches (*i.e.*, Urca Beach - UB and Fora Beach - RB). The number of people transiting in this area was counted during 30 min. When this time was up, the sediment samples were collected (Figure 1). This procedure was made during the weekends (one day in each season) and week days (one day in each season) for Urca Beach and Fora Beach.

Experimental Design (Trampled vs. Without Trample)

Two sectors were determined on each beach, one without the trample treatment (Wt) and another

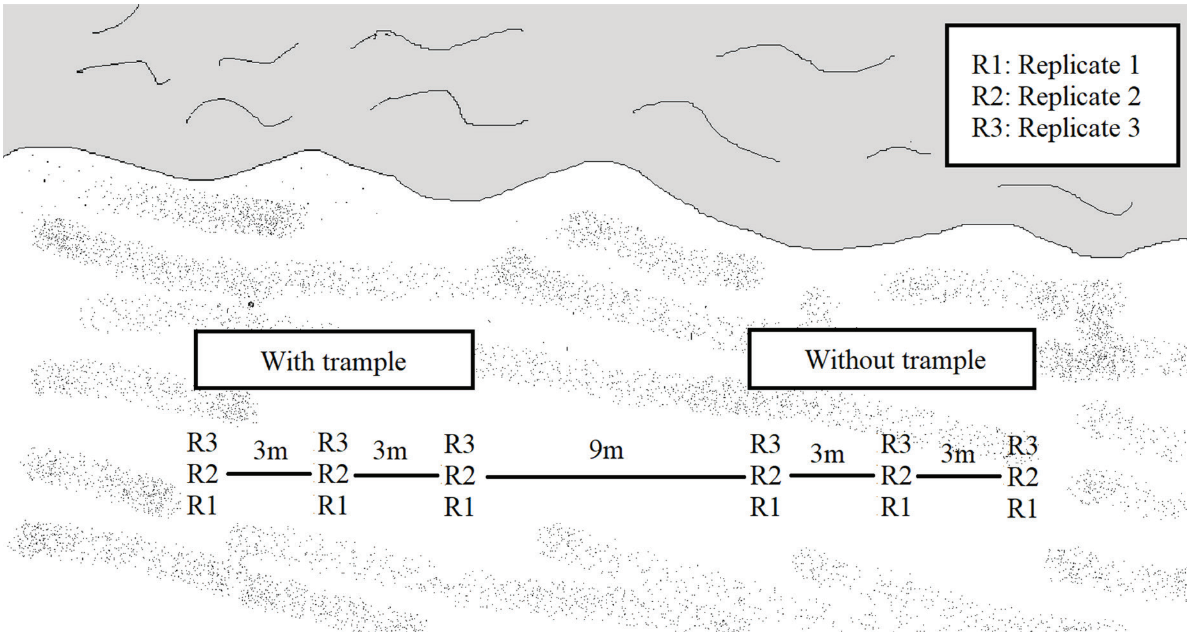

Figure 1. Sampling design organized by treatments: With Trample (Tr) and Without Trample (Wt).

with human trample (Tr). On the first one, the samples were collected and treated as previously described. On the second one (Tr), the demarked area was trampled by three people with 65-85 Kg, during 30 min. The march rhythm simulated a normal walk, next to the water line. This way, we aimed to verify if the tourists walking across the beach could have negative effects on the presence, abundance and diversity of the benthic fauna. After 30 min, the sediment samples were collected equally for both treatments.

The simulated treatment was applied on two sectors of 2 x 6 m each one, apart 9 m and both parallel to the water line (Figure 1). The main difference in relation to the seasonal experiment was that we used two areas instead of one when compared to the previous session. In each sector, it was demarked three points with three replicates, totalizing nine replicates (Figure 1). The samplings in both beaches were made bimonthly between June and December 2012 (winter = June and August; summer = October and December).

Statistical Analyses

As the main objective was to detect if there is any change in the benthic fauna abundance as we simulated an impact by human trampling, the methodology aimed to count the fauna in different treatments. Treatments were compared using Generalized Linear Models (GLM), with Poisson Distribution. This choice was based on the non-metric data obtained from the organisms count, that could not allow us to use a t-test analysis. The GLM was an alternative test to compare groups without a normal distribution, without the need of a non-parametric analyze, which substitute the real results by ranks. Thus, we used GLM to compare (1) the counts between the "trampled" and "without trample" groups, in the four studied months, as (2) the seasonal tests "during the week" against "weekend" at "summer" and "winter" seasons. Both analyses were performed in full models (with all interactions). Best models were selected using AICc criteria. Analyzes were performed in the software R 3.5.0, with packages "lattice" for plot graphics and "MuMIn" for model selection.

RESULTS

A total of 180 samples and 8,229 organisms were collected belonging to Polychaeta (82%), Crustacea (1%), Turbellaria (1%) and Nematoda (16%) (Figure 2). Polychaetes were composed primarily by Saccocirridae family, with 6,622 individuals (81.15%) belonging to the species *Saccocirrus pussicus*, followed by the Capitellidae family, with 62 individuals (*Capitella jonesi*; 0.76%), Syllidae family, with only 16 individuals and one individual of Spionidae family (*Scolelepis chilensis*). Nematodes were present in higher abundances at Urca Beach (1,015 ind.) and were less abundant at Fora Beach (317 ind.). Some taxa were present only in one of the two beaches (Tables 1 and 2). Among the crustaceans, there was a predominance of amphipods (79 ind.) at Urca Beach, only two individuals of isopods, and the decapod *Emerita brasiliensis* (18 ind.) and two others isopods were collected at Fora Beach. Platyhelminthes were represented by turbellarians, with only 29 individuals at Urca Beach (0.36%). Nematodes, amphipods and turbellarians were not identified to the species level as well as the nemerteans with only four individuals collected.

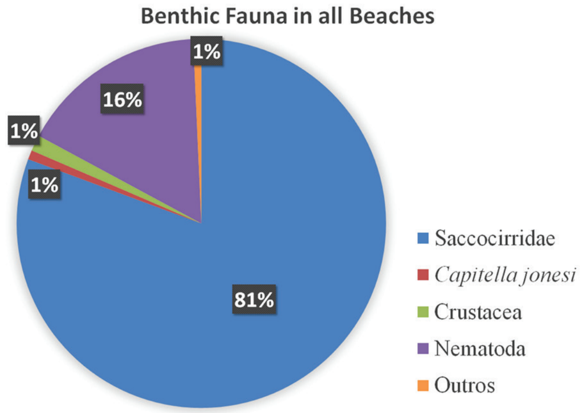

Figure 2. Percentage contribution of the benthic fauna found at Urca and Fora beaches in all treatments (Rio de Janeiro, Brazil).

Table 1. Total of individuals collected at Fora Beach and Urca Beach With trample (Tr) and Without Trample (Wt), Rio de Janeiro, 2012.

	June				August				October				December			
	Urca		Fora		Urca		Fora		Urca		Fora		Urca		Fora	
Treatment	Wt	Tr	Wt	Tr	Wt	Tr	Wt	Tr	Wt	Tr	Wt	Tr	Wt	Tr	Wt	Tr
POLYCHAETA																
Capitella jonesi	1	2	0	0	8	8	0	0	2	1	2	2	0	0	2	1
Opheliidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Syllidae n.id.	0	0	0	0	0	3	0	0	1	0	0	0	4	5	0	0
Saccocirrus pussicus	0	0	0	0	208	307	0	0	1454	3302	1	1	165	28	0	0
CRUSTACEA																
Amphipoda n.id.	1	12	2	0	11	0	0	0	0	18	0	0	1	1	0	0
TURBELLARIA n.id.	0	0	4	3	0	0	0	2	0	0	4	5	0	1	0	0
NEMATODA n.id.	52	167	41	31	35	42	5	7	41	29	12	15	74	64	72	22

Table 2. Total of individuals collected at Fora Beach and Urca Beach during Week days (DW) and on Weekend (WE), Rio de Janeiro, 2012.

	Winter				Summer			
	Urca		Fora		Urca		Fora	
Treatment	DW	WE	DW	WE	DW	WE	DW	WE
POLYCHAETA								
Syllidae n.id.	2	0	0	0	0	1	0	0
Saccocirrus pussicus	546	0	0	0	593	17	0	0
CRUSTACEA								
Amphipoda n.id.	0	24	0	0	0	11	0	0
Emerita brasiliensis (Decapoda)	0	0	4	0	0	0	0	1
Macrochiridothea sp. (Isopoda)	0	0	1	1	2	0	0	0
TURBELLARIA n.id.	0	0	1	5	0	0	0	4
NEMATODA	130	289	13	42	15	77	22	35

Winter vs. Summer

The mean density of organisms was higher at Urca Beach, in all study periods, compared to Fora Beach (Table 3). The GLMs comparing the two sampling periods "during the week" and "weekend" showed significant differences (p < 0,0001) in the Urca Beach and in the Fora Beach during both sampling periods. The model using all the variables was the best fitted. The mean density was lower in the weekend than the week days (Table 4; Figure 3). The highest number of people passing by the study area was 437 during the weekend in the summer, followed by 54 in Urca Beach during weekend at winter. All other values were lesser than 12 people passing by in each one of the beaches (Table 5).

It was observed some variations in the mean density of the benthic fauna in both beaches. The changes could be seen during weekends and week, summer or winter (Table 6). In general, the density value was higher at Urca Beach when compared to Fora Beach as mentioned before. At Urca Beach, the top value was during week days, whereas at Fora Beach, during the weekend. In relation to the values of richness, it was noticed that the values decreased during the weekend, compared to week days on the samples collected during the winter, with the opposite observed during the summer (Table 7).

Trampled (Tr) vs. Without trample (Wt)

In every month, 18 sampling spots were done, nine in Tr condition and nine in Wt. Among the nine samples collected in October 2012 (Tr) at Urca Beach, one had four times more organisms, contrasting with the other data obtained, reflecting in the median value (Table 3). We decided for the exclusion of this sample to calculate the mean values. Therefore, the mean value was close to the results of the treatment without trampling (Wt). There were significant statistical differences in both beaches (P>0,001), with decrease in means from without trample to trampled samples (Figure 4). The best fitted model, again, uses all the variables, although we didn't mean to analyze "month" differences (Table 8). The richness variations were observed to be low in both treatments (Table 9).

Table 3. Mean density of benthic fauna during June to December/2012 at Fora and Urca Beaches (Wt: Without trample; Tr: With trample).

	Fora Beach		Urca Beach	
Month	Wt	Tr	Wt	Tr
June	10.8	7.4	10.8	34.2
August	1.2	1.8	52.4	72
October	4.2	5.3	299	670
December	15	4.6	48.8	24.2

DISCUSSION

The high abundance of meiofaunal organisms was expected, mainly on Polychaeta and Nematoda. Although we have used a 0.5 mm sieve, these organisms are very representative of sandy beaches and well adapted to the abiotic variations in the environment (Gheskiere *et al.* 2005). The polychaete *Saccocirrus pussicus* and the nematodes were found in high densities at Urca Beach, in August and October 2012. These organisms are frequently associated to reflective beaches, which present a median grain size, such as that found in the Urca Beach. *Saccocirrus pussicus* prefers zones of higher hydrodynamism, which could be a factor that changes the density of this species (Di Domenico *et al.* 2014). Even without analyzing dissolved carbon values, a study about the conditions of recreative use, showed that the Urca Beach has no proper conditions to it (INEA 2012). At about 10 days in October/2012 and almost for the entire month of December/2012 there were unique periods that this beach showed good condition of balneability for recreative use. In these same months, mainly in October, the densities of *S. pussicus* were very high. Others polychaetes, such as Capitellidae and Syllidae, showed a lower presence, as well as the nemerteans.

Table 4. General Linear Model Parameters Fit Data (Winter and Summer).

(Int)	Beach (B)	Station (S)	Treatment (T)	B:S	B:T	S:T	B:S:T	df	AICc	Delta	Weight
128 / -0.40550	+	+	+	+	+	+	+	16	9317.2	0.00	0.929
64 / 0.04913	+	+	+	+	+	+		13	9322.4	5.15	0.071

In sandy beaches with low diversity of polychaetes, the occurrence of bioindicator species could be an alert to organic matter enrichment (Rizzo & Amaral 2001, Omena *et al.* 2012). As the abiotic features were not analyzed here, we are cautious to determine the reasons of the dominance of Saccocirridae and Nematoda. Nematodes are also responsive to organic enrichment, being the base of trophic webs, normally replaced by k-strategist species in balanced ecosystems (Omena *et al.* 2012).

From July to December 2012 at Fora Beach, we found a drastic decrease in abundance of Saccocirridae and Nematoda, compared to June. The total absence of *Saccocirrus* in the beach could be related to the hydrodynamic features, as previously mentioned. The coarse sediments and high energy of waves seems to provide the best conditions to the occurrence of *Saccocirrus*. On the other hand, a drastic change in the dynamic could cause its absence (Di Domenico *et al.* 2014).

The species richness in the simulated experiment (Trampled x Without Trample) almost did not varied. Differences in richness appear only in December with one new taxon (Turbellaria). This could have happened because of the number of samples that could be underrepresenting the diversity of the environment in that area. *Emerita brasiliensis*, for example, is a species that tends to increase their occurrence from reflective to dissipative beaches next to swash zone (Defeo & Cardoso 2004). Spatial migration in a sandy beach could happen due to food distribution and temperature changes (Defeo & McLachlan 2005, Cardoso *et al.* 2016). Even in the winter samples, there was a low variation on richness for both beaches. In summer months there was a higher variation in species richness at Fora Beach, that presents a greater extension than the Urca beach. The occurrence of *E. brasiliensis* at Fora Beach and its absence at Urca Beach could be related to sensibility to disturbances as intense and frequent presence of people at Urca Beach, confirming the trend to a low density of this species in a high-impact beach by human use (Veloso *et al.* 2006). Thus, in the Fora Beach we found meiofaunal organisms, as Nematoda, but in lower densities compared to Urca Beach (24% as opposed to 76% of the total organisms, respectively).

Emerita brasiliensis is a decapod (family Hippidae) that occurs in South America in both

Table 5. People passing by amostral area, Urca Beach and Fora Beach. Rio de Janeiro, 2012 (DW: During the Week; WE: Weekend).

	Urca Beach		Fora Beach	
	DW	WE	DW	WE
Winter	8	54	12	0
Summer	0	437	0	10

Table 6. Mean density of benthic fauna during Winter and Summer/2012 at Urca and Fora beaches (DW: During the Week; WE: Weekend).

	Urca Beach		Fora Beach	
	DW	WE	DW	WE
Winter	143	70.2	4	10.7
Summer	122.6	21.8	4.6	8.2

Table 7. Richness of benthic fauna at Urca and Fora beaches, in the samples during Winter and Summer/2012 (DW: During the Week; WE: Weekend).

	Urca Beach		Fora Beach	
	DW	WE	DW	WE
Winter	5	4	4	3
Summer	3	4	1	3

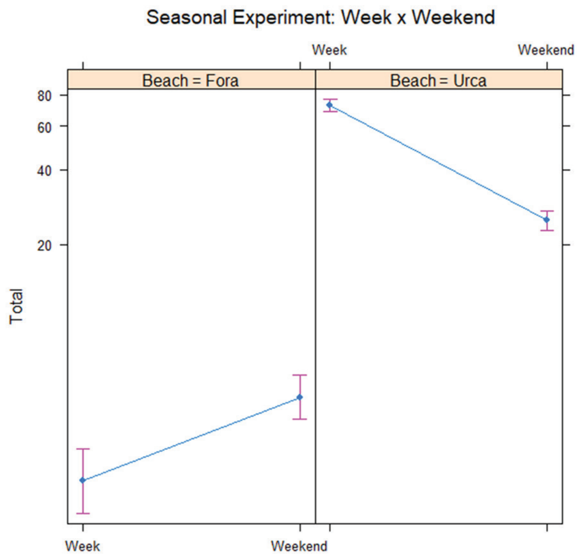

Figure 3. Mean differences between Week x Weekend seasonal treatment in Urca and Fora beaches (Rio de Janeiro, Brazil).

dissipative and reflective beaches, but this species is more frequent in the last type (Defeo *et al.* 2001). This species is used as bait to fishery and for human consumption, and is considered an excellent bioindicator as it does not tolerate pollution or even areas with high human density (Defeo *et al.* 2001). In the Rio de Janeiro state beaches, it is common to see gatherers collecting these organisms (personal observation). In the studied areas in the present work, local residents relate that the number of individuals of *E. brasiliensis* is decreasing in the last decades. It is known that slope and its dynamics could change diversity of fauna, but not interfering in the abundance of populations, which could be the case of *E. brasiliensis* (Veloso *et al.* 2003). In beaches from Uruguay, during the months of March and April, this species showed the highest abundances (Defeo *et al.* 2001). In the present study, higher abundances of this species were observed in all months, being higher in October, 2012. No samples were collected in the first months of the year and, although this had not been the aim of this study, it is not possible to affirm if there was some fluctuation or a higher period of species abundance, due to reproductive events for example. However, there are studies reporting that the reproductive period of this species is between January and April in the South-southeast of Brazil (Eutrópio *et al.* 2006, Neves *et al.* 2008). *Emerita brasiliensis* was pointed by Veloso *et al.* (2003) as a common species at the lower zone of intertidal zone in reflective beaches of the Rio de Janeiro state.

In the present study we found some turbellarian flatworms (7.26% of the total) only in a few samples in the Fora Beach. Some groups of meiofaunal turbellarians may set the composition of a specific vertical strata, due to present high densities, mainly in swallower sediment areas (1-2 cm deep) (Kotwicki *et al.* 2005). However, this dominance is frequently followed by nematodes, one of the most abundant in this type of environment (Kotwicki *et al.* 2005).

In this study, although it has not been observed physical damage in organisms after trampling, there was observed some variation in their occurrence among treatments. In beaches with lower trampling intensities, damages tend to be less impacting and the fauna may escape to deeper depths on their burrow, protecting itself from possible heavier damages (Moffett *et al.* 1998). This displacement to deeper layers of sediment, could be a temporary escape to avoid damages. In the present study, we have checked that there was a difference in abundance, in general, when

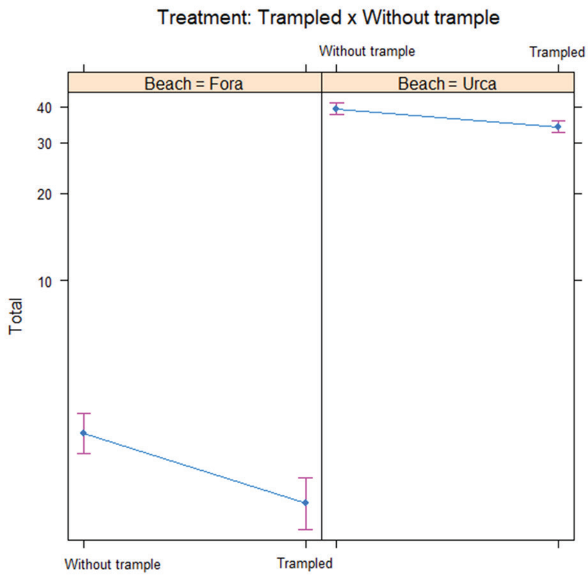

Figure 4. Mean differences between Without trample x Trample treatment in Urca and Fora beaches (Rio de Janeiro, Brazil).

Table 8. General Linear Model Parameters Fit Data (Trampled and Control).

(Int)	Beach (B)	Month (M)	Treatment (T)	B:M	B:T	M:T	B:M:T	df	AICc	Delta	Weight
128 / 0.8938	+	+	+	+	+	+	+	8	825.4	0.00	0.609
64 / 1.0830	+	+	+	+	+	+		7	826.3	0.89	0.391

Table 9. Richness of benthic fauna at Urca Beach and Fora Beach, during June to December/2012 (Wt: Without trample; Tr: With trample).

	June		August		October		December	
	Wt	Tr	Wt	Tr	Wt	Tr	Wt	Tr
Urca Beach	3	3	4	4	4	4	4	5
Fora Beach	4	3	2	2	5	5	3	2

compared the samples “trampled” against “without trample”. Although one month (June) have had an opposite effect, the expected decrease in the density of organisms was similar in both beaches. This result was different from that found in a previous study (Moffett *et al.* 1998), but we have to consider that our scope covers the entirely benthic fauna collected. Great part of our responses was hold by *Saccocirrus pussicus* and nematods. However, when a small area is being highly impacted by trampling, it could cause damage independent of the type of studied organism.

In experiments of impact simulation caused by sportive activities as beach volleyball in Eastern Cape (South Africa), in general, there was no significant difference in the fauna density between treatments, maybe due to low density of organisms (Moffett *et al.* 1998). However, it was verified a difference on the size of damaged organisms, which were smaller when compared to those not damaged, in the treatment with higher trampling intensity (Moffett *et al.* 1998). They also found in the controlled experiments differences in trampling damage only between high-impact group against both the low-impact and the control groups (these last two without statistical differences) (Moffett *et al.* 1998).

We could observe a difference between treatments realized during weekend and week days, mainly in the summer months, when the number of tourists on the beach was very high. Mean density was 122.6 organisms during the week and only 21.8 during the weekend in the Urca Beach (Table 3). As showed by Machado *et al.* (2017), the consequences of human impacts should generate chronic responses, reducing the density of certain species through seasons, as happened with *H. californiensis* and nemerteans during winter on their study. In the present study, we observed an opposite result in the Fora Beach with significant statistical differences, both during the summer and winter. Besides that, we had a higher footpass count in week days than in weekend during winter. As the density of organisms was very low in this beach, this may have influenced the results.

The manner on how the beach is being utilized, the faunistic composition and the physical characteristics of sediment are fundamental to understand the potential of each beach to resist the impacts and their limits to support damages. This experiment aimed to verify if there was a change in composition and density of the benthic macrofauna on the organisms at 20 cm depth in the sediment layer after impact by trampling. We concluded that trampling-impact could affect organisms, while decreasing drastically their abundance, causing them probably to move to deeper layers of the sediment, as could be observed in this present study and also in previous ones.

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REFERENCES

Blankensteyn, A. 2006. O uso do caranguejo maria-farinha *Ocypode quadrata* (Fabricius) (Crustacea, Ocypodidae) como indicador de impactos antropogênicos em praias arenosas da Ilha de Santa Catarina, Santa Catarina, Brasil. Revista Brasileira de Zoologia, 23(3), 870–876. DOI: 10.1590/S0101-81752006000300034

Cardoso, R. S., Barbosa, C. A. M., Skinner, V. B., & Cabrini, T.M. B. 2016. Crustaceans as ecological indicators of sandy beaches health. Ecological Indicators, 62, 154–162. DOI: 10.1016/j.ecolind.2015.11.039

Cardoso, R. S., Mattos, G., Caetano, C., & Cabrini, T. M. B. 2011. Effects of environmental gradients on sandy beach macrofauna of a semi-enclosed bay. Marine Ecology, 33, 106–116. DOI: 10.1111/j.1439-0485.2011.00457.x.

Cardoso, R. S., & Veloso, V. G. 1997. Estratégia amostral para caracterização da macrofauna da região entre-marés em três praias arenosas expostas do estado do Rio de Janeiro. Oecologia

Brasiliensis, 3, 171–182.

Defeo, O., Cardoso, R. S. 2004. Latitudinal patterns in abundance and life-history traits of the mole crab Emerita brasiliensis on South American sandy beaches. Diversity and Distributions, 10, 89-98. DOI: 10.1111/j.1366-9516.2004.00070.x

Defeo, O., Gomez, J., & Lercari, D. 2001. Testing the swash exclusion hypothesis in sandy beach populations: the mole crab *Emerita brasiliensis* in Uruguay. Marine Ecology, Progress Series (Halstenbek), 212, 159–170. DOI: 10.3354/meps212159.

Defeo, O., & Mclachlan, A. 2005. Patterns, processes and regulatory mechanisms in sandy beach macrofauna: a multi-scale analysis. Marine Ecology. Progress Series (Halstenbek), 295, 1–20. DOI: 10.3354/meps295001.

Defeo, O., Mclachlan, A., Schoeman, D. S., Schlacher, T. A., Dugan, J., Jones, A., Lastra, M., & Scapini, F. 2009. Threats to sandy beach ecosystems: A review. Estuarine, Coastal and Shelf Science, 81, 1–12. DOI: 10.1016/j.ecss.2008.09.022.

Di Domenico, M., Martínez, A., Almeida, T. C. M., Martins, M. O., Worsaae, K., & Lana, P. C. 2015. Response of the meiofaunal annelid *Saccocirrus pussicus* (Saccocirridae) to sandy beach morphodynamics. Hydrobiologia (The Hague Print), 31, 250–276. DOI: 10.1007/s10750-014-1858-9.

Eutrópio, F. J., Sá, F. S., & Sá, H. S. 2006. Ecologia populacional de *Emerita brasiliensis* Schmitt, 1935 (Crustacea, Hippidae) de um trecho da praia de Itapoã, Vila Velha, Espírito Santo, Brasil. Natureza on line, 4(2), 67–71.

Garrison, T. 2007. Oceanography: An Invitation to Marine Science. 6th edition. Belmont.

Gheskiere, T., Vincx, M., Weslawski, J. M., Scapini, F., & Degraer, S. 2005. Meiofauna as descriptor of tourism-induced changes at sandy beaches. Marine Environmental Research, 60(2), 245–265. DOI: 10.1016/j.marenvres.2004.10.006.

Instituto Brasileiro de Geografia e Estatística – IBGE. 2011. Atlas geográfico das zonas costeiras e oceânicas do Brasil. Rio de Janeiro, Brasil.

Instituto Estadual do Ambiente – INEA, 2012. Histórico dos Boletins Semanais das Praias da Barra e Zona sul. Retrieved on 2013, from http://www.inea.rj.gov.br/Portal/index.htm

Kotwicki, L., Troch, M., Urban-Malinga, B., Gheskiere, T., & Węsławski, J.M. 2005. Horizontal and vertical distribution of meiofauna on sandy beaches of the North Sea (The Netherlands, Belgium, France). Helgoland Marine Research, 59, 255–264. DOI: 10.1007/s10152-005-0001-8

Lucrezi, S., Schlacher, T. A., & Robinson, W. 2009. Human disturbance as a cause of bias in ecological indicators for sandy beaches: Experimental evidence for the effects of human trampling on ghost crab (*Ocypode* spp.). Ecological Indicators, 9, 913–921. DOI: 10.1016/j.ecolind.2008.10.013

Machado, P. M, Suciu, M. C., Costa, L. L., Tavares, D. C., & Zalmon, I. R. 2017. Tourism Impacts on benthic communities of sandy beaches. Marine Ecology, 38, 1–11. DOI: 10.1111/maec.12440

Moffett, M. D., McLachlan, A., Winter, P. E. D., & De Ruyck, A. M. C. 1998. Impact of trampling on sandy beach macrofauna. Journal of Coastal Conservation 4, 87–90. DOI: 10.1007/BF02806494

Neves, L. P., Silva, P. N., & Bemvenuti, C.E. 2008. Temporal variability of benthic macrofauna on Cassino beach, southernmost Brazil. Iheringia, Série Zoologia, Porto Alegre, 98(1), 36–44. DOI: 10.1590/S0073-47212008000100005

Omena, E. P., Lavrado, H. P., Paranhos, R., & Silva, T. A. 2012. Spatial distribution of intertidal sandy beach polychaeta along an estuarine and morphodynamic gradient in an eutrophic tropical bay. Marine Pollution Bulletin, 64, 1861–1873. DOI: 10.1016/j.marpolbul.2012.06.009

Rizzo, A. E., & Amaral, A. C. Z. 2001. Environmental variables and intertidal beach annelids of São Sebastião Channel (State of São Paulo, Brazil). Revista de Biología Tropical, Costa Rica, 49(3), 849–857.

Schlacher, T. A. 2007. Vehicles versus conservation of invertebrates on sandy beaches: mortalities inflicted by off-road vehicles on ghost crabs. Marine Ecology, 28, 354–367. DOI: 10.1111/j.1439-0485.2007.00156.x

Silva, I. R., Nascimento, H. M., & Rebouças, R. C. 2009. Oceanography: An Invitation to Marine Science. Geociências, 28(2), 193–201.

Veloso, V. G.; & Cardoso, R. S. 1999. Population biology of the mole crab *Emerita brasiliensis* (Decapoda: Hippidae) at Fora Beach, Brazil. Journal of Crustacean Biology, 19, 147–153. DOI: 10.1163/193724099X00349

Veloso, V. G., & Cardoso, R. S. 2001. The Effect of

Morphodynamics on the Spatial and Temporal Variation of the Macrofauna of Three Sandy Beaches on the Rio de Janeiro State, Brazil. Journal of the Marine Biological Association of the United Kingdom, 81, 369–375. DOI: 10.1017/S0025315401003976

Veloso, V. G., Cardoso, R. S., & Petracco, M. 2003. Secondary production on the intertidal macrofauna of Prainha Beach, Brazil. Journal of Coastal Research, Rio de Janeiro, 35, 385–391.

Veloso, V. G., Silva, E. S., Caetano, C. H. S., & Cardoso, R. S. 2006. Comparison between the macroinfauna of urbanized and protected beaches in Rio de Janeiro State, Brasil. Biological Conservation, 127, 510–515. DOI: 10.1016/j.biocon.2005.09.027

Wright, L. D., & Short, A. D. 1984. Morphodynamic variability of beaches and surf zones, a synthesis. Marine Geology, 56, 92–118. DOI: 10.1016/0025-3227(84)90008-2

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