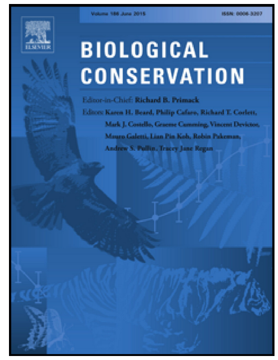

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How does the beach ecosystem change without tourists during COVID-19 lockdown?

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How does the beach ecosystem change without tourists during COVID-19 lockdown?

Abstract

Urban tourist beach ecosystems provide the essential service of recreation. These ecosystems also support critical ecological functions where biodiversity conservation is not usually a priority. The sudden lockdown due to the COVID-19 pandemic created a unique opportunity to evaluate the effects of human absence in these urban-coastal ecosystems. This study examined bioindicators from 29 urban tourist beaches in seven Latin-American countries and assesses their response to lockdown about some relevant anthropogenic stressors such as pollution, noise, human activities, and user density. The presence of animals and plants, as well as the intensity of stressors, were assessed through a standardized protocol during lockdown conditions. Additionally, the environmental conditions of the beaches before and during lockdown were qualitatively compared using multivariate non-parametric statistics. We found notable positive changes in biological components and a clear decrease in human stressors on almost all the beaches. Dune vegetation increased on most sites. Similarly, high burrow densities of ghost crabs were observed on beaches, except those where cleaning activity persisted. Because of the lockdown, there was an exceptionally low frequency of beach users, which in turn reduced litter, noise and unnatural odors. The observed patterns suggest that tourist beaches can be restored to natural settings relatively quickly. We propose several indicators to measure changes in beaches once lockdown is relaxed. Adequate conservation strategies will render the recreational service of tourist beaches more environmental-friendly.

Keywords: Tourist beaches, Bioindicators, Stressors, Coronavirus, Coastal biodiversity, Wildlife conservation.

1. Introduction

Sandy beaches are one of the most common ecosystems of the coastal zone. They provide a wide range of ecosystem services, harbor unique biological diversity and deliver important socio-ecological value (Schlacher et al., 2014a; Olds et al., 2018). However, they are affected by natural threats and anthropic pressures, which are the main changing factors influencing these ecosystems (Defeo et al., 2009; Reyes-Martínez et al., 2015). Climate change translates to increasing impacts of sea-level rise, waves, storms, erosion and landward recession of the shoreline (Jones et al., 2007; Harley et al., 2006). A warming climate also brings rising temperatures, changes in rainfall magnitude, and occurrence of extreme weather events like hurricanes (Becken, 2016). At the same time, pressures mostly related to rapid human population growth and urban expansion exacerbate the negative impacts of human activities such as pollution, construction, exploitation, and recreation on tourist beaches (Brown and McLachlan, 2002; Schlacher et al., 2016).

Tourist beaches are specifically affected by humans, and the extent and type of impacts may differ between urban and more natural tourist beaches. Urban beaches suffer from loss of habitat, beach erosion, sediment plumes, disruption of sand transport, overall pollution, resources overexploitation, maritime accidents, overcrowding, lack of services, loss and change of species, disruption of ecosystem structure and function, and reduced ecosystem resilience (Brown and McLachlan, 2002; Defeo et al., 2009). More natural beaches, located remote from the urban watershed may still suffer from anthropogenic stresses. These include loss of biodiversity, disruption of ecosystem function, saltwater intrusion from freshwater extraction, invasive species, loss of habitat, reduced plant coverage loss, algae accumulation, beach degradation, water pollution from mining and other activities, and eutrophication (Canteiro et al., 2018; Dodds and Holmes, 2019b).

The great majority of tourist beaches record the presence of improperly disposed solid wastes from recreational activities. Commercial tourism activities generate a continuous stream of noise pollution and effluents (Cristiano et al., 2020; Souza and Silva, 2015). In addition, coastal processes deliver a constant supply of floating solid waste, some originating thousands of kilometers away from the receiving beaches. However, on more natural beaches the main human impacts are occupation and construction in the back-beach area (access roads, second homes, small businesses, etc.). This results in the suppression of native vegetation, artificial structures to stabilize sandy terraces and dune cords, all leading to a decrease in important ecosystem services (Souza Filho et al., 2019).

Although scarce, the few studies comparing impacts on protected non-tourist and urbanized-tourist beaches illustrate the negative influence of intensive use on biological communities, resulting in a reduction in the density and diversity of species (Martins, 2007; Gheskiere et al., 2005). Veloso et al. (2006) compared urbanized and natural beaches, finding species richness similar for both. However, the density of some species was lower in urbanized beaches and some species were more vulnerable to trampling. Tourist impacts can be so damaging that Niefer (2002) suggests continuous monitoring of visitors, the establishment of information centers, educational trails, and environmental education projects. Recently, Guerra et al. (2020) used an open beach biodiversity assessment methodology to establish solid baselines to compare in cases of extreme impacts applied in Mexican tourist and non-tourist beaches.

Beaches are social-ecological systems where interactions among species and humans shape community structure and biodiversity. Human activities often generate negative effects on coastal ecosystems (Halpern et al. 2008; Andrés et al. 2017). Even short periods of reduced human activities on beaches increases species abundance and diversity (Davis, 2019). The reduction of beach use due to COVID-19 lockdowns resulted in cleaner beaches and less environmental noise (Zambrano-Monserrate et al., 2020) with longer-term ecological implications as yet unknown.

Proximity to urban centers or other attractions enables many tourists to visit a nearby beautiful beach (Amyot and Grant, 2014; Dodds and Holmes, 2019a). However, visitors often do know that various forms of beach wildlife suffer from leisure and recreational activities that disturb critical habitat (Schlacher and Thomson, 2012). Tourist beaches have not been recognized as priority areas for conservation, perhaps due to the absence of an extensive vegetation cover or the perception of limited biodiversity (Blankensteyn, 2006; Villar de Araujo et al., 2008). One example is the Playas Villamil National Recreational Area in Ecuador (2,472 hectares and 14 kilometers of beaches), which attracts many tourists throughout the year (Zambrano-Monserrate et al., 2018). Urban tourist beaches are highly frequented, and the visitor is unaware of the wildlife importance, therefore the beach becomes a biologically desolate ecosystem and valued only for the landscape and recreational aspects and the Playas Villamil is no exception.

Some recreational activities could seem harmless; however, others can generate deleterious impacts on the beach environment, wildlife, and resources (Marion et al., 2016). The first response to human disturbances by wildlife is usually behavioral, indicating that changes in ethology are good indicators of anthropogenic impacts (Schlacher et al., 2013). Effects can become severe, such as global species extinction or disruption of communities and ecosystems (Green and Giese, 2004: Halpern et al., 2019). Some common impacts are disturbances, habitat loss and modification, decrease in population, and displacement from critical resources like food or water (Marion, 2019). Wildlife seeking to avoid human presence must change their habits or adapt to the new circumstances (Gaynor et al., 2018). These impacts are evident in urban beaches because of the high tourism pressure and urban development (Ariza et al., 2007; Marion et al., 2016).

The sharing of living spaces among humans and wildlife proves problematic since anthropic stressors often drive migrations, redistribution, and life cycle shifts in nature (Gaynor et al., 2018). This complex coexistence results in the need to establish different coastal ecosystem management schemes, with goals often associated with biological conservation to avoid adverse effects caused by human interaction (Jarratt and Davies, 2019) and enabling in some cases the development of scientific research. However, the management of highly visited urban tourist beaches usually promotes services, infrastructure, and leisure activities for tourists (Botero et al., 2018). These decisions do not account for the protection of wildlife and set priorities of economic benefits to satisfy human needs (Mendoza et al., 2018). Therefore, the lack of management strategies will affect wildlife and its conservation, generating impacts such as habitat alteration, biodiversity loss, unintended interactions, information gaps, distribution changes and invasive species (Defeo et al., 2009).

Urban tourist beaches generally arise in places of natural beauty associated with human settlements (Mendoza et al., 2018). These environments commonly present a wide variety of environmental stressors such as noise, pollution, human activities, and odors that, according to their magnitude and occurrence, impact nature in different ways (Araújo et al., 2018). Generally, an urban beach with high tourist densities and stressors negatively alter the natural environment, affecting biodiversity, ecological processes, and ecosystem services (Marshall et al., 2014). The effects of anthropogenic pressures are known (Brown and McLachlan, 2002) and some have been studied like Brazilian beaches where litter and solid wastes abundances changed significantly, according to tourist's presence or urbanization degree (Suciu et al. 2017: Araújo et al., 2018). Even specific methodologies have been developed to assess tourism impacts on natural protected areas (Canteiro et al., 2018). However, the response of these ecosystems to the lack of stressors or its reduction is currently unknown.

Tourist beaches with visitors all year often show a decrease in their anthropogenic pressures during low season (Reyes-Martínez et al., 2015); nevertheless, the total absence of environmental stressors should be highly unlikely. Yet knowing the effects of eliminating anthropogenic impacts would help establish a baseline condition closer to natural conditions. Moreover, studies assessing tourist beaches under pandemic and lockdown conditions are novel (Zielinski and Botero, 2020). Therefore, the current COVID-19 lockdown allows a unique and unprecedented opportunity to study this response as a "Global Human Confinement Experiment" (Bates et al., 2020; Rutz et al., 2020). This new period of dramatic and unusual slowdown in human activity, that many call the "anthropause," could provide important insights into human-wildlife interactions (Rutz et al., 2020). The current world scenario also allows unconventional assessment and valuation of stressors and bioindicators, providing new knowledge for management and wildlife conservation. Similar studies prove useful to evaluate the ecological condition, variations and effects in sandy beach systems, being a relevant tool for coastal managers and biodiversity conservationists (McLachlan et al., 2013; Schlacher et al., 2014).

Considering the scenarios described above, conditions on tourist beaches will probably change under lockdown restrictions. Therefore, we set the hypothesis that urban tourist beaches should exhibit better environmental conditions, driven by a decrease in their anthropogenic stressors, and the improvement of selected bioindicators. To test this hypothesis, the goals of this study were: a) Determine the environmental conditions of tourist beaches during lockdown and pandemic time, b) Describe the presence or absence of selected stressors and bioindicators under lockdown conditions, c) Compare stressors and bioindicators results with previous records and d) Assess changes on wildlife and stressors of tourist beaches due to COVID-19 lockdown.

2. Materials and methods

2.1. Study area

The study area consisted of twenty-nine tourist beaches at seven countries from South America, Central America, and the Caribbean, covering the West Tropical Atlantic and the East Tropical Pacific coasts. All beaches were monitored by members of Proplayas Network [1]. Fieldwork was made between July 2nd and August 1st, 2020, when all beaches were closed due to lockdown restrictions. Information about study sites is detailed in Figure 1 and Supplementary material A.

(Here Figure 1)

2.2. Beach background and COVID-19 context

Most of the beaches studied belong to sandy beach ecosystems. Most beaches are microtidal (<2m of tidal ranges) and mesotidal (between 2-4m of tidal ranges), except for macrotidal beaches (>4m tidal range) monitored in Panama and Ecuador. All beaches show a low slope and are mainly composed of biogenic sand. Tourist areas may encompass kilometers long to hundreds of meters wide. All beaches present a high tourist influx, mainly during weekends, high season, holidays, Easter and summer under typical conditions. Recreational facilities, tourist services, and infrastructure, in some cases as resorts and apartment buildings, are present for all beaches, hence they are considered as highly modified ones. Anthropogenic pressures, such as vehicles, fishing, and maritime traffic, are common. Some beaches have biological, historical, or cultural importance such as turtle nesting and spawning areas for various animals, or they are in cities with heritage categories. The beaches studied are highly impacted by human presence and generally show absent or reduced dune vegetation (e.g., beachgrass) and regional fauna (e.g., ghost crabs.) (Defeo, 2009). Main features of each studied beach are described in Supplementary 1. The world spreading of new coronavirus has obligated all-level government authorities to establish lockdown and restrictions measures, including banning access to tourist beaches.

[1]

Therefore, beaches were monitored after authorization by local authorities. Each team followed sanitary and safety protocols.

2.3. Protocols and fieldwork

We used the beach typology proposed by Williams and Micallef (2009), which emphasizes the managerial aspects. Therefore, urban, village, and resort beaches were prioritized over rural and remote beaches, because the former usually have the highest tourist pressure (Williams and Micallef, 2009). Most of the studied beaches are of the urban type, (21 of the 29). The others included six village beaches, one resort beach and one rural beach (Supplementary A). As an exception, Caracas Beach (Puerto Rico) and El Estero Santa Catalina Beach (Panamá), despite being tourist beaches, are also protected areas for wildlife conservation. Previous knowledge of each beach was also considered to compare the results with normal beach conditions. Surveys took place between 10:00 h and 15:00 h, at the time when the beach is traditionally more crowded. Likewise, we avoided fieldwork during the weekends to reduce possibility of encountering a higher number of illegal visitors at beaches defying lockdown and restriction measures.

2.3.1. Bioindicators

Categories for bioindicators were chosen considering broad taxonomic attributes of the fauna and flora. For fauna, the presence of the following animals was recorded: crabs, lizards, turtles, iguanas, opportunistic birds, sea birds, and domestic animals. For flora, the presence of seaweed, seagrasses, beachgrass, shrubbery, vines, mangroves, and other trees was recorded. As all the

[1] The international group named by the acronym “Proplayas” is an Ibero-American network formed by members of the academia, civil society, scientists, activists, officials, and businesspeople. All of them working on beach issues (www.proplayas.org).

beaches studied met the requisite of being highly crowded in typical tourism seasons, user density was expected to affect typical flora and fauna and could increase the presence and extent of opportunistic species associated with human activities. Data were registered *in situ* in a digital format designed for the mobile application termed Kobo Collect (Supplementary 2) and linked to a Web cloud. We performed monitoring of biological indicators in three defined zones (parallel to the waterline) within the touristic use zone of each beach. These zones were (1) Active: area of sand strip closest to the waterline, dedicated to the circulation of bathers. (2) Rest: an area dedicated to users' rest and sunbathing. (3) Service: an area for shops and services. Records of bioindicators were completed at 100 m transects in each of the defined zones. To generate evidence about the environmental beaches condition during the lockdown, short videos were taken at both ends and the midpoint of each transect. The taxonomic resolution of bioindicators was supported with photographs of each observed organism.

2.3.2. Stressors

An anthropogenic stressor is an action that generates direct or indirect pressure on the beach. To assess the potential effects of this human pressure we chose seven stressors based on their ease and relevance of measurement: 1. Noise; 2. Odor; 3. Litter; 4. User density; 5. Activities; 6. Infrastructure; and 7. Anthropogenic threats. The first three stressors are part of the Environmental Beach Quality Index proposed by Botero et al. (2015), and the fourth is considered a parameter that affects all the other metrics of this index (called 'meta-parameter', such as the concept of 'meta-data'). The last three stressors named -Activities; Infrastructure and Anthropogenic threats-, were considered as tourist stressors with a relevant incidence in COVID-19 lockdown. The importance of making this analysis was to check how many anthropogenic activities were carried out on beaches during the lockdown, identifying specific potential pressures of tourist activity over these ecosystems. Each stressor had its survey format on the virtual platform Kobo Toolbox (https://www.kobotoolbox.org/), which was linked to the Kobo Collect application, where each researcher registered the data gathered on the field. The surveys were performed in the same three zones defined for the bioindicators (Supplementary 2).

2.4. Data processing, visualization, and statistical analyses

The data collected in the fieldworks was downloaded from the Kobo Toolbox Cloud and organized in a tidy structure (details about this structure are expanded by Wickham, 2014). We used bar graphs to visualize the frequency of occurrence of each indicator by beach zone. We pooled all of the data from beaches since the research focused on before and during effects of lockdowns rather than differences due to spatial variability. All data processing was done with the *tidyverse* packages (Wickham et al., 2019) of the statistical software R (R Core Team, 2019).

To evaluate potential changes in the environmental conditions of the beaches generated by the lockdown, a qualitative assessment instrument was designed based on four anthropogenic stressors (noise, odors, litters, and activities) and one general stressor for the biological component of the beach. Each indicator was rated on a semi-quantitative ordinal scale from 1 to

5, where 5 is the worst condition for that indicator in the beach. The characteristics of each value for each indicator are described in an assessment tool available as supplementary material (Supplementary 3). This instrument allows controlling the subjectivity of assessment among researchers. The pre-COVID assessments were assigned based on literature, data, and observations made in previous studies. The assessments during lockdown were applied after visiting the beaches. We recognized the superiority of using quantitative data obtained with standardized procedures, such as the developed by the PROPLAYAS network (Botero et al., 2015) as well as the MBON Pole to Pole network (2019), instead of qualitative assessments. However, carrying out such quantitative methodologies proved infeasible during the lockdown. Restrictions on the number of researches and the time they could stay on site, as well as the impossibility to process chemical and biological samples in our institutional facilities suggests the efficacy of the semi-quantitative ordinal approach we adopted.

Valuations were arranged in a matrix with beaches as rows (before and during lockdown) and indicators as columns. Then, non-parametric multivariate statistics based on similarities were used to compare the beaches before and during the lockdown. We explored several similarity/distance indices before definitive analyzes (i.e., Gower, Bray-Curtis, χ^2, Binomial deviance, Euclidean distances, Chord distance), all resulting in patterns of similarities with very high correlation (Spearman rank correlation coefficients all > 0.9). For clarity of interpretation, we decided to use the Gower similarity index. This is a quantitative symmetric index that allows the use of qualitative descriptors, like those employed in this study (Legendre and Legendre, 2012). Pairwise similarities were estimated for each pair of rows, then an Analysis of Similarities (ANOSIM) based on 9999 permutations (Clarke, 1993) was performed to test the null hypothesis of differences in valuation of stressors and bioindicators before and during COVID-19 lockdown. A non-metric multidimensional scaling (nMDS) was plotted to represent the patterns of similarity between moments. The contribution of each indicator to the dissimilarity between moments was identified with the routine Similarity Percentage (SIMPER) (Clarke, 1993). These statistical analyses were done with PRIMER v7 (Clarke et al., 2014).

3. Results

3.1. Biological indicators recorded during the lockdown

We found the most bioindicators in the service zone of urban beaches. Thirteen of the fourteen groups of monitored bioindicators were present and the only one absent was seagrass on this beach zone. Crabs were found to be a widespread component of the fauna, particularly in the active zone. Most of the crabs belong to the species *Ocypode quadrata* and were present in 13 of 29 beaches (Fig. 2). Seabirds and non-seabirds were also recorded frequently in this zone (16/29 beaches), particularly *Fregata magnificens*, *Leucophaeus atricilla*, *Phalacrocorax sp*, and *Larus delawarensis*. Fauna was rare (found in 5 out of 20 beaches) in the rest zone, however, when some animals were recorded these were mostly domestic animals, seabirds and opportunistic birds. Turtle nests were registered on only three beaches, all in the rest zone. In this zone, beach grass was the most frequent bioindicator, present in 11 of 29 beaches. The occurrence of opportunistic species was higher in the service zone, especially pigeons (*Columba livia*), common grackles (*Quiscalus mexicanus)* and domestic species such as dogs (Fig. 2).

Beach grass, shrubbery, and vines appeared frequently in the service zone, growing in areas of regular transit of people; these bioindicators were registered on 13 beaches. Trees were also prevalent, especially coconut palms, palm trees, and beach grape trees. Besides opportunistic birds, lizards and iguanas were the most frequent fauna bioindicators in the service area (Fig. 2). A higher beachgrass coverage was observed on many beaches and it was also noted that dunes were forming or increasing in size. This new habitat availability could lead to a possible improved condition for increased activity of ghost crabs and other species. Details of bioindicators are provided in Supplementary 4.

(Here Figure 2)

3.2. Changes on anthropogenic stressors during the lockdown

3.2.1. Noise

Unnatural noises were almost imperceptible on most beaches (Supplementary 5.1). The signs of its existence were concentrated on urban beaches, caused by motorized vehicles (such as motorcycles, cars, cleaning vehicles) and construction. Noises were sometimes detected from alarm sirens and music from restaurants in three urban beaches, as well as music from festivals, was perceived in one urban beach. Motor vehicles and watercraft noises were only recorded on three village-type beaches.

3.2.2. Odor

Unnatural odors were rarely perceived on studied beaches (Supplementary 5.2.A). With some exceptions, various types of unnatural odor associated with human activity were recognized in village and urban beaches (e.g., smoke, garbage, fuel). The odor sources reported were mainly waste containers and restaurants, closely followed by wrack in urban beaches. Nevertheless, none of the odor sources was reported in more than four beaches (13.33%) (Supplementary 5.2.B). Unnatural odor categories were not perceived in rural and resort beaches.

3.2.3. Litter

Litter was either absent or in exceptionally low abundance for most of the beaches studied (Supplementary 5.3.A). Potentially harmful litter such as broken glasses, glass bottles, syringes and knives appeared in low abundance in 10 beaches. Cigarette butts and polystyrene were similarly registered with low abundances in a few beaches. Conversely, gross and small vegetable items such as tree-trunks, branches, leaves and, stranded vegetation from shallow waters (e.g. seagrass and algae) dominated the large particulate matter for most of the beaches. This type of litter would not be causally related to human activities (Supplementary 5.3.A). The primary source of litter was associated with recreation in the active zone, while the secondary source corresponded to commercial facilities (Supplementary 5.3.B). Both results could indicate that some activities considered as litter sources were not interrupted during lockdown (e.g. transport, trading). However, it should be noted that some sources, such as commercial facilities, are only not related to the tourism activity on the beach.

3.2.4. User Density

User density was low in most studied beaches. During the monitoring, less than five beaches (>15%) had visitors in the three beach zones (Fig. 3A). Fieldwork observations showed the overall number of users was less than 10, mainly on urban and village beaches, and in the active and rest beach zones (Fig. 3A). At least ten beaches (33%) had public visitors (local inhabitants), and seven had the presence of authorities during monitoring. A relevant finding was the spatial distribution of users on the beach, which showed clearly how the active zone was empty in many cases, while the service zone had the highest occupation.

(Here Figure 3)

3.2.5. Activities

We observed recreational activities on 13 urban beaches in three different zones (Fig. 3A and 3B). The frequency of these activities changed according to the beach zone. For example, people running, swimming, or socializing were mainly registered in the active beach zone, while runners, children playing with sand, and people practicing sports were mostly registered in the rest beach zone. Recreational activities regarding people relaxing and socializing were mainly registered in the service zone (Fig. 3B). Commercial activities were practically not observed on the four types of beaches analyzed (Fig. 3C), while maintenance activities such as cleaning and vigilance were recorded in only eight urban beaches (Fig. 3D).

3.2.6. Infrastructure

This stressor included two types of infrastructure: first, those related directly with the COVID-19 measures, and second, buildings, promenades and structures constructed before the pandemic. The most common infrastructure presents on the beaches analyzed was the seafront. This type of infrastructure is referred to as a public walk located along the coast which is quite common in most of the Caribbean and Latin American beaches. Kiosks and low-rise facilities are usually frequent on the seafront at service zones on the beaches in normal conditions. However, during COVID-19 lockdown, only two urban beaches had facilities on the active beach zone, while ten beaches had the presence of low and mid-rise kiosks in the services zone and the seafront which were associated with commercial activities. During COVID-19 lockdown new infrastructures recently built with local materials (guano, wooden pitchforks) were present in the four types of beaches analyzed, with greater predominance in the village and urban beaches. Details are provided in Supplementary 5.4.

3.2.7. Anthropogenic threats

Activities that affect the marine and terrestrial zones of the beach environment were analyzed as anthropogenic threats. Only six beaches showed signs of such. The threats were invasive species, vehicles on the beach, and sand extraction. The latter was evident on four urban beaches. The potential for invasive species and wastewater discharges appeared at seven beaches: four urban and three villages. Details are provided as Supplementary 5.5.

3.3. Potential changes in beach condition due to COVID-19 lockdown

The similarity patterns recorded in the qualitative assessment were significantly different between before/during lockdown conditions (ANOSIM test, $R = 0.875$, $p < 0.001$). The magnitude of the ANOSIM R statistic was relatively high (the maximum possible value is 1), indicating a solid differentiation between these conditions. The dissimilarities between beaches considering the condition were plotted in Fig. 4A. Besides, the multivariate dispersion was greater for the condition "before" than "during" the lockdown, indicating the variability of the characteristics of use and conservation of the beaches in the region. The dispersion is lower during the lockdown because most of the indicators were consistently scored with the minimum possible values (Fig. 4B). That is, the various beaches converged to a better state of health during the lockdown.

The SIMPER analysis shows that the indicators with greater change before/during the lockdown were the Noises and Activities, both contributing to 51 % of differences (Table 1). Both indicators, on average, decrease from 3.4-3.2 to 1.5-1.3, respectively. As expected, most beaches presented little if any human activity during the lockdown. Surveillance and maintenance accounted for most of the activity.

Before COVID-19, most beaches scored high for user density and activities such as the presence of off-road vehicles. Similarly, unnatural noise was more intense and frequent for all beaches (grades 3 and 4) before lockdown, mostly music emanating loudspeakers and off-road vehicles. Litter and odors accounted for the lowest contribution to differences (Table 1). During the lockdown, most of the beaches had no or little litter contrasting with the extensive refuse typical of pre-lockdown conditions. However, this indicator was very variable because some beaches were consistently under cleaning programs, even during the lockdown, such as beaches in Cancún, México. Similarly, unnatural odors such as smoke, garbage, fuel, body lotions, food, smoke from grills or campfires, among others were quite frequent (grade 3) before COVID-19, but practically absent (grade 1) during the lockdown.

The biological component contributes to 23 % of differences in scores between before and during lockdown, decreasing on average from 3.4 to 2.1. During lockdown most of the beaches scored a qualitative biological assessment of 1 or 2, indicating a presence of dune vegetation, coconut palm, wildlife (reptiles, mammals, birds), coastal crustaceans (ghost crab, blue crab) and turtle nests. Conversely, before the COVID-19 lockdown, many beaches had low presence or absence of natural biological traits, but the presence of opportunistic fauna (grades 3, 4, and 5).

(Here Figure 4)

(Here Table 1)

4. Discussion

4.1. Signs of bioindicator recovery due to the COVID-19 lockdown

The potential recovery of some bioindicators was observed in most beaches. The consistent presence of crabs and, specifically ghost crabs, in the active zone was evident. It is highlighted not only due to their reported occurrence but also because researchers noticed crabs being more active than usual and even more confident in human presence. Ghost crabs are known to be important bioindicators (Blankensteyn, 2006) and species of the genus *Ocypode* are semiterrestrial invertebrates inhabiting areas from the waterline to the dunes (Lucrezi and Schlacher, 2014). The recovery of this species supports the notion of resilient capacity as suggested by Stelling-Wood et al. (2016) for Australian urban beaches. Likewise, the appearance of beach grass, as well as the extension of vines and shrubs in areas where they were not seen before could also be considered an indicator of the dune vegetation resilience (Rickard et al., 1994). In essence, pre-lockdown human disturbance maintains the beach community in an earlier sere of succession.

The records opportunistic birds like grackles were frequent in our beaches during lockdown. Gilby et al. (this issue) found great increases of Torresian crows (*Corvus orru*) on Australian beaches during lockdown. Hence, the recovery of some bioindicators demonstrates the resilience capacity of tourist beaches. Despite variability in the data, indicators of ecosystem health clearly improved during the lockdown. We note that positive changes in the presence, abundance, diversity, and activity of the main flora and fauna occurred during lockdown. We can say this with confidence as we are well acquainted with the beaches studied in our respective countries.

Managers and conservationists should give special attention the presence of protected and sensitive species in high tourist beaches as highlighted by Boudouresque et al (2017) and Steven and Castley (2013). A remarkable finding in our study was the presence of turtles and iguanas during lock-down, including threatened species. Records in these species during lockdown occurred in well-established reserves and protected areas, as in Puerto Rico and Panama. This suggests insufficiency in the level of protection afforded by these reserves during normal times. This finding should cause mangers to reconsider the extent of human activity allowed in protected areas. Anthropogenic activities may threaten the population stability of sensitive species (Brown and McLachlan, 2002; Defeo et al., 2009; Canteiro et al., 2018). Hockings (2020) explored the factors that reserves, and protected areas could use to build a more sustainable future for people and nature after COVID-19 pandemic.

4.2. Decline of human stressors due to the COVID-19 lockdown

Consistent with our hypothesis, we documented an overall reduction in anthropogenic stressors during the lockdown. This suggests that the restrictions and confinement measures proved effective in, limiting and preventing access and human activities, and hence generating a positive effect on environmental conditions. Positive effects derived from the COVID-19 lockdown are documented for different environments (Manenti et al., 2020; Derryberry et al. 2020). Considering all the measured stressors, we believe that physical disturbances generated by human activities had the most remarkable effects on biological beach traits and functioning. The improvement of biological indicators during the COVID-19 lockdown support this contention. It is widely documented that the constant disturbances generated by pedestrian traffic and off-road vehicles on the beach frequently alter the natural substrate stability and prevents the establishment and growth of dune vegetation, as well as of benthic macrofauna (Bom and Colling, 2020; Rickard et al., 1994). The lack of tourists also generated a great change in the landscape of several beaches: Acapulco (Mexico), Salinas (Ecuador) and Barcelona (Spain) now look cleaner and with crystal waters (Zambrano-Monserrate et al., 2020). Even the physical disturbance caused by just a few tourists might produce a loss of biodiversity on beaches, especially in sensitive microscopic animals (meiofauna) that live buried in the sand (Martínez et al., 2020). This effect may cascade up to higher trophic levels such as macrofaunal that depend on the sensitive meiofauna (Afghan et al., 2020), thus generating a negative effect on the ecosystem functioning (Bracken et al., 2008).

The COVID-19 lockdown drove a reduction of noise, odor, and litter on the studied beaches. Different types of anthropogenic stressors produce different impacts on biota (Birk et al., 2020), and noise is an emerging pollutant that affects marine organisms (Peng et al., 2015). Noise during lockdown diminished due to lower human presence. This included reductions in recreational and commercial activities, maritime traffic, fishing, and construction. Unnatural sounds alter avian communities, reducing nesting species richness, and contributing to the success of urban-adapted birds (Francis et al., 2009). It is also a problem for the population and the environment. Noise pollution is associated with various diseases and altered ecosystems (Zambrano-Monserrate and Ruano, 2019).

The absence of open restaurants, food sellers, and cooking tourists on the beaches also reduced the presence and intensity of unnatural odors and organic wastes. This may explain diminished opportunistic fauna on beaches during lockdown. The food orders may have served as attractants prior to lockdown. However, we think some odors would not be associated with lockdown effect.

Another aspect to highlight was the low density of litter on all beaches during the lockdown. It may indicate that the few residues found are remnants of recreational activities carried out before the pandemic, as well as residues found in the active zone are subject to intense mobility due to tides and coastal currents brought from other locations. On the other hand, on many beaches, constant cleaning was perceived, especially on the shores of the Riviera Maya, Mexico. Although this cleaning activity is common in the region throughout the year, the absence of tourists due to lockdown contributed to keeping it cleaner. However, cleaning is usually supported using rakes, and in some places with sand cleaning machines. This disrupts infauna habitat, preventing establishment of ghost crabs and various other fauna (Ocaña *et al.* 2020). Studies carried out by Lucrezi et al. (2009) and Schlacher et al (2016) using ghost crabs as indicators confirm human disturbances contribute to the loss of habitat for these species. Although the harmful effects of litter on marine life are well documented (Kühn et al., 2015), beach raking is not a solution that protects biological diversity of the beaches despite this activity removes beach litter.

DPPE (disposable personal protective equipment) and other single-use plastic items have been promoted during the pandemic as a mandatory policy in public spaces, including beaches. These items are emerging pollutants of beaches, such as the discarded masks

found in Praia da Ribeira, Brazil. Masks, contaminated gloves, used or expired medications plus other items could be mixed with ordinary wastes, magnifying marine litter issues and the consequences to marine biodiversity and population health (Canning-Clode et al., 2020). The safe management and disposal of common and biohazard waste on beaches will be complex during a pandemic. This situation is especially worrying because the industry has taken the opportunity to repeal disposable bag bans, even though single-use plastic can still harbor viruses and bacteria (Bir, 2020). The reopening of the beaches could make this type of litter more frequent. We encourage monitoring this situation since many beaches already allow access to tourists.

4.3. Perspectives and projections for biological conservation and management

Results from this study suggest that tourist beaches offer important biodiversity that requires conservation initiatives (McLachlan et al., 2013). Some of the studied beaches also support essential ecological processes such as turtle nesting and spawning areas, bird reproduction, nesting and feeding, crab habitat, and increased habitat for plants that in some cases were not recorded before the pandemic. Caracas beach (Puerto Rico), located inside the Vieques U.S. Fish and Wildlife National Reserve, recorded turtle nesting zones for endangered species such as the

Green Turtle (*Chelonia mydas)*. Itapuã beach in Brazil showed spawning areas for sea turtles, while El Estero Santa Catalina beach in Panama as part of the buffer zone at Coiba National Park supported a high diversity of wildlife.

Recreation is the primary service provided by tourist beaches to society (Bessa et al., 2014; Zhang et al., 2015) and conservation aims are secondary. However, tourist sandy beaches are not only crucial for recreation; they also need conservation (Jaramillo, 2012; McLachlan et al., 2013). These ecosystems also provide food, economic services, biodiversity, maintenance and regulation of natural processes, aesthetic and cultural values and many other benefits and services (Schlacher et al., 2014a). Therefore, it is necessary to propose mechanisms for setting conservation targets (Harris et al., 2014) for those beaches that meet selected ecological criteria. The recovery capacity observed in several beaches related to wildlife repopulation could be a criterion. Opportunistic species were common on urban and village beaches, so any conservation action should consider the interactions with native and non-native species.

On tourist beaches, initiatives with a focus on wildlife conservation may be new and attractive. However, they may be complex and difficult to develop, since tourist beach management traditionally focuses on protecting infrastructure and sediment structural maintenance (Schlacher et al., 2006). The conservation of habitats, species, and ecological functions is often a minor aspect (Peterson and Bishop, 2005). However, our results would allow thinking that this new scenario called 'anthropause' opens a window for biological conservation purposes that promote unique global experiments in nature (Bates et al., 2020, Rutz et al., 2020). Even more so for urban tourist beaches where the possibility to conduct studies without anthropogenic stressors are impossible in practice.

New initiatives and perspectives should define first the conservation targets focusing on species, communities, functions, processes, services, and ecosystems. Nature-based tourism proves to be a sustainable activity under certain circumstances (Winter et al., 2020), providing education and good practices for visitors and local communities as well as economic and political support for wildlife conservation (Wilson and Tisdell, 2003). New concepts like Wildlife Conservation Tourism (W.C.T.) may also be implemented as an ecological conservation strategy that prioritizes endangered species through meaningful interactions with tourists (Boyes, 2016). The current pandemic offers to all actors a unique opportunity to design and consolidate the transition towards a greener and more sustainable tourism (Ioannides and Gyimóthy, 2020), rethinking the way to promote beach tourism based on recreation but also being mindful of the protection of coastal ecosystems biodiversity.

This study evidences an increase in frequency and magnitude of living organisms in Latin American beaches during the lockdown and reveals a reduction in anthropogenic stressors. Our results support the findings of Martínez et al. (2020), who consider it essential to restrict access to beaches in tourist areas to preserve biodiversity. Therefore, better practices of sustainable tourism (i.e., maximum load capacity and better waste disposal) must emerge and be implemented to minimize the impact of human activities. Executive actions should be adjusted to the different regional contexts considering active public participation of the local communities (Milanés et al., 2020). Regarding beach management, the current legal framework (GORC, 2000) and coastal policies of each Latin American country should be considered, and some of these regulations must be adapted (Milanés et al., 2019). The natural characteristics of the beaches and their level of anthropogenic impact should also be considered to carry out effective planning of the coastal areas (Moraes and Milanés, 2020; Batista, 2018). The general lockdown limited the possibility of performing exhaustive and more quantitative analyses (Manenti et al., 2020), yet such monitoring is important to verify the trends revealed in this study.

5. Conclusions

The new environmental setting derived from the COVID-19 lockdown generated conspicuous changes in the biological community of beaches previously impacted by human activity that should be assessed with caution. Yet, our results correspond to only a "snapshot" of an unprecedented condition that should be followed over time. Long-term and more robust studies focused on vulnerable species, functioning, and ecosystem services would allow knowing if tourist beaches can become appropriate places for effective biological conservation. Despite the extensive history of human activity on these beaches prior to lockdown, these ecosystems displayed the ability to recover, with increases in biodiversity and system functionality as response to lower environmental alteration by stressors. This supported our initial hypothesis. This suggests an impressive resilience of these environments not previously evaluated to support biodiversity and possibly its conservation.

The positive implications of how most of the bioindicators changed during lockdown are likely to be temporary, and it is currently not clear how conservation will fare in the aftermath of the pandemic. We hope that information gathered in this study may contribute for conservation strategies of sensitive ecosystems like sandy beaches of high tourist use. Adequate monitoring of bioindicators is necessary for a more effective coastal management system, which seeks to consider the conservation of biodiversity, ecosystem balance, and the maintenance of essential services for humankind such as leisure and recreation provided by tourist beaches.

6. References

Afghan, A., Cerrano, C., Luzi, G., Calcinai, B., Puce, S., Pulido Mantas, T., Roveta, C., Di Camillo, C.G., 2020. Main Anthropogenic Impacts on Benthic Macrofauna of Sandy Beaches: A Review. J. Mar. Sci. Eng. 8, 405.

Andrés, M., Barragan, J.M., Garcia-Sambria, J., 2017. Relationships between coastal urbanization and ecosystems in Spain. CITIES 68, 8-17.

Amyot, J., Grant, J., 2014. Environmental Function Analysis: A decision support tool for integrated sandy beach planning. Ocean Coast. Manag. 102, 317-327. https://doi.org/10.1016/j.ocecoaman.2014.10.009

Araújo, M., Silva-Cavalcanti, J., Costa, M., 2018. Anthropogenic Litter on Beaches with Different Levels of Development and Use: A Snapshot of a Coast in Pernambuco (Brazil). Front. Mar. Sci. 5, 233. DOI: 10.3389/fmars.2018.00233.

Ariza, E., Sardá, R., Jiménez, J.A., Mora, J., Ávila, C., 2007. Beyond Performance Assessment Measurements for Beach Management: Application to Spanish Mediterranean Beaches, Coast. Manag. 36 (1), 47-66, DOI: 10.1080/08920750701682023

Bates, A.E., Primack, R., Moraga, P., Duarte, C., 2020. COVID-19 pandemic and associated lockdown as a "Global Human Confinement Experiment" to investigate biodiversity conservation. Biol. Conserv. 248, 108665. doi.org/10.1016/j.biocon.2020.108665

Bessa, F., Gonçalves, S.C., Franco, J., André, J., Cunha, P., Marques, J., 2014. Temporal changes in macrofauna as response indicator to potential human pressures on sandy beaches. Ecol. Indic. 41,49-57

Batista, C., 2018. Coastal Boundaries. In: Finkl C., Makowski C. (eds) Encyclopedia of Coastal Science. Encyclopedia of Earth Sciences Series. Springer, Cham, DOI: https://doi.org/10.1007/978-3-319-48657-4_74-2

Becken, S., 2016. Climate change impacts on coastal tourism. CoastAdapt Impact Sheet 6, National Climate Change Adaptation Research Facility, Gold Coast.

Bir, B., 2020. https://www.aa.com.tr/en/health/single-use-items-not-safest-option-amidcovid-19/1787067 Accessed date: September 4th 2020.

Birk, S., Chapman, D., Carvalho, L. et al. 2020. Impacts of multiple stressors on freshwater biota across spatial scales and ecosystems. Nat. Ecol. Evol. 4, 1060–1068. https://doi.org/10.1038/s41559-020-1216-4

Blankensteyn, A. 2006. O uso do caranguejo maria-farinha Ocypode quadrata (Fabricius, 1787) (Crustacea, Ocypodidae) como indicador de impactos antropogênicos em praias arenosas da Ilha de Santa Catarina, Santa Catarina, Brasil. Rev. Bras. de Zool. 23 (3), 870-876. https://doi.org/10.1590/S0101-81752006000300034

Bom, F., Colling, L., 2020. Impact of vehicles on benthic macrofauna on a subtropical sand beach. Mar. Ecol.41:e12595. https://doi.org/10.1111/maec.12595

Botero, C., Pereira, C., Tosic, M., Manjarrez, G., 2015. Design of an index for monitoring the environmental quality of tourist beaches from a holistic approach. Ocean Coast. Manag. 108, 65–73. https://doi.org/10.1016/j.ocecoaman.2014.07.017

Botero, C.M., Cabrera, J.A., Zielinski, S., 2018. Tourist Beaches. In: Finkl C., Makowski C. (eds) Encyclopedia of Coastal Science. Encyclopedia of Earth Sciences Series. Springer, Cham. https://doi.org/10.1007/978-3-319-48657-4_401-1

Boudouresque, C.F., Ponel, P., Astruch, P., Barcelo, A., Blanfuné, A., Geoffroy, D., Thibaut, T., 2017. The high heritage value of the Mediterranean sandy beaches, with a particular focus on the Posidonia oceanica “banquettes”: a review. Sci. Rep. Port-Cros Natl. Park, 31, 23-70.

Boyes, K., 2016. Applying Wildlife Conservation Tourism to Marine Endangered Species: Identifying Indicators for Triple Bottom Line Sustainability. Master of Marine Affairs Thesis, University of Washington, 78 pages.

Bracken, M., Friberg, S., Gonzalez-Dorantes, C., Williams, S., 2008. Functional consequences of realistic biodiversity changes in a marine ecosystem. Proc. Natl. Acad. Sci. USA. 105, 924–928.

Brown, A., McLachlan, A., 2002. Sandy shore ecosystems and the threats facing them: some predictions for the year 2025. Env. Conserv. 29, 62–77. https://doi.org/10.1017/S037689290200005X

Canning-Clode, J., Sepúlveda, P., Almeida, S., Monteiro, J., 2020. Will COVID-19 Containment and Treatment Measures Drive Shifts in Marine Litter Pollution? Front. Mar. Sci. 7, 691. DOI: 10.3389/fmars.2020.00691

Canteiro, M., Córdova-Tapia, F., Brazeiro, A., 2018. Tourism impact assessment: A tool to evaluate the environmental impacts of touristic activities in Natural Protected Areas. Tour. Manag. Pers. 28, 220-227. https://doi.org/10.1016/j.tmp.2018.09.007

Clarke, K.,1993. Non-parametric multivariate analyses of changes in community structure. Austral. Jour. Ecol. 18, 117-143. doi:https://doi.org/10.1111/j.1442-9993.1993.tb00438.x.

Clarke, K., Gorley, R., Somerfield, P., Warwick, R., 2014. Change in marine communities: an approach to statistical analysis and interpretation. Plymouth: PRIMER-E, Ltd.

Cristiano, S.C., Rockett, G.C., Portz, L.C., Souza Filho, J. R., 2020. Beach landscape management as a sustainable tourism resource in Fernando de Noronha Island (Brazil). Mar. Poll. Bull. 150, 1-13. DOI:https://doi.org/10.1016/j.marpolbul.2019.110621.

Davis, R.A., 2019. Human Impact on Coasts. In: Finkl C.W., Makowski C. (eds) Encyclopedia of Coastal Science. Encyclopedia of Earth Sciences Series. Springer, Cham. https://doi.org/10.1007/978-3-319-93806-6_175

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. Est. Coast. Shelf Sci. 81, 1-12. doi:10.1016/j.ecss.2008.09.022

Derryberry, E.P., Phillips, J.N., Derryberry, G.E., Blum, M. J., Luther, D., 2020. Singing in a silent spring: Birds respond to a half-century soundscape reversion during the COVID-19 shutdown. Science 340, 574-579.

Dodds, R., Holmes, M., 2019a. Beach tourists; what factors satisfy them and drive them to return. Ocean Coast. Manag. 168, 158-166. https://doi.org/10.1016/j.ocecoaman.2018.10.034

Dodds, R., Holmes, M.R., 2019b. Preferences at city and rural beaches: are the tourists different? Jour. of Coast. Res. 36 (2), 393–402. https://doi.org/10.2112/JCOASTRES-D-19-00048.1

Francis, C., Ortega, C., Cruz, A., 2009. Noise Pollution Changes Avian Communities and Species Interactions. Curr. Biol. 19 (16), 1415-1419. DOI: https://doi.org/10.1016/j.cub.2009.06.052.

Gaynor, K., Hojnowski, C., Carter, N., Brashares, J., 2018. The influence of human disturbance on wildlife nocturnality. Science 360, 1232-1235.

DOI: 10.1126/science.aar7121

Gheskiere, T., Vincx, M., Weslawski, J.M., Scapini, F., Degraer, S., 2005. Meiofauna as descriptor of tourism-induced changes at sandy beaches. Mar Environ Res. 60 (2), 245-65. DOI: 10.1016/j.marenvres.2004.10.006. Epub 2004 Dec 7. PMID: 15757751.

Gilby, B., Henderson, C., Olds, A., Schlacher, T., Ballantyne, J., Bingham, E., Elliott, B., Jones, T., Mosman, J., 2021. Negative ecological consequences of animal redistribution on beaches during COVID-19 lockdown. Biol Conserv. (this issue)

GORC, 2000. Decreto-Ley 212. Gestión de la Zona Costera. Official Gazette of the Republic of Cuba. Citma, La Habana, Cuba, p. 18.

Green, R., Giese, M. 2004. Negative Effects of Wildlife Tourism on Wildlife. Chapter 5, Part 2, In: Wildlife Tourism: Impacts, Management and Planning. Editor, Karen Higginbottom.

Guerra-Castro E., Hidalgo, G., Castillo, R., Muciño-Reyes, M., Noreña-Barroso, E., Quiroz-Deaquino, J., Mascaro, M., Simoes, N., 2020. Sandy Beach Macrofauna of Yucatán State (Mexico) and Oil Industry Development in the Gulf of Mexico: First Approach for Detecting Environmental Impacts. Front. Mar. Sci. 7:589656. doi: 10.3389/fmars.2020.589656

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E. M. P., Perry, M. T., Selig, E. R., Spalding, M., Steneck, R., Watson, R., 2008. A global map of human impact on marine ecosystems. Science 319, 948. DOI: 10.1126/science.1149345

Halpern, B.S., Frazier, M., Afflerbach, J., Lowndes, J.S., Micheli, F., O'Hara, C., Scarborough, C., Selkoe, K.A., 2019. Recent pace of change in human impact on the world's ocean. Sci. Rep. 9, 11609. doi.org/10.1038/s41598-019-47201-9

Harris, L., Nel, R., Holness, S., Sink, K., Schoeman, D., 2014. Setting conservation targets for sandy beach ecosystems. Est. Coast. Shelf. Sci. 150, 45-57.

Harley, C., Hughes, A., Hultgren, K., Miner, B., Sorte, C., Thornber, C., Rodriguez, L., Tomanek, L., Williams, S., 2006. The impacts of climate change in coastal marine systems. Ecol. Lett. 9, 228–241. DOI: 10.1111/j.1461-0248.2005.00871.x.

Hockings, M., Dudley, N., Elliott, W., Ferreira, M., Mackinnon, K., Pasha, M., Phillips, A., Stolton, S., Woodley, S., Appleton, M., Chassot, O., Fitzsimons, J., Galliers, C., Golden Kroner, R., Goodrich, J., Hopkins, J, Jackson, W., Jonas, H., Long, B., Yang, A. 2020. COVID-19 and protected and conserved areas. Parks. 26, 7-24. 10.2305/IUCN.CH.2020.PARKS-26-1MH.en.

Ioannides, D., Gyimóthy, S., 2020. The COVID-19 crisis as an opportunity for escaping the unsustainable global tourism path, Tourism Geographies, 22 (3), 624-632, DOI: 10.1080/14616688.2020.1763445

Jaramillo, E., 2012. Ecological implications of extreme events on exposed sandy beaches: insights from the 2010 Chilean earthquake. In: VI th International Sandy Beach Symposium. Public Presentation, SouthAfrica, June 26th.

Jarratt, D., Davies, N., 2019. Planning for Climate Change Impacts: Coastal Tourism Destination Resilience Policies. Tour. Plann. and Develop, 17 (4), 423-440, DOI: 10.1080/21568316.2019.1667861

Jones, A., Gladstone, W., Hacking, N., 2007. Australian sandy-beach ecosystems and climate change: ecology and management. Zoologist 34, 2: 190–202. https://doi.org/10.7882/AZ.2007.018

Kühn, S., Bravo, E., van Franeker, J., 2015. "Deleterious Effects of Litter on Marine Life," in *Marine Anthropogenic Litter,* eds. M. Bergmann, L. Gutow & M. Klages. (Cham: Springer International Publishing), 75-116.

Legendre, P., Legendre, L., 2012. Numerical Ecology. Amsterdam: Elsevier.

Lucrezi, S., Schlacher, T.A., Walker, S., 2009. Monitoring human impacts on sandy shore ecosystems: a test of ghost crabs (*Ocypode* spp.) as biological indicators on an urban beach. Environ. Monit. Assess. 152, 413–424. https://doi.org/10.1007/s10661-008-0326-2

Lucrezi, S., Schlacher, T.A., 2014. The Ecology of Ghost Crabs, Oce. and

Mar. Biol: An Ann. Rev. 52, 201-256.

Manenti, R., Mori, E., Di Canio, V., Mercurio, S., Picone, M., Caffi, M., Brambilla, M., Ficetola, G., Rubolini, D., 2020. The good, the bad and the ugly of COVID-19 lockdown effects on wildlife conservation: Insights from the first European locked down country. Biol. Conserv. 249, 108728. doi.org/10.1016/j.biocon.2020.108728

Marion, J., 2019. Impacts to Wildlife: Managing Visitors and Resources to Protect Wildlife. Contributing Paper. Prepared for the Interagency Visitor Use Management Council, March 2019, Edition One

Marion, J., Leung, Y., Eagleston, H., Burroughs, K., 2016. A review and synthesis of recreation ecology research findings on visitor impacts to wilderness and protected natural areas. Jour. of Forest. 114 (3), 352-362. https://doi.org/10.5849/jof.15-498

Marshall, F., Banks, K., Cook, G., 2014. Ecosystem indicators for Southeast Florida beaches. Ecol. Indic. 44, 81-91. DOI: 10.1016/j.ecolind.2013.12.021

Martínez, A., Eckert, E.M., Artois, T., Careddu, G., Casu, M., Curini-Galletti, M., Gazale, V., Gobert, S., Ivanenko, V., Jondelius, U., Marzano, M., Pesole, G., Zanello, A., Todaro, M.A., Fontaneto, D., 2020. Human access impacts biodiversity of microscopic animals in sandy beaches. Commun. Biol. 3, 175. https://doi.org/10.1038/s42003-020-0912-6

Martins, G.A.L., 2007. A macrofauna bentônica das praias arenosas expostas do Parque Nacional de Superagüi – PR: Subsídios ao Plano de Manejo. Dissertação (Mestrado em Ecologia e Conservação). Programa de Pós Graduação em Ecologia e Conservação, Setor de Ciências Biológicas da Universidade Federal do Paraná. Curitiba.

MBON Pole to Pole (2019) Sampling protocol for assessment of marine diversity on sandy beaches. Marine Biodiversity Observation Network Pole to Pole of the Americas, 14pp. DOI: http://dx.doi.org/10.25607/OBP-665

McLachlan, A., Defeo, O., Jaramillo, E., Short, A.D., 2013. Sandy beach conservation and recreation: Guidelines for optimising management strategies for multi-purpose use. Oc. Coast. Manag. 71, 256-268. https://doi.org/10.1016/j.ocecoaman.2012.10.005

Mendoza-González, G., Martínez, M., Guevara, R, Pérez-Maqueo, O., Garza-Lagler, M., Howard, A., 2018. Towards a Sustainable Sun, Sea, and Sand Tourism: The Value of Ocean View and Proximity to the Coast. Sustainability 10, 1012; doi:10.3390/su10041012

Milanés C., Planas, J., Pelot, R., Núñez, J., 2020. A new methodology incorporating public participation within Cuba's ICZM program. Oce. Coast. Manag. 186, 105101. https://doi.org/10.1016/j.ocecoaman.2020.105101

Milanés, C., Pereira, C., Botero, C., 2019. Improving a decree law about coastal zone management in a small island developing state: The case of Cuba. Marine Policy Volume 101, March 2019, Pages 93-107, doi.org/10.1016/j.marpol.2018.12.030

Moraes, F., Milanés, C., 2020. Os limites espaciais da zona costeira para fins de gestão a partir de uma perspectiva integrada. Cap. 1 pp. [22-50]. In: Souto, R.D. (org.) Gestão Ambiental e Sustentabilidade em Áreas Costeiras e Marinhas: Conceitos e Práticas. Vol. 1. Rio de Janeiro: Instituto Virtual para o Desenvolvimento Sustentável - IVIDES.org, 2020. [260 p].

Niefer, I.A., 2002. Análise do perfil dos visitantes das Ilhas do Superagüi e do Mel: Marketing como instrumento para um turismo sustentável. Tese (Doutorado em Engenharia Florestal). Setor de Ciências Agrárias, Universidade Federal do Paraná. Curitiba.

Ocaña, F., de Jesús, A., Hernández, H., 2020. Co-occurring factors affecting ghost crab density at four sandy beaches in the Mexican Caribbean. Reg. Stu. in Mar. Sci. 36, 101310. https://doi.org/10.1016/j.rsma.2020.101310.

Olds, A.D., Vargas-Fonseca, E., Connolly, R.M., Gilby, B.L., Huijbers, C.M., Hyndes G.A., Layman, C.A., Whitfield, A.K., Schlacher, T.A., 2018. The ecology of fish in the surf zones of ocean beaches: A global review. Fish and Fisher. 19, 78-89.

Peng, C., Zhao, X., Liu, G., 2015. Noise in the Sea and Its Impacts on Marine Organisms. Int. J. Environ. Res. Public Health, 12, 12304-12323; doi:10.3390/ijerph121012304

Peterson, C., Bishop, M., 2005. Assessing the environmental impacts of beach nourishment. BioScience 55, 887e896.

R Core Team, 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Reyes-Martínez, M.J., Lercari, D., Ruíz-Delgado, M.C., Sánchez-Moyano, J.E., Jiménez-Rodríguez, A., Pérez-Hurtado, A., García-García, F.J., 2015. Human Pressure on Sandy Beaches: Implications for Trophic Functioning. Estuaries and Coasts 38, 1782–1796. https://doi.org/10.1007/s12237-014-9910-6

Rickard, C., McLachlan, A., Kerley, G.,1994. The effects of vehicular and pedestrian traffic on dune vegetation in South Africa. Oc. Coast. Manag. 23 (3), 225-247. DOI: https://doi.org/10.1016/0964-5691(94)90021-3.

Rutz, C., Loretto, M., Bates, A., Davidson, S., Duarte, C., Jetz, W., Johnson, M., Kato, A., Kays, R., Mueller, T., Primack, R., Ropert-Coudert, Y., Tucker, M., Wikelski, M., Cagnacci, F., 2020. COVID-19 lockdown allows researchers to quantify the effects of human activity on wildlife. Nat. Ecol. Evo. 4, 1156–1159. doi.org/10.1038/s41559-020-1237-z

Schlacher, T., Schoeman, D., Lastra, M., Jones, A., Dugan, J., Scapini, F., McLachlan, A., 2006. Neglected ecosystems bear the brunt of change. Ethol. Ecol. Evol. 18, 349e351.

Schlacher, T., Thomson, L., 2012. Beach recreation impacts benthic invertebrates on ocean-exposed sandy shores. Biol. Conserv. 147 (1), 123-132. doi:10.1016/j.biocon.2011.12.022

Schlacher, T., Nielsen, T., Weston, M., 2013. Human recreation alters behaviour profiles of non-breeding birds on open-coast sandy shores. Estuar. Coast. Shelf Sci. 118, 31-42. https://doi.org/10.1016/j.ecss.2012.12.016

Schlacher, T., Schoeman, D., Jones, A., Dugan, J., Hubbard, D., Defeo, O., Peterson, C., Weston, M., Maslo, B., Olds, A., Scapini, F., Nel, R., Harris, L., Lucrezi, S., Lastra, M., Huijbers, C., Connolly, R., 2014. Metrics to assess ecological condition, change, and impacts in sandy beach ecosystems. Jour. of Env. Manag. 144, 322-335. http://dx.doi.org/10.1016/j.jenvman.2014.05.036

Schlacher, T.A., Jones, A.R., Dugan, J.E., Weston, M.A., Harris, L.L., Schoeman, D.S., Hubbard, D., Scapini, F., Nel, R., Lastra, M., McLachlan, A., Peterson, C.H., 2014a. Open-coast sandy beaches and coastal dunes. Chapter 5. In: Lockwood, J.L., Maslo, B. (Eds.), Coastal Conservation. Cambridge University Press, Cambridge, pp. 37e94.

Schlacher, T.A., Lucrezi, S., Connolly, R.M., Peterson, C.H., Gilby, B.L., Maslo, B., Olds, A.D., Walker, S.J., Leon, J.X., Huijbers, C.M., Weston, M.A., Turra, A., Hyndes, G.A., Holt, R.A., Schoeman, D.S., 2016. Human threats to sandy beaches: A meta-analysis of ghost crabs illustrates global anthropogenic impacts. Estuar. Coast. and Shelf Sci. 169, 56-73.

Souza, J.L, Silva, I.R., 2015. Avaliação da qualidade ambiental das praias da ilha de Itaparica, Baía de Todos os Santos, Bahia. Soc. & Nat. 27 (3), 469-484. DOI: http://dx.doi.org/10.1590/1982-451320150308.

Souza Filho, J.R., Silva, I.R., Nunes, F.N., 2019. Avaliação qualitativa dos serviços ecossistêmicos oferecidos pelas praias da APA Lagoa Encantada/Rio Almada, Bahia, Brasil. Caminhos de Geografia Uberlândia 20 (72), 15–32. DOI: http://dx.doi.org/10.14393/RCG207241182.

Stelling-Wood, T.P., Clark, G.F., Poore, A.G.B., 2016. Responses of ghost crabs to habitat modification of urban sandy beaches. Mar. Env. Res. 116, 32-40. https://doi.org/10.1016/j.marenvres.2016.02.009

Steven, R., Castley, J.G., 2013. Tourism as a threat to critically endangered and endangered birds: global patterns and trends in conservation hotspots. Biodivers. Conserv. 22, 1063–1082. https://doi.org/10.1007/s10531-013-0470-z

Suciu, M., Tavares, D., Costa, L., Silva, M., Zalmon, I., 2017. Evaluation of environmental quality of sandy beaches in southeastern Brazil. Mar. Poll. Bull. 199; 133-142. https://doi.org/10.1016/j.marpolbul.2017.04.045

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, Brazil. Biol. Conserv. 127, 510-515.

Vilar de Araujo, C.C., Melo Rosa, D., Fernandes, J.M., 2008. Densidade e distribuição espacial do caranguejo Ocypode quadrata (Fabricius, 1787) (Crustacea, Ocypodidae) em três praias arenosas do Espírito Santo, Brasil. Biotemas, 21, 73-80. https://doi.org/10.5007/2175-7925.2008v21n4p73

Wickham, H., 2014. Tidy data. Journal of Statistical Software 59(10), 1-23. DOI: 10.18637/jss.v059.i10.

Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L., François, R., et al. (2019). Welcome to the Tidyverse. Journal of Open Source Software 4 (43), 1686. DOI: https://doi.org/10.21105/joss.01686.

Wilson, C., Tisdell, C., 2003. Conservation and Economic Benefits of Wildlife-Based Marine Tourism: Sea Turtles and Whales as Case Studies, Human Dimensions of Wildlife: An International Journal, 8 (1), 49-58. DOI: 10.1080/10871200390180145

Williams, A., Micallef, A., 2009. Beach management: principles and practice. London: Earthscan Publishers.

Winter, P.L., Selin, S., Cerveny, L., Bricker, K., 2020. Outdoor Recreation, Nature-Based Tourism, and Sustainability. Sustainability, 12 (1), 81.

Zambrano-Monserrate, M., Silva-Zambrano, C., Ruano, M., 2018. The economic value of natural protected areas in Ecuador: A case of Villamil Beach National Recreation Area. Ocean Coast. Manag. 157, 193-202. https://doi.org/10.1016/j.ocecoaman.2018.02.020

Zambrano-Monserrate, M., Ruano, M., 2019. Does environmental noise affect housing rental prices in developing countries? Evidence from Ecuador. Land Use Policy 87,104059.

Zambrano-Monserrate, M., Ruano, M., Sánchez-Alcalde, L., 2020. Indirect effects of COVID-19 on the environment. Sci.Total Env. 728, 138813. https://doi.org/10.1016/j.scitotenv.2020.138813

Zhang, F., Wang, X.A., Nunes, P., Ma, C., 2015. The recreational value of gold coast beaches, Australia: An application of the travel cost method. Eco. Serv. 11,106-114. https://doi.org/10.1016/j.ecoser.2014.09.001

Zielinski, S.; Botero, C.M., 2020. Beach Tourism in Times of COVID-19 Pandemic: Critical Issues, Knowledge Gaps and Research Opportunities. Int. J. Environ. Res. Public Health. 17, 7288. https://doi.org/10.3390/ijerph17197288

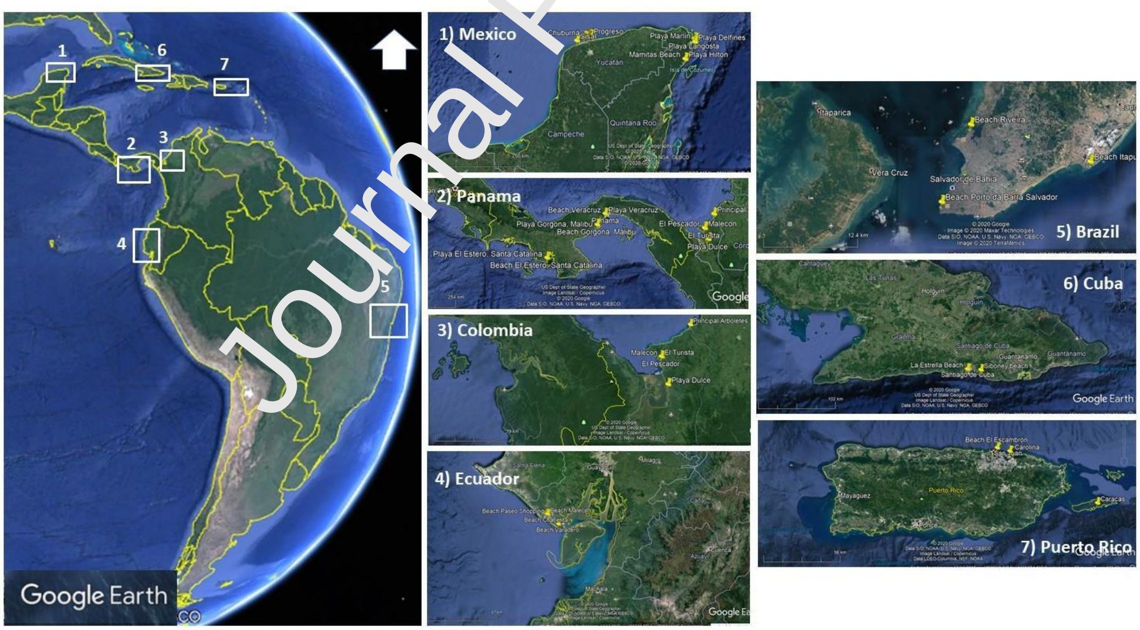


Fig. 1. Location of beaches in the study area (*Source: Images designed using Google Earth*).

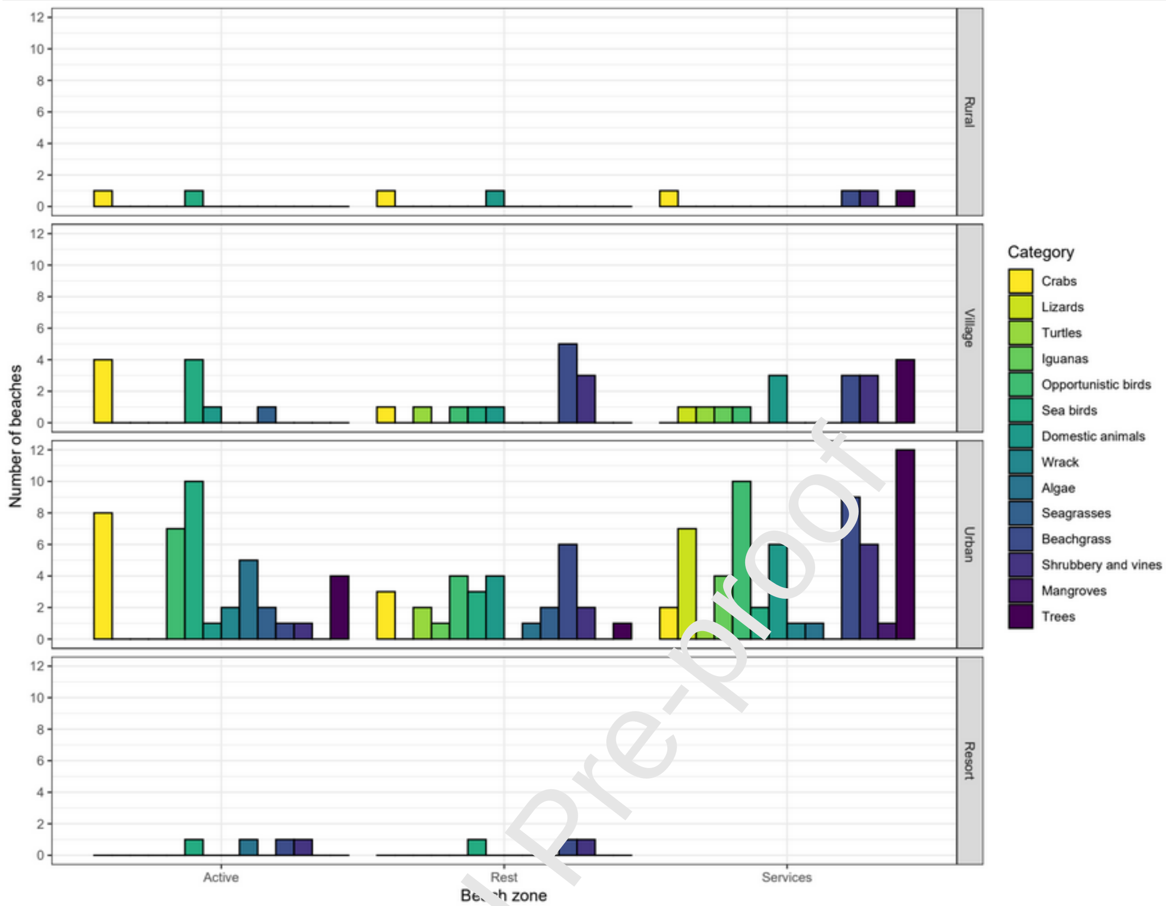


Fig. 2. Bioindicators observed in 3 zones of 29 recreational beaches in Latin America during the COVID-19 lockdown. Bars represent the number of beaches presenting each category. Details with the full list of species are provided in Supplementary 4.

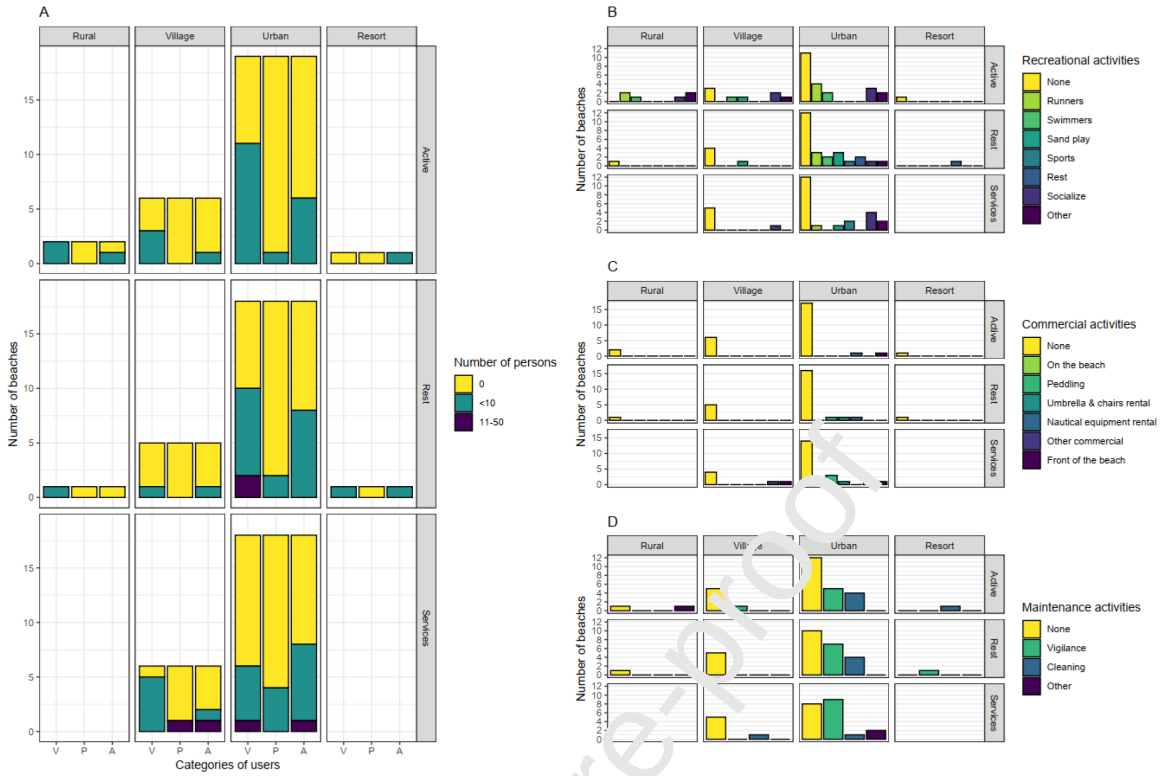


Fig. 3. Users density and activities in 29 recreational beaches in Latin America during the COVID-19 lockdown.

(The data are presented considering the type of beach and the beach zone. In A, user density is represented as the frequency of beaches without people, few people (<10), and many people (11-20) for each type of user (V = visitors, P = peddling, A = authorities). In B, the frequency of beaches for each type of recreational activity. In C, the frequency of beaches for each type of commercial activity. In D, the frequency of beaches with maintenance activities. Empty panels in Resort and Rural beaches indicate that this zone could not be evaluated or was absent.)

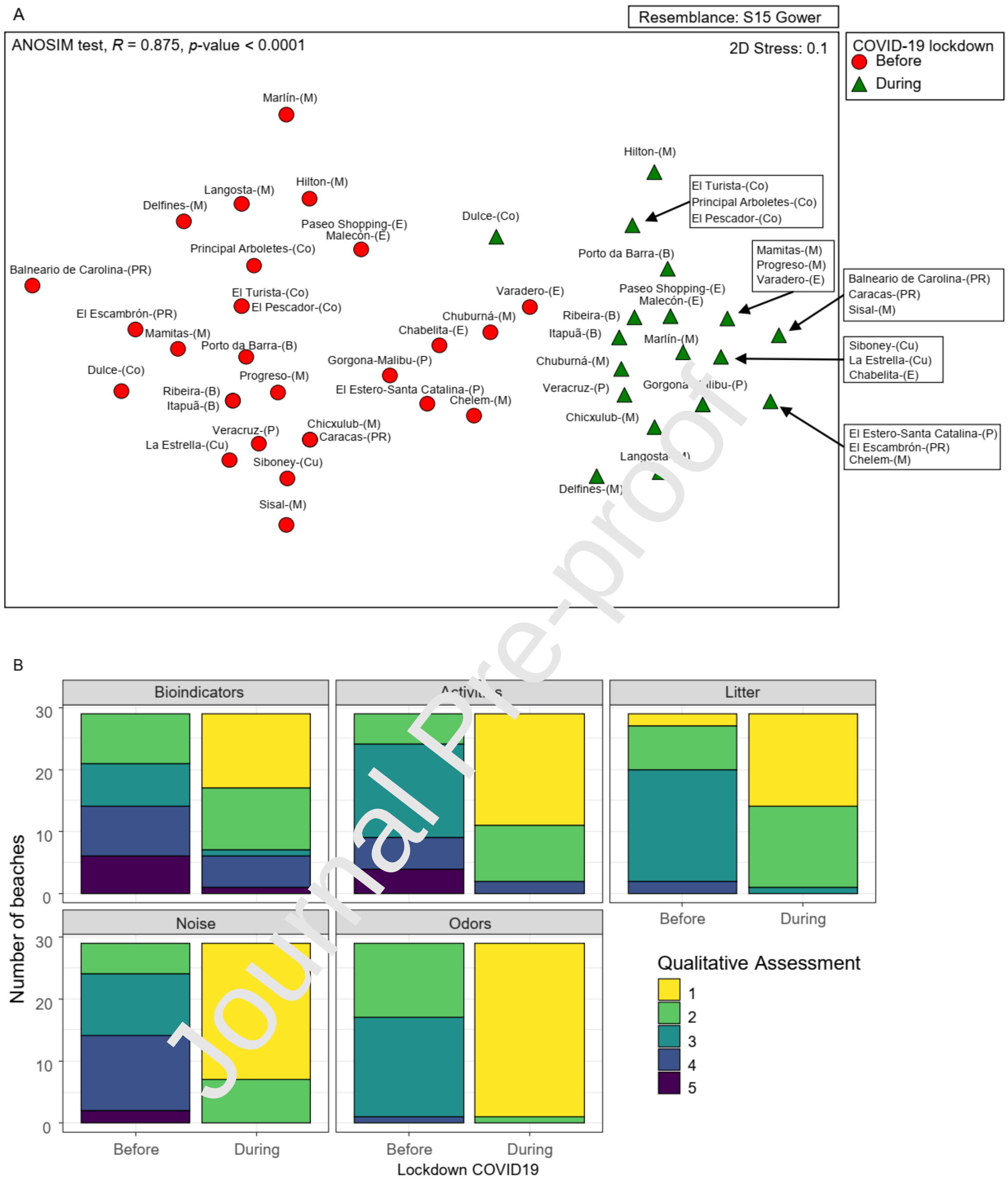


Fig. 4. Analyses of the qualitative assessments of bioindicators and anthropogenic stressors in 29 beaches in Latin America, before and during the COVID-19 lockdown. In A, a non-Metric Multidimensional Scaling based on Gower similarities between beaches considering the five indicators of biological conditions and anthropogenic stressors. Labels indicate the beach's name and in parentheses the letter of the corresponding country. Several beaches overlap, so the labels were arranged or grouped to facilitate graphic representation. In the upper left corner, the ANOSIM test result is indicated. In B, the frequency of beaches for each type indicator, before and during the lockdown. The indicators get worse as they approach 5. The definitions of each value for each indicator are detailed in Supplementary material 3.

Table 1. Contribution of each indicator to the differences in the perception of changes in Latin-American beaches before and during the COVID-19 lockdown, using the Similarity Percentage routine (SIMPER) to the Gower dissimilarities and the one-way ANOSIM test.

Indicator	Average Before	Average During	Sq.Dist/SD	Contrib%	Cum.%
Noise	3.4	1.3	1.33	27.5	27.5
Activities	3.2	1.5	1.02	23.3	50.8
Bioindicators	3.4	2.1	0.95	23.0	73.8
Odors	2.6	1.0	1.56	15.0	88.8
Litter	2.7	1.5	1.05	11.2	100.0

CRediT authorship contribution statement

E.H. Soto: Conceptualization, Methodology, Data Curation, Writing - Original Draft, Writing - Review & Editing, Project administration;

C.M. Botero: Conceptualization, Methodology, Validation, Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing;

C.B. Milanés: Conceptualization, Methodology, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization;

A. Rodríguez-Santiago: Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization.

M. Palacios-Moreno: Investigation, Data Curation, Writing - Original Draft, Visualization.

E. Díaz-Ferguson: Investigation, Writing, Review & Editing.

Y.R. Velázquez: Investigation.

A. Abbehusen: Investigation, Writing - Original Draft.

E. Guerra-Castro: Formal analysis, Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization.

N. Simoes: Investigation, Writing - Review & Editing.

M. Muciño-Reyes: Investigation.

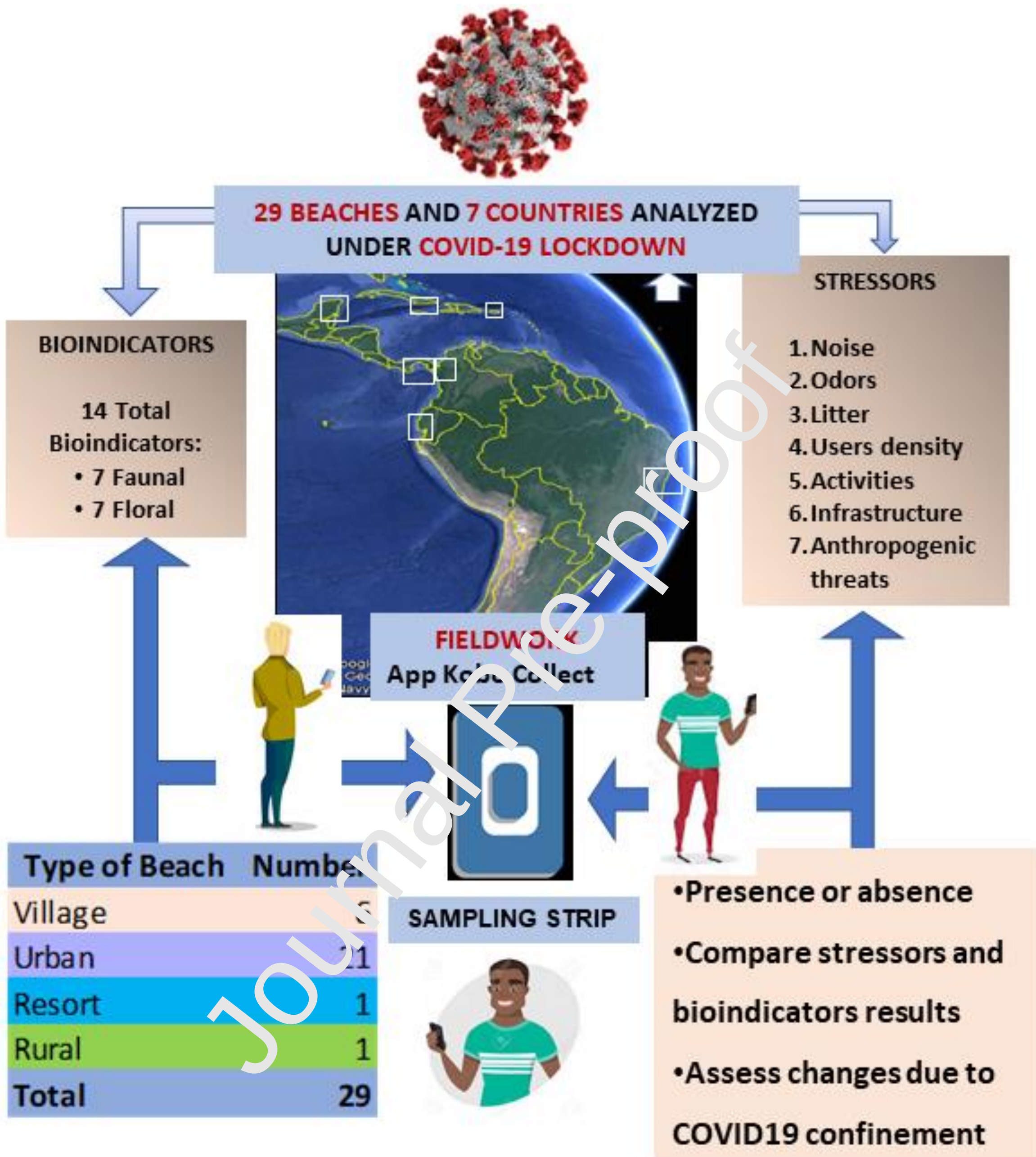
J.R. Souza Filho: Investigation, Writing - Review & Editing

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Graphical abstract



Highlights

Data collected on fieldworks was registered in a dedicated survey format on the virtual platform Kobo Toolbox which was linked to the Kobo Collect App

An overall increase of presence and activity of most bioindicators was observed mainly ghost crabs and dune vegetation

Anthropogenic stressors such as noise, odor, litter, user density and activities decreased remarkably during COVID-19 lockdown

The similarity patterns in the qualitative assessment of the beaches were significantly different between the conditions before/during the lockdown (ANOSIM, $R = 0.875$, $p < 0.0001$)