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IX INTERNATIONAL SANDY BEACHES SYMPOSIUM

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DAY 1. MONDAY 24TH JUNE 2024

KEYNOTE "Past, present and future of sandy beach ecology"

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Sandy beach research began intermittently about a century ago, only broadening in the second half of the 20th century and always lagging behind attention given to other coastal ecosystem types. While still behind other coastal habitats in annual research output, beaches have been receiving much greater attention in recent decades, especially since the initiation of a series of international symposia on the ecology of these systems. The first international sandy beach symposium, held in Port Elizabeth, South Africa in 1983, was a milestone and established modern sandy beach research as a recognized discipline in coastal ecology. Main emphasis was placed on the underlying physical structure and basic ecological processes that define and control the beach system, through the uniquely adapted fauna and flora, to the ecosystem structure. For the first time, sandy beaches were seen as ecosystems, and this foundation was built upon by seven further meetings, which were held in Chile, Italy, Spain, Morocco, South Africa, Brazil, and Crete. As time goes by, researchers have delved deeply into elucidating the intricate interactions among organisms inhabiting sandy shores, shedding light on their biodiversity, ecological processes, and responses to environmental changes. Further, despite sandy beaches being seen as intertidal interfaces between sea and land, a wider perspective was taken, seeing the beach as tightly coupled to its adjacent dunes and surf zone, which together defines the holistic littoral active zone. Through innovative methodologies and technologies, such as remote sensing, molecular analysis, and ecological modelling, scientists have gained insights into the complex dynamics of these ecosystems. Beach science has now developed beyond the initial exploratory stage and is an established and expanding field, based on paradigms, concepts and ideas of ecosystem structure.

Research has evolved and humans have become an ever more central part of the social-ecological system that is the sandy beach. Studies have increasingly focused on the impacts of human activities on sandy shore ecosystems, as well as the services that healthy, functional beaches provide to societies. Our understanding of the challenges facing sandy coasts, amidst the compounded impacts of natural and anthropogenic perturbations, requires holistic approaches to keep expanding our knowledge base. The inevitable reality of the significant human footprint on sandy shores highlights the need for collective action as the foundation for participatory governance.

Despite progress, numerous questions remain unanswered, offering ample opportunity for further understanding and improved management of these invaluable ecosystems.

Establishing the macroinvertebrate baseline assemblage and ecological quality status for 13 Orkney sandy beaches

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Data from Orkney Islands Council Harbour Authority's (OICHA) long-term intertidal macroinvertebrate monitoring programme were used to set a baseline, against which any future assessments can compare with. Time series (1974-1990 and 2002-2016) of macroinvertebrate data from 13 sites were analysed for temporal (between year) and spatial (between site) variability. Baseline macroinvertebrate data and Ecological Quality for the 13 Scapa Flow sites are described; the mean number of taxa (family level) was high (48) for all sites but with some inter- site variation in the dominant taxa and in agreement with the expected number of taxa for sheltered sandy beaches. All sites were classed as having at least a slightly disturbed ecological condition with one being classed as moderately disturbed in both recent (since 2002) and historical (1974-1990) time periods, reasons for these will be addressed.
Monitoring at these sandy beaches continues. The baseline data are used to help understand fluctuations in macroinvertebrate populations and any possible changes to the macroinvertebrate communities from new activities in the harbour area or from climate change. How these data provide a means to alert scientists and managers to potential 'effects' and also provide insight into how much change over time is normal will be discussed. This data set demonstrates the importance of long-term studies to provide reference for any future community differences that may take place following anthropogenic or natural changes.

Biodiversity and distribution of marine Gastrotricha along the Pacific coast of Costa Rica

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Gastrotricha is a minor but exciting phylum of small-sized invertebrates that, in marine settings, appear particularly speciose in clean sandy sediments. However, not much is known about their biodiversity and ecology on the beaches of the Neotropical region. Therefore, the objective of the current study was to determine the biodiversity of these small metazoans and their distribution in the Pacific Coast of Costa Rica and the relationships with local environment variables. To achieve this, we collected sediment samples from 27 beaches and measured various factors like granulometric characteristics, organic matter, carbonate content of the sand, salinity, and geographical location. We found a total of 50 species of Gastrotricha, most of which were potentially new to science. Although the overall diversity was high, individual beaches had low numbers of species. The main environmental factors that produced the species turnover between samples were sediment grain size and calcium carbonate content. The study found that species of the order Chaetonotida were mainly present in the littoral zone, while Macrodasyida were present in both the littoral and sublittoral zones. Additionally, Chaetonotida species showed a preference

for finer sediments. We also observed a slight change in species composition from north to south of the investigated coastline, which could be attributed to environmental and regional differences such as upwelling influence, estuarine systems, and exposure to oceanic influence.

A comparison of the abundance and distribution of three isopod species (*Eurydice kensleyi, Exirolana latipes* and *Excirolana natalensis*) at sandy beaches along the Namibian coastline

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Although sandy beaches constitute >50% of the shoreline along the Namib Coast, no attempt has been made to examine biogeographical changes in the macrofauna along the coastline and most of the existing studies were either done several decades ago or remain unpublished. Between July - October 2019, 16 sandy beaches running from North (Bosluis Bay) to South (Angra Point), along the Namibian coast were sampled to determine intertidal macrofaunal community structure and zonation patterns. The sampled beaches support diverse communities of microbenthic invertebrates, varying along the sampled transects. The main aim of this section of the study, was to quantifying the distribution and abundance of three isopod species, *Excirolana natalensis, Eurydice kensleyi* and *Excirolana latipes* on the different sandy beaches and demonstrate their occurrence along the beach zones. The study demonstrated that *Excirolana natalensis* was abundant on all beaches from the north to the south, whilst the isopod *Eurydice kensleyi* was absent on the northern beaches, but present at some central beaches and present at all southern beaches. *Exirolana latipes* had patchy presence across the northern and central beaches, however present on all southern beaches. Also, *Excirolana natalensis* was more abundant in the dry and retention zones, whilst *Eurydice kensleyi* was more abundant in the zone of retention and resurgence. The *Excirolana latipes* species was distributed along all beach zones, as per Salvat's zonation scheme. The differences in isopod abundance were attributed to possible environmental conditions such as water temperature, sediment grain size and disturbance occurring on the beaches.

Sandy beach macrofauna along the Southwest coast of Fiji: low species richness due to beach morphodynamics or low productivity in nearshore waters?

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Six sandy beach sites located on the south coast of Vit-Levu, Fiji, were sampled to study abiotic features and species richness and abundances of intertidal macroinvertebrates, to test the hypotheses that along this coast, those biotic attributes are closely related to beach morphodynamics, as established paradigmatically. At each site, beach face slopes were measured at four replicated transects extended between the front dunes or the seaward reach of the tree vegetation (upper shore level) and the low tide level. Sediment samples were collected at four the upper shore level, the drift and effluent lines and at the low tide level. Sediments for macroinvertebrates were sampled with a 10 cm diameter metallic core at the dry, retention and resurgence & swash zones of each beach. Sites were categorized according to

beach morphodynamic types, based upon pictures collected on sites, beach face slopes, mean grain size of sands and expert judgment. Univariate analyses showed that the mean number of intertidal species (dominated by crustaceans and polychaetes) and abundances of macroinvertebrates across all sites was 4.1 taxa (ranges = 2 - 6; sd = 1.7) and 917 ind. per linear meter of beach (m-1) (ranges = 133 - 1154; sd = 490). Densities were between 0.5 and 70 individuals m-2. Multivariate analysis indicated that biotic richness decreased significantly with increasing sediment grain size and beach slope. Based on upwelling and downwelling data at worldwide scale, we hypothesize that oligotrophic ocean conditions explain the low biodiversity of macroinvertebrate assemblages inhabiting sandy beaches of the tropical South Pacific islands, contrasting with the neighbor coastal ecosystems, such as coral reefs, mangroves, etc. Our study provides for the first time a reliable baseline that should contribute to the protection of natural sandy beaches along the shores of the Fiji Islands. This appears to be the most effective and sustainable initiative for monitoring a coastal zone profoundly threatened by human occupation and artificial coastal protection in the loom of climate change and sea level rise.

Long term patterns of bird use on a southern California beach.

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Birds can be valuable indicators of sandy beach conditions and food webs. The diversity and abundance of shorebirds have been associated with variation in resource supply including marine subsidies (e.g. macrophyte wrack) and intertidal invertebrate prey, and with impacts, such as coastal armoring and beach filling. Long-term data from bird surveys can reveal important trends in bird use including variation at population and community scales, synchrony across sites, habitat change, and shifts in timing and phenology of migration. We explore long term variation in beach birds using data from more than 30 years of surveys on an open coast beach. Birds at the study site occur in high numbers and diversity for an open coast beach (mean 131 birds per km, 9 species per km). Bird abundance and beach condition are strongly seasonal over the study period with higher abundance during spring and fall migration, and the overwintering period. Common birds (mean >1 km) include: numerically dominant shorebirds (9 spp.), and gulls (4 spp.) and terrestrial birds (2 spp.). These groups use beach habitat differently: most shorebirds feed by probing or surface-picking for beach invertebrates, gulls rest or scavenge and terrestrial birds do both. We detected responses of birds to event-based variation in beach conditions, changes in management and long-term trends in abundance and composition. Climate forcing and shoreline evolution, in particular the ENSO events in 1997- 98, 2015-16 and 2023-24, reduced the extent of sandy intertidal habitat at the study site. Overall shorebird and gull abundance declined during the study. Significant long-term trends in abundance were also detected at a species level. For shorebirds we saw a decline in abundance of one species (Sanderling) and increases in abundance of two species. Three species declined in abundance. For terrestrial birds, one species increased and one species declined. Our results suggest time series data on indicators like beach birds can provide valuable insights on the responses to a changing climate and highlight the need for long term observations of sandy beach ecosystems.

Organic carbon dynamics in sandy beaches:
Lessons learned from a high-energy subterranean estuary

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Sandy beaches are land-ocean interfaces where fresh groundwater mixes with seawater entrained by waves and tides, also termed the subterranean estuary (STE). Within the unconsolidated sandy beach aquifer, organic matter from both terrestrial and marine sources serves as a substrate for active, ubiquitous, and opportunistic microbial communities. Although beaches were well known sites of organic matter turnover for many decades, the mechanisms governing inputs, processing, and (re-)release of organic matter into the adjacent coastal ocean are still poorly resolved. We investigated organic matter dynamics at a high-energy beach STE located on a barrier island in the German North Sea. We were interested in the following questions: (1) What are the main sources and sinks of dissolved and particulate organic matter to the beach STE? (2) How is organic matter linked to STE microbial community structures and functioning? (3) What are the implications of STE-processes for the land-ocean transfer of organic matter? To this end we investigated porewaters, seawater, and sediments over almost a decade along cross-shore transects and sampling grids from the supra-o to the intertidal zone. Additionally, we analyzed groundwater from the islands' freshwater lens and conducted biogeochemical incubation experiments. We found that the beach STE porewater has relatively low dissolved organic carbon (DOC) concentrations compared to seawater and inland fresh groundwater, probably due to rapid microbial degradation fueled by high throughputs of oxygenated seawater. Moreover, the meteoric groundwater transports dissolved organic matter (DOM) from inland soils and buried peats into the shallow beach aquifer. Microbial communities in the beach STE adapt quickly to changing electron donor and acceptor availabilities and may even utilize DOM of advanced degradation state. Adsorption to minerals and coagulation with iron oxides are additional sinks of organic matter in the beach subsurface. We conclude that high-energy beaches are loci of substantial organic carbon retention and turnover, serving as important links between the organic and inorganic carbon cycle. Although investigating high-energy beaches is challenging, filling this knowledge gap will be essential to accurately estimate carbon fluxes across the global coastline.

Experimental design to know the adaptation of crustaceans to environmental change in suborbital flights

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Organisms from sandy shores, like Crustaceans, are adapted to live under extremous conditions. Suborbital space present physical and chemical conditions which are beyond the instability of the sustratum and heavy wave action that they can found on sandy beaches. If we elevated the crustaceans to suborbital space we will found changes in their behaviour, mobility, orientation and rhythmic activity because are key adaptive traits of invertebrates. However, we need design first special apparatus and devices that keep the organisms alive and can return to land safely. In addition to ensuring the biosafety of our experiment with the smallest amount of load since we only have 4.4 pounds of margin. The launches of suborbital flights are carried out on the continent far from the coast, therefore, we take the crustaceans of the Onicidea family as a model. We are currently researching the materials necessary for the prototype in which we are going to elevate these organisms. There are more questions than answers regarding stratospheric exploration in the search for knowledge of adaptation to drastic changes.

DAY 2. TUESDAY 25TH JUNE 2024.

KEYNOTE "Connectivity between beaches: the challenges of creating a network of marine protected areas"

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As the number of designated Marine Protected Areas (MPAs) in the world increases, many Countries claim to have created MPA networks to meet their 30 x 30 commitments. The IUCN defines an MPA network as 'A collection of individual MPAs operating cooperatively and synergistically at various spatial scales and with a range of protection levels that are designed to meet objectives that a single reserve cannot achieve'. In reality, most 'so called' networks of MPAs are at best collections of MPAs each having been selected for their individual features, and any actual connectivity between sites is coincidental and at best incomplete. The various aspects of connectivity, including passive connectivity, active connectivity, and habitat and seascape scale connectivity will be discussed. The complexity of the issues that need to be taken into account when designing a truly connected network of protected areas will be explored using the example of horse mussel beds in Scotland. Although not a sandy beach species the lessons learned from investigating this species are relevant to ensuring that what is created is a connected network of sandy shore sites. No measure of connectivity between sites is absolute – different species' dispersal mechanisms and ranges exist. What may represent the optimal connectivity between various sites for one species may be totally inadequate for another. Thus, any claims of connectivity need to be clearly defined.

To establish connectivity within a network of MPAs there needs to be better understanding of how connections between sites operate in both time and space, as well as greater recognition of the impacts of present and future climate change together with the importance of identifying and protecting refugia for given species, better monitoring to demonstrate continuing or new connectivity. Finally, it is important to establish what level of certainty in the effectiveness of any connectivity is acceptable and whether it can be determined by inference rather than more labour-intensive procedures such as genetics studies or tagging.

Geoenvironmental dynamics-benthic species distribution modelling for sandy beaches and sandflats based on the ecohabitat chart and saturated-unsaturated seepage analysis

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The dynamics of suction that represents the tension of moisture in sediment play a pivotal role in controlling the geophysical environments of sandy beaches and sandflats, and there is a close linkage between the suction dynamics-induced variations of geophysical environments and diverse biological activities, yielding a range of geophysical environmental conditions that enable burrowing, burrow development, and physiological activity of Arthropoda, Mollusca, and Annelida species. In ISBS 2018, I presented an ecohabitat chart showing the critical geophysical environments for diverse macro-infauna from juveniles to adults inhabiting sandy beaches and sandflats. However, there was no predictive modelling framework for evaluating the linkage between such coastal geoenvironmental dynamics and the benthic species distribution in sandy beaches and sandflats. Here, I present an integrated platform for predicting and evaluating the coastal geoenvironmental dynamics-induced benthic species distribution, by combining the ecohabitat chart and a saturated-unsaturated seepage analysis. In this development process, the ecohabitat chart was upgraded by reflecting the geophysical environmental characteristics of nineteen sandy flats and sandy beaches with diverse tidal ranges, sediment characteristics and morphology, and by superimposing the optimal geophysical environment for the sand bubbler crab *Scopimera globosa*. The integrated platform was then validated against the observed distribution changes of *S. globosa, Haustorioides japonicus, Excirolana chiltoni* and *Trinorchestia trinitatis*, caused by typhoon- and monsoonal storm-induced geomorphological changes in Naha sandy flat and Gokahama sandy beach, Japan. Essentially, the platform consistently accounted for the distribution changes in the four decapod, amphipod, and isopod species, associated with the event-induced morphological changes. The developed integrated platform is expected to facilitate the prediction and evaluation of the benthic species responses to a range of coastal geoenvironmental dynamics manifested in sandy beaches and sandflats, including the response of species to a climate change-induced sea-level rise and associated geomorphological changes. Hence, the platform could contribute to a geoenvironmental dynamics-based ecological management with significant difference in their characteristics.

Physical control paradigm shift? New evidences of predator-prey regulation on sandy beaches

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Sandy beaches are a harsh and homogeneous coastal ecosystem in appearance, but hold intricate ecological dynamics assumed to be governed by physical conditions. While ecological interactions are often considered weak predictors of population dynamics on sandy beaches, their significance remains underexplored. This study aims to investigate the regulatory role of consumer-resource relationships on sandy beaches populations in northern Rio de Janeiro, southeastern Brazil. The study focusses on four indicators species: ghost crab (*Ocypode quadrata*) and tiger beetle (*Cylindera nivea*) as generalist and specialist predators, respectively; and sandhopper (*Atlantorchestoidea brasiliensis*) and golden beetle

(*Phaleria testacea*) as potential preys. Over 18 months, population densities were monitored across three low urbanized beaches with different morphodynamics: Farol de São Tomé (intermediate-reflective), Grussaí (intermediate), and Santa Clara (intermediate-dissipative). The potential reciprocal regulation of the populations for four target species was tested comparing the theorical predator-prey models distribution and the respective population via Kolmogorov-Smirnov test. The physical influence in population density was tested via multiple regression. The trophic ecology and relationship between populations was evaluated by stable isotope analysis. Circular statistics revealed seasonal patterns in tiger beetles and ghost crabs, though without significant annual pattern. Using predator-prey models, the tiger beetle population appears significantly influenced by sandhopper abundance. Multiple regression analysis showed limited influence of physical variables on predators and preys' density, suggesting that physical factors may not be primary drives of temporal variation at local scale. Given the tropical setting, seasonal fluctuations are expected to be minimal, but reproduction events and niche requirements (evaluated by stable isotopes and physical influence) might justify this variation. While the predator-prey models require refinement, initial findings suggest at least a potential one-way bottom-up regulation. In conclusion, different from spatial patterns, which emphasize physical drives on population and community dynamics, this study highlights the importance of ecological interactions shaping temporal variation. By shedding light on predator-prey and temporal patterns, this study offers valuable insights for conservation efforts on beach ecosystems, and provide new evidence that challenges the paradigm of exclusively physical control over beach biodiversity.

Scavengers at the ocean's edge: Landscape features shape carrion processing on ocean-exposed sandy beaches.

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Ocean beaches are conventionally regarded as depositional environments where marine-derived matter, including washed-up carcasses of animals, typically accumulates in distinct strandlines; these stranded animal carcasses support diverse and abundant assemblages of vertebrate 'beach scavengers'. Ocean beaches are also backed by various geomorphic features and diverse vegetation. Here we explore, on ocean shores in Australia, how permutations of spatial interface properties (e.g. distance upland into dunes), broad habitat types (e.g. beach vs headland), and dune forest vegetation (e.g. canopy cover) shape the detection and consumption rate of carrion. Scavenging rates peaked in a narrow zone straddling the supratidal storm drift line, creating a distinct spatial cline in carrion processing. A diverse suite of birds (several raptor species, corvids, gulls), mammals (dingos, foxes, feral cats and dogs, pigs, rats) and lizards foraged for animal carcasses on the beaches. By contrast, carcass consumption in upland, forested areas was substantially less and, when it occurred, was dominated by large monitor lizards. Carrion detection and consumption were also lower on rocky shores of headlands than on sandy beaches. Vegetation characteristics modified these patterns to some degree, with fewer carcasses being consumed by birds under denser canopies. Overall, the distribution and activity of scavengers broadly map carrion resources, modified by seascape and habitat features that influence the probability of carcass detection by consumers and their spatial foraging patterns. Irrespective of some variation in carrion consumption patterns, distinct functional trophic hotspots are a recurring trait of ocean beaches.

Behavioural patterns of coastal talitroids under scenarios of coastal erosion

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In order to highlight the effects of Global Change on sandy shores worldwide, the escape response of beach resident Talitroidea was investigated via a meta-analytical approach. Assumptions were that: 1) Talitroidea are keystone species of sandy shores across temperate to subtropical areas 2) their direct development ties them to the beach of origin, making them sensitive to environmental changes, and 3) a measurable behavioural shift is their expected response to a changing environment. A dataset proceeding from 35 beaches and 16,179 individual records was hence investigated, with queries related to behavioural variations under scenarios of coastal erosion by 2050 and 2080, extracted from the "Global long-term shoreline evolution" dataset made available by JRC and expressed as meters of beach loss. Escape directions recorded in situ were transformed to be considered as sectors, each one subtending 90° and centered around the 45th degree. Sectors hence included the following range of options: transformed seawards escape direction; transformed landwards escape direction; transformed directions parallel to the shoreline. A qualitative modelling was then performed with a Naïve Bayesian approach (a probabilistic machine learning algorithm which allowed to deal with the non-random directional choice, specific of that dataset). Models highlighted an increase of escape along the directions parallel to the shoreline when beaches were under erosional dynamics. A high-precision seawards escape direction is known to be the behaviour displayed by talitroids under dynamic equilibrium conditions. The increase of long-shore movements seems to be a meaningful response to changes, with distribution patterns of populations and species expected to change rather than facing local extirpations. These models integrate the perspective of talitroids as isolated, locally-bound populations, highlighting potential for connectivity in a dynamic context such as global changes-related scenarios, and calling for attention towards the landscape scale.

The role of massive wrack accumulations of an invasive macroalgal species to beach metabolic activity

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Accumulations of macroalgal wrack are of crucial importance for recycling nutrients and regulating trophic connectivity in sandy beaches. In addition, beach wrack can be considered metabolic hotspots with high activity and rates of CO2 flux. However, the sudden beaching of huge seaweed masses smothers the coastline and forms rotting piles on the shore. The decomposition of sudden pulses of wrack can modify

dramatically the biogeochemistry of beach sands, and the presence of invasive macroalgae may involve deleterious effects on the wrack metabolic activity. We quantified the biomass of *Rugulopteryx okamurae*, a very aggressive invasive species, on five sandy beaches from the Atlantic coast of the Strait of Gibraltar (Spain), and we tested the effects on respiratory CO2 fluxes using an infrared gas analyser (IRGA). All the beaches showed large accumulations of *Rugulopteryx* wrack deposits, mainly in the intertidal area, ranging from 23.4 ± 5.2 to 96.0 ± 3.2 % (mean ± SE) cover of the sampled area. The biomass changed significantly between beaches, ranging from 968.3 ± 287.7 kg m-1 to 9210 ± 1279.4 kg m-1 (mean ± SE). The wrack patches supported high metabolic activity, with CO2 fluxes averaging (±SE) 19.15 ± 5.5 µmol C m-2 s-1, > 5 times as high as that of tropical rain forests. Wrack metabolic rates (mean ± SE) ranged 60-fold across beaches, from a minimum of 2.04 ± 0.06 to a maximum of 123.1± 59.87 µmol C m-2 s-1. There was a considerable within-beach variability in the metabolic rates related to the distance of the wrack from the shoreline, as the average respiration rates tended to increase significantly from the swash to the drift line. Moreover, thicker wrack patches combined with a more degraded algal stage showed significantly higher CO2 fluxes. Massive amounts of beach wrack accumulations release huge amounts of CO2 and we suggest they can become a significant source of greenhouse gas emissions. With climate change and increasing anthropogenic waste expected to accelerate the rate of wrack accumulation on beaches, this study provides timely information for developing nearshore carbon budgets.

Deciphering spatial scales of connectivity in subsidy-dependent coastal ecosystems

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Ecosystem connectivity may bolster the resilience of ecosystems to climate change. Subsidies of material and energy from donor ecosystems can significantly influence the structure and dynamics of recipient communities and food webs. The largest observed cross-ecosystem fluxes are from marine to terrestrial systems, which primarily consist of exported primary production delivered by currents and tides. These fluxes are exemplified by the substantial subsidy of organic matter exported by highly productive nearshore kelp forests to sandy beaches. The wrack subsidies exported from kelp forests to beaches support biodiversity and numerous ecosystem functions while fueling productive beach food webs. Kelp wrack inputs to beaches are known to be temporally dynamic, but the relative spatial scales at which this connectivity operates are largely unresolved. Here, we determine the scale at which connectivity between beaches and giant kelp (*Macrocystis pyrifera*) forests is maximized using comparisons on local (100 m) to regional (100 km) scale measurements of kelp wrack inputs along with nearshore kelp supply, via Landsat-derived kelp canopy biomass estimates. Our results indicated that connectivity between kelp forests and beaches is maximized on local scales of 3 to 6 km. Further, these relationships are strongest in winter and weakest in summer. In addition, the form of kelp wrack (fronds vs. whole plants) is an important factor in determining the spatial scale of connectivity with kelp forests. As the impacts of stressors, like climate change and anthropogenic development, weaken ecosystem connectivity, elucidating the scales of variability in cross-ecosystem fluxes will be critical for conservation of beach ecosystems and their ecological functioning.

Understanding the role of the dead foundation species *Posidonia oceanica* in Mediterranean sandy beaches

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In the Mediterranean sea, the dead leaves and rhizomes of the endemic seagrass *Posidonia oceanica* (L) Delile accumulates in sheltered and embayed sandy beaches and form an organically-enriched substratum on the supralittoral and shallow subtidal. This necromass is considered important as food and refuge for the invertebrates that constitute an important food subsidy to demersal fishes, when the necromass is in the intertidal and subtidal beach zone, and to seabirds. Sometimes, this necromass has been indicated as an important subsidy that may maintain local fisheries, but evidence is scant. In addition, these deposits are considered a nuisance by tourists and local authorities and often removed to maintain the "economic value" of the beach, especially during high season. In this paper, we have quantified how dead seagrass leaves and rhizomes contribute to invertebrate and coastal fish nutrition in the urban area of Cote d'Azur, North-Western Mediterranean, France. We have used visual census, quantitative sampling of necromass and experimental fishing in order to estimate necromass characteristics, invertebrate abundance and stable isotope composition of the necromass, the invertebrates and fishes in 6 beaches characterised by a different coastal development and tourism. In particular, we have focused on two dominant invertivorous fishes, one of commercial interest. These results are the conclusions of a locally funded project, by RegionSud. Invertebrate and fish assemblages varied across beaches according to the level of development and decomposition of the necromass, but the necromass was always an important trophic subsidy to invertebrates. Dead *Posidonia* indirect (through invertebrates) trophic contribution to the fishes was found relevant, but variable among beaches. We suggest that urbanisation can play an important role in determining the importance of this necromass as trophic subsidy to sandy beaches and that maintaining *Posidonia* dead leaf biomass on the beach is important for preserving or restoring the ecological role of urban beaches.

Testing the Cumulative Harshness Hypothesis in sandy beach populations: What should be expected?

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The Cumulative Harshness Hypothesis predicts that human disturbances amplify the impact of natural beach harshness on sandy beach populations. This hypothesis was introduced in a meta-analysis and it was initially tested across higher taxonomic groups. The meta-analysis compared the response of indicator families such as Ocypodidae, Talitridae, Hippidae, Cirolanidae and Glyceridae to human disturbances on beaches exhibiting different morphodynamic characteristics. While this hypothesis contributes for understanding the ecology of sandy beaches in the Anthropocene era and the efficiency of indicator taxa in signalize human disturbances, it still awaits validation at species level. Here, we showcase studies where

efforts were made to test the Cumulative Harshness Hypothesis using three species with markedly different biology: the ghost shrimp *Callichirus corruptus* (Hernáez, Miranda, Rio & Pinheiro, 2022); the tiger beetle *Cylindera* (Plectographa) nivea (Kirby, 1819) and the wolf spider *Allocosa brasiliensis* (Petrunkevitch, 1910). Ghost shrimp exhibited a significant response to beach morphodynamics, showing higher density, larger body size, and greater fecundity on less severe areas, corroborating the Habitat Harshness Hypothesis. Moreover, ghost shrimp from more urbanized beaches displayed slightly smaller body size and fecundity, although this pattern remained consistent regardless of morphodynamics. The impact of an urbanization metric on the tiger beetle was more pronounced on dissipative and reflective beaches. It is suggested that on intermediate beaches the risk of sedentary larval flooding in the supralittoral might be comparatively lower than in dissipative beaches, and adult energy expenditure to evade the harsh swash during feeding might be less than on reflective beaches. Finally, the wolf spider demonstrated higher abundance on reflective and dissipative extremes, as well as in less urbanized areas, but these effects were independent of each other. In conclusion, only the tiger beetle appeared to be influenced by the combined effects of natural and anthropogenic severity, corroborating the Cumulative Harshness Hypothesis. Our findings further underscore the significance of understudied beach fauna as indicator species, highlighting their crucial role in monitoring human impacts on this threatened ecosystem.

KEYNOTE: "Collapse disasters at/around natural and artificial sandy beaches with mitigation measures"

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Amid global climate change, the ocean wave conditions are becoming more severe along more than half of the world's coasts, posing risks of coastal disasters worldwide. Here, I present some recent advances in understanding and mitigating the impact of collapse disasters at/around natural and artificial sandy beaches. Collapse is a consequence of coastal internal erosion, cavity formation and cavity destabilization under diverse environmental forcing such as waves, tides, flows, groundwater level fluctuations, rainfalls, and earthquakes. Collapse can lead to a fatal accident where a cavity formed in sands suddenly collapses without giving any alarming signs to the sand surface. The key factors and processes involved are: propagation of fluctuating water pressure, wash out of sand particles, arch effect and the role of suction. The role of suction, i.e. negative pore water pressure relative to atmospheric pressure, is of particular importance, since no significant cavities would be formed in dry or saturated states of sands. This means that suction may control the lifetime of cavities in unsaturated granular materials above groundwater levels accompanying flows of pore fluids (air and water) under complex hydro-environmental conditions. In an artificial sandy beach, internal erosion stems from defects in joints or sand covers of coastal facilities, allowing sand particles to be washed out through the joints and/or defects under continued hydrodynamic forcing such as waves and tides. Cavity collapses when suction decreases irrespective of the types of forcing conditions. A practical countermeasure for suppressing such internal erosion and collapse in artificial sandy beaches has been developed for disaster prevention/mitigation. Severe wave impacts can occasionally cause damages to coastal roads surrounding natural sandy beaches owing to scour and erosion. The combined analyses of wind waves, hydraulic flume experiments, and field surveys of the past coastal disasters demonstrate that the collapses of the coastal road embankment slopes behind natural sandy beaches are the consequence of coupled surface erosion, scour, and internal erosion subject to waves, flows, and overtopping. The presence of overtopping enlarges the extent of collapses. New filter design criteria can facilitate preventing and mitigating the impact of such collapse disasters against various dynamic forcing conditions.

Just add sand: beach nourishment effects on subtidal benthic macrofauna in SE Florida

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Shoreline erosion is a major concern for many urban beaches. Sand nourishment is a common corrective practice but must be repeated approximately every 7-10 years (SE Florida). The large amounts of freshly translocated sand on the beach, intertidal, and subtidal regions bury many smaller invertebrates which are unable to dig themselves out of the 1 m plus deposition. We were interested in how beach nourishment affected benthic subtidal communities. Specifically, we wished to look at species resilience and how nourishment affects the nearshore benthic macrofaunal community closer to the shoreline compared to distance from shore and depth. This study examined an urban beach in southeast Florida before and after a beach nourishment event. Benthic macrofaunal communities, geological surveys and beach profiles were surveyed annually in June from 2018-2023 off Palm Beach, Florida, USA. The beach underwent two nourishment events, in January-April 2015 and another in March-May 2020. Sixty subtidal macrofaunal sampling cores were collected along 4 transects (15 cores each) at 50 m, 100 m, 150 m, and 200 m from the shoreline. Geological cores were also taken at each transect (3 cores per transect, 12 total per sampling dates). Macrofaunal survey results revealed 54 taxa amongst 680 individuals. 25 taxa were only found 1 or 2 times over the 6 years. Seven taxa were identified as being dominant (over 5% of the total abundance during the 6 years) comprising 56.8% of the total counts. One taxon, *Ancinus depressus*, was found commonly throughout six years and though each transect. Other taxa were found more commonly along the closest transects, *Scolelepis squamata* and *Scoloplos fragilis*, while others were found in the deeper and further transects, *Armandia agilis*, *Haustorius jayneae*, and *Eurydice personata*. The lowest abundance and richness count occurred in 2021, approximately one year following a beach nourishment event. Abundance partially rebounded through 2022 and 2023 but they did not retain the pre-nourishment 2018 numbers, which was also 3 years post a nourishment. Recovery does seem to be occurring but the more frequent a nourishment project the less of the ability for continuous recovery to occur.

Projecting the effects of sand nourishment projects on sandy beach ecosystems

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Climate change is affecting coastal communities globally, with growing impacts of sea level rise, flooding, and erosion. Determining the appropriate coastal adaptation approach (or combination of approaches) to improve resilience to climate impacts carries tradeoffs, especially for beaches. Beach nourishment or filling is widely used to address coastal erosion in many regions, and its use is expected to increase. During the last century, over 1.2 billion m3 of sand have been used across more than 3,200 nourishment projects in the USA, exhibiting a trend of exponential growth in volume over time. While often framed as a less impactful approach than traditional, hard infrastructure (e.g., seawalls, breakwaters), the environmental impacts of nourishment across a diversity of fauna, vegetation, and connected ecosystems are significant. However, every nourishment project is different, which makes predictions of impacts or recovery

trajectories for beach ecosystems especially challenging. To assess research needs for the California coast, we identified information gaps on the ecological impacts of nourishment for beaches. Key gaps included spatial (e.g., geographic regions), temporal (e.g., long-term or repeat projects), as well as ecological impacts, such as nearshore fish communities, invertebrate communities, shorebirds, and submerged and dune vegetation. In many studies, comparative baseline and reference site data were not available, which further impairs impact assessments. To address this deficit, we developed a conceptual model for projecting the relative impacts of different attributes of these projects including size, frequency, placement location, starting conditions, fill grain size, and sediment matching, using results from the literature. Relative impacts increase as the size and frequency of the nourishment activities increases and as the grain size and other sediment characteristics diverge from baseline conditions. Starting site conditions and placement location also substantially affect the degree and type of impacts; for example, sand placement on a groomed upper beach may have fewer impacts than placement on the lower intertidal beach. Our model provides a framework for projecting the relative impacts of these projects and highlights the need for continued research on the ecological impacts of beach nourishment as a climate adaptation approach.

Anthropogenic debris on ocean beaches: The dominant role of geomorphology in creating hotspots.

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Ocean beaches accumulate anthropogenic rubbish at unprecedented amounts and spatial scales. This 'global beach litter crisis' is matched by equally unprecedented investments in beach clean-ups by an astonishing diversity and number of citizens and NGOs. Yet, fundamental questions about the distribution of beach litter and the drivers of spatial patterns have, curiously, remained largely unresolved. Potentially, this makes beach clean-ups less effective for a given amount of investment.
Here we mapped debris across diverse seascapes in Australia to assess whether and how litter amounts are associated with particular geomorphological traits of the shoreline. Litters distributions were extraordinarily variable, creating a complex spatial mosaic of debris strandings. Several features consistently accumulated litter, often orders of magnitude higher than abutting shoreline segments: small creeks discharging across sandy beaches, embayed shores ('pocket beaches'), and ravines all represented distinct litter hotspots. By contrast, significantly fewer litter items washed up on rocky shores composed of bedrock. Boulder and cobble shores effectively function as gigantic 'filters', concentrating litter at depth between stones. The practical implication of mapping debris at scales and identifying recurring hotspots is that it enables the community to target their beach clean-ups more effectively and hence deliver better debris mitigation for coastlines.

Producing a digital sandy beach and applications in ecology

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Ecological studies and management strategies can utilize geospatial analysis tools to facilitate decision-making. Geospatial data, such as GNSS-based shoreline monitoring methods and semantic information extracted from satellite and/or aerial images provide a better understanding of this complex ecosystem. However, the use of orbital images typically involves high costs and low temporal and spatial resolution, making it unsuitable, especially in small areas. Unmanned Aerial System (UAS, aka drone) based on Photogrammetry procedure is a valuable tool for topographic mapping and tridimensional models. The greater accessibility of this technique to the scientific community expands the possibilities for use into: i) description of beach morphodynamic; ii) coupling information to other environmental surveys; iii) beach management strategies. The aim of this study was to integrate environmental digital layers of abiotic and biotic variables, such as organic matter content, topographic information, temperature, sediment characteristics and spatial distribution of macrofauna. Through the integration of these different layers of information, it was possible to conceptualize the term "digital beach" and show how these data can be explicitly used in ecological models or management. The aerial images were recorded with DJI Mavic Air multirotor quadcopter with 80% front and 75% side overlaps. The flight altitude was 45 m above ground level resulting in image nominal spatial resolution, expressed in ground sample distance (GSD) of 1.5 cm. Ground Control Points (GCPs) were pre-signalized and measured with a GNSS/RTK base station and rover. The Digital Surface Model (DSM) and the orthomosaic map were generated applying a Structure from Motion - MultiView Stereo (SfM-MVS) photogrammetric processing on Agisoft Metashape. To gather information about macrofauna communities, pitfall traps were used, and location of burrows of the species *Ocypode quadrata* were identified. Interpolation and integration of these data allowed spatial representation of environmental characteristics and macrofauna distribution. We demonstrated how this information can be used to produce species distribution models of *O. quadrata* burrows using environmental predictors, explicitly testing ecological hypothesis. Knowing and monitoring these indicators in a GIS and creating a "digital beach environment," is an innovative tool in ecology, conservation, management, and governance of beach ecosystems.

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Conservation shortcuts on sandy beaches: local and global studies (2020-2024)

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Long-term ecological studies are challenging due to ecosystems' complexity, conservation urgency, and financial constraints. Therefore, conservation scientists use tools like indicator, umbrella, and flagship species to optimize monitoring and enhance biodiversity management. Over the past four years, we have

identified different conservation shortcuts for assessing the impacts of human disturbances on sandy beaches, prioritizing conservation efforts in key areas, and fostering community engagement in conservation actions. This trajectory began with meta-analyses, which revealed that 11 macroinvertebrate families respond adversely to diverse human disturbances and pollutants. Overall, population abundance serves as a more robust indicator compared to aggregate community descriptors. In addition, early-warning bioindicators encompass measurements like body size and trophic niche, exemplified by ocypodid crab, which indicate sharp declines in individual performance and health at the organism level. "Microplastic ecology" has also been applied as an approach to identify diagnostic environmental indicators. The ingestion of microplastics by macroinvertebrates and fish, primarily detritivores and planktivores, has been verified. However, only a limited number of taxa ingest microplastics at a similar rate that these particles are commonly found in water and sediment. Applying the “road ecology” approach, we found animals like sea-turtle hatchlings and crabs killed by vehicles on avenues and streets near beaches. The main indicator of road impacts on coastal biodiversity is the ocypodid crab. These animals are especially susceptible in low-urban areas experiencing erosion and during storm events, evidencing the impact of coastal squeeze. Indeed, areas undergoing erosion have already been avoided by sea turtles nesting. Our next step is to investigate whether beach patches with the highest nesting activity have also the greatest diversity of supralittoral macroinvertebrates, supporting the application of sea turtles as potential umbrella species. It is well-established that sea turtles show the highest level of charisma among beach visitors. However, a choice experiment indicates that shorebirds, pompano fish, ocypodid crabs, and hippid mole crabs also raise positive feelings among beachgoers, different from sandhoppers and tiger-beetles. Currently, we have prioritized understanding the responses of understudied species like ghost-shrimps, tiger-beetles, wolf-spiders and shorebirds to human disturbances, with conclusions aligning with the observed global pattern of negative effects.

Urbanization impacts on sandy beach fauna: Insights from environmental DNA metabarcoding and advanced statistical models

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Sandy beaches are globally significant ecosystems increasingly threatened by anthropogenic pressures and sea level rise, resulting in coastal squeeze. In this study, we applied sediment DNA metabarcoding to 660 sediment samples from an urbanization gradient along the Dutch West Coast to understand the effects of human activities on these beach ecosystems. Our sampling included the lower and upper intertidal areas, supralittoral zones, foredunes, and primary dunes, extending from the dunes to the low tide line across 55 transects. We combined this sampling with a reference barcoding campaign, resulting in the addition of 750 new cytochrome c oxidase I (COI) barcodes for beach meiofauna, which helped with the annotation of metabarcoding data. We applied Generalised Dissimilarity Modelling (GDM) and scalable joint species distribution models (sjSDM) to examine changes in beta diversity and the ecological preferences of micro- and meiofaunal taxa due to increasing urbanization, measured using the Urbanization Index and the Recreation Index. The results show a significant impact of urbanization across all studied beach and dune zones, with the strongest effects in the upper intertidal zones and foredunes, where the most important factor was beach driving and trampling. We observed a strong increase in community dissimilarity with increasing urbanization, both in microfaunal and especially in meiofaunal taxa. Moreover, the sjSDM models allowed for the assessment of ecological preferences, spatial patterns, and co-distribution of over 300 species identified in our study, highlighting the potential of combining environmental DNA metabarcoding with advanced statistical tools to gain deeper insights into the ecology of beach ecosystems and species. This approach not only enhances our understanding of the complex

interactions within beach metacommunities but also provides crucial information for conservation planning and ecological research.

Physiological responses to Artificial Light at Night (ALAN) are proportional to exposure time.

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Artificial Light at Night (ALAN) has been considered a major driver of biodiversity loss, affecting various biological traits in multiple species. Although ALAN impacts have been documented on many coastal species and geographic regions, most of the studies have focused on the sole presence of this stressor, without considering ALAN properties such as intensity or exposure time. A careful examination of the light properties behind those impacts is critically important to understand and manage the effects of this stressor. Therefore, this study aimed at evaluating ALAN effects on the prominent sandy beach isopod *Tylos spinulosus*, considering different exposure times to this stressor. We hypothesized that effect of ALAN is proportional to exposure duration when other light characteristics remain constant. Specifically, we compared locomotor activity, consumption and growth rate of juvenile isopods exposed to three treatment levels: control (C, 12 hours day: 12 hours night), switched off (SO, 12 hours day, 6 hours ALAN, 6 hours night), and continuous exposure (CE, 12 hours day: 12 hours ALAN). Locomotor activity was disrupted in SO and CE compared to the control treatment. Moreover, the locomotor activity was significantly lower in CE than SO, indicating proportionality in ALAN's effect on this process. No significant differences in food consumption rates were observed between control and SO, but individuals in CE showed significantly lower consumption rates than those registered in control treatment. Growth rate was significantly higher in control compared to both ALAN exposure levels, which did not show significant differences between each other. These findings suggest that ALAN effects on *Tylos spinulosus'* eco-physiological responses are proportional to exposure time at constant intensity in visible wavelengths, thus confirming our hypothesis regarding ALAN effects.

Path analysis approach points out the effects of management of sandy beaches on intertidal macrobenthic fauna

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Sandy beaches dominate the global open coastlines in terms of extension, comprising approximately 70% of them. They are transitional environments, naturally dynamic, and primarily structured by physical drivers that also exert strong control over sandy beach ecological patterns. While physical

morphodynamic and climatic drivers are widely known and measured, anthropogenic drivers are challenging to measure accurately in terms of their degrees of interaction with the beach system. The effects of multiple natural and anthropogenic drivers on communities can be cumulative, synergistic, antagonistic, and non-linear. So, it becomes a priority essential to understand how these factors interact and drive the ecological status of beaches, research on five beaches in the northern Adriatic belonging to the same climatic cell but affected by different type of anthropogenic impacts was done. At each beach macrobenthic fauna and the main morpho-physical variables were sampled in the intertidal zone, at high and low tide. Information on urbanization, erosion protection interventions, and tourism management were assessed and categorized by expert knowledge. Data regarding erosion (volumes and rates), nourishment (volume) and subsidence (cm/year), were taken from the regional environmental protection agency. Significant differences among communities inhabiting the five beaches were revealed regarding both abundance and number of taxa. Path analysis (a structural equation modeling approach) was applied to test relationships between dependent and independent variables against a theoretical cause-effect model based on the presence of latent variables and their different contributions to the observed variability. The structure of the Path analysis featured alternatively 6 dependent variables (number of taxa, total abundances, and abundances of the 4 taxa that most contributed to the observed inter-populations differences) as a function of 5 latent variables which are composed of the measured or estimated climatic and anthropogenic factors. The Path analysis not only confirmed the results of the descriptive statistics, but also allowed to estimate the intensity and direction of the effects of the different factors considered. Results shows that both abundances and taxa numbers are heavily influenced by the state of the backshore and tourist management. The analysis conducted on the five species contributing most to observed variability among macrobenthic communities reveals how the relative abundance of some taxa may serve as indicators of disturbance specifically related to urbanization and tourist management. The high variability recorded among distinct yet nearby beaches belonging to the same climatic cell, confirms that local-scale information is essential for effective management.

DAY 3. WEDNESDAY 26TH JUNE 2024.

Sandy Beach Ecosystem and Species Red Listing: The Tools to Catalyse Global Action for Change?

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Sandy beaches are often referred to as 'threatened' or even 'endangered' ecosystems. These terms carry specific meaning in the context of IUCN Red Listing, and although our expert judgement is correct, beaches rarely have formal assessments to support claims that they are ecosystems at risk. Similarly for species, given the myriad of threats to beaches, and local extirpations being documented, we know that beach species are also at risk. However, none of the major beach macrofauna taxa worldwide have been formally assessed to date. South Africa has been Red Listing both ecosystems and species for a long time, even before the global standards were established. The aim of this study was to undertake the first ecosystem and species Red Listing for sandy beaches globally. The IUCN Red List of Ecosystems criteria (primarily criteria C3 and B) were applied to the 12 sandy beach ecosystem types in South Africa, using data on pressures to beaches and expert opinion to assess ecological degradation and condition. The IUCN Red List of Species criteria (primarily criteria B and A) were applied to 20 macrofauna species, using data from GBIF, iNaturalist, field sampling, threats to beaches, and expert opinion to complete global assessments for the species. Three ecosystem types were classified as threatened, including one Endangered and two Vulnerable types, with the remaining ecosystem types being Near Threatened (n=4) or Least Concern (n=5). Draft results for the species indicate three Endangered (*Tylos capensis, Capeorchestia capensis*, *Donax serra*), one Vulnerable (*Tylos granulatus*), and three Near Threatened species (*Acanthoscelis ruficornis, Pachyphaleria capensis, Africorchestia quadrispinosa*), with the remaining 13 species being Least Concern. Notably, six of the seven threatened and Near Threatened species are high shore species, the other is harvested, and all are endemic to only one or two countries. The implications of Red Listing are shared, and the potential for undertaking global Red List assessments for beach ecosystems and species is proposed. These may be the tools to highlight the plight of beaches and the urgency for conservation and restoration, especially as countries work to achieve the goals and targets in the Kunming-Montreal Global Biodiversity Framework.

Evaluating the responses of surf zone fish to Marine Protected Areas

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At the edge of land and sea, sandy beach and surf zone ecosystems are included in many of California's extensive network of 124 Marine Protected Areas (MPAs). These dynamic ecosystems play a pivotal role in the life cycles of numerous fish species, and serve as prime areas for subsistence and recreational fishing. We compared responses of surf zone fish to MPAs using beach seines and baited remote

underwater video (BRUV) in paired MPA and reference sites across 1300 km and more than 8 degrees of latitude in three marine bioregions in California, USA. Our study sites were microtidal intermediate type beaches that included a variety of exposures, shoreline lengths and MPA characteristics. Overall, our surveys detected the influence of MPAs in several surf zone fish metrics but effects varied significantly with survey method and bioregion. Deeper surf zone BRUVs detected positive MPA signals in fish richness and abundance, while higher biomass of fish in MPAs was evident in shallower beach seines. These MPA signals varied strongly across bioregions and site pairs, with the majority of significant positive MPA effects observed only in the southern bioregion. The composition of surf zone fish assemblages differed significantly between survey methods and among bioregions potentially contributing to the variety of MPA signals we observed. Important fishery targeted groups of live-bearing or egg-laying fish also exhibited varied responses to MPAs. The elasmobranchs, including small live-bearing species of sharks and rays, were primarily observed in the south bioregion where they exhibited positive MPA signals. The majority of sharks and rays detected in seines were juveniles or pups, while in deeper surf zones the BRUVs recorded primarily larger individuals. Although we found no overall MPA signal for the live-bearing surfperch family (Embiotocidae), abundances of both juveniles and large adults of the most prevalent fished species, barred surfperch, were higher inside MPAs. Our findings highlight the diversity of MPA signals possible in surf zone fish and suggest that MPAs may be valuable management tools for these dynamic and highly vulnerable edge ecosystems.

Sandy beaches as socio-ecological systems: a means of tackling the tourism-environment paradox.

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The overriding aim of coastal management is to protect the natural system, its structure and functioning, while supporting ecosystem services from which society gathers goods and benefits. This review introduces and illustrates the theories of socio-ecological systems and systems analysis in relation to the dynamic nature of sandy beaches. It addresses the 'tourism-environment paradox' within the DAPSI(W)R(M) cause-consequence-response system by considering that, in many areas, tourism ultimately damages the natural and societal attributes that were the initial reason for tourism and recreation to be attracted to an area. The analysis considers cultural goods and benefits and proposes the contrast in the behaviour of residents, many of which will be regularly using the beaches for low level recreation and who are more likely to appreciate the natural character, with that of tourists who are from outside the area; hence the priorities of the latter will differ from residents (i.e. the demands for 'sun, sea and sand' over and above that for the pleasures afforded by natural habitats). The outcome of these patterns therefore is the separation of a type of tourists who do not value natural habitats from those seeking ecotourism opportunities further afield. Examples will be given from South America and Europe predominantly but also from other recreation and tourism hotspots worldwide.

Coastal Morphological Changes Using Video Monitoring System and Xbeach Model

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Coastal areas are highly dynamic environments, subject to morphological changes due to the action of waves, tides, and winds. Monitoring these changes is crucial for understanding coastal evolution and planning sustainable management strategies. The data collection method involves an HD IP video camera system implemented by the Apulian regional Basin Authority (AdBP) in collaboration with Polytechnic University of Bari located at two vulnerable sites in South Italy, namely Torre Canne (Brindisi), and Porto Cesareo (Lecce) (Bruno et al., 2020). These sites employ cameras to capture coastal images every 30 minutes, facilitating the automatic extraction of shoreline data through the Shoreline Detection Model (Valentini et al., 2017). The resulting shoreline data, offer invaluable insights into the temporal dynamics of beach morphology and shoreline positioning, and are accessible in real-time on a dedicated website (http://93.51.158.173/). In the present work, the Xbeach model (Roelvink et al., 2009), is validated by using data collected during two storm events in 2016 from these video monitoring stations. This model is crucial for simulating coastal morphological changes. The study integrates various data sources, including UAV imagery and multibeam surveys, to create a detailed depth grid necessary for analyzing wave interaction in shallow waters. The focus is on the beach of Porto Cesareo, known for low-lying shores with sandy and calcarenite rocky beaches, which generally experiences a moderate to low wave climate, with the primary wave directions being SSE and SW. The objective of the work is to analyze shoreline adjustments, sediment distribution, and key beach parameters, like width and slope variations along the foreshore and swash zones. It employs cutting-edge methodologies to study shallow water dynamics and beach morphodynamics, emphasizing the importance of understanding run-up and temporal shoreline evolution. By evaluating the Xbeach model's accuracy against observed coastal changes, the study aims to support confidence in the model's predictive capabilities, thereby supporting coastal management and hazard mitigation strategies. This comprehensive approach enhances the foundation for decision-making in coastal management and risk mitigation by offering a more holistic view of coastal behavior and morphological changes over time.

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Coste360: a platform to monitor coastlines and seaside facilities

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A demo of the platform will be presented

"Praia com Vida" Project: Promoting environmental education and scientific outreach on

sandy beaches

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The “Praia com Vida” project is a non-profit organization operating primarily in the state of Rio de Janeiro, Brazil. It was designed by undergraduate and postgraduate students studying biology at the Universidade Estadual do Norte Fluminense Darcy Ribeiro. The project began as a university extension initiative and has evolved into a structured organization dedicated to operating within the third sector. “Praia com Vida” focuses on promoting environmental education through various virtual and face-to-face activities in schools, in the community and on the beaches themselves. These activities include beach clean-ups, guided technical-scientific visits, and participation in environmental and scientific fairs. The project comprises a multidisciplinary team responsible for planning activities and managing social media platforms relying on conservation marketing strategies. The organization's efforts are guided by three main objectives: to increase people’s compassion for the underappreciated sandy beach biodiversity, to raise public awareness about human disturbances on the coast, and to disseminate scientific knowledge using accessible and attractive communication. On social media, the audiovisual content is organized into educational series like "React," where members share their reactions to
controversial internet videos discussing beach biodiversity and anthropic impacts. Additionally, the series "Science in 1 Minute" is the primary channel for scientific outreach, summarizing papers related to sandy beach ecology and conservation. Since its inauguration in 2020, the project's Instagram page has garnered over 4,000 followers with significant organic engagement. For example, over the past three months, paid advertising campaigns have successfully reached 60,000 individual accounts, generating a total of 180,000 impressions. The TikTok page was established in 2022 and has garnered over 3,000 followers. While initially covering similar subjects as the Instagram page, the TikTok page now primarily focuses on short videos using artificial intelligence. In this format, two videos addressing plastic pollution have surpassed 1 million views, indicating the promising potential of this subject for scientific outreach and environmental awareness. The project also delves into scientific inquiries concerning conservation marketing, such as testing the efficiency of message framing approaches and selecting flagship species. In conclusion, the “Praia com Vida” project represents a promising initiative to the conservation of sandy beaches.

Societal Influences on Coastal Ecosystem Biodiversity Loss: A Multi-level Analytical Approach

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In the proposed paper, we present the research within the framework of the PRO-Coast project, initiated in November 2023 with funding from Horizon Europe. The study aims to identify the complex societal drivers of biodiversity loss in coastal ecosystems through an in-depth, multi-level analytical framework. This framework evaluates demographic, social, ethnic, religious, gender, organizational, and societal factors that influence attitudes and actions towards coastal biodiversity conservation. An extensive review

of existing literature was conducted to understand the complex interplay between societal factors and the loss of coastal biodiversity. Our findings emphasize the significant impact of age, gender, socioeconomic status (SES), and education on conservation efforts, highlighting the need for a sophisticated understanding and approaches towards biodiversity preservation. This paper underlines the critical need for comprehensive conservation strategies that are inclusive and engage diverse social groups in the conservation discourse. The literature review demonstrates that theories related to many existing studies, including this body of evidence, often lack depth in the context of the social sciences. Theories, which could be fruitful not only for scientific understanding but also for interventions in practice, primarily draw from environmental psychology, personality psychology, and sociological theories at the meso and macro levels of society. For instance, insights from the Sociology of Risk (Beck, 1992; Giddens, 1991), Social Capital Theory (Bourdieu, 1986; Putnam, 2000), theories of Social inequality (Bourdieu, 1984; Douglas et al., 1993), and Critical Theory (Adorno & Horkheimer, 1944; Marcuse, 1964) prove to have high explanatory power. These theories offer a perspective on the overall relationships that link various aspects to environmental destruction and participation in environmental efforts, including aspects of biodiversity in coastal regions.

Understanding the responses of beach wrack ecosystems to global change using citizen science—Lessons from the "Plages Vivantes" monitoring program

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Assessing the effects of anthropogenic pressures and environmental policies on biodiversity necessitates the development of extensive observation networks. The involvement of citizens in biodiversity monitoring can increase the sampling effort across space and time, but also contributes to their apprehension of the scientific method and to their awareness of the importance and challenges of biodiversity conservation. The "Plages Vivantes" citizen science monitoring and research program developed by the Muséum national d'Histoire naturelle (France) aims to understand the dynamics of beach wrack socio-ecosystems under global changes. It seeks to answer the following questions: What are the drivers of the composition of macrophyte communities in beach wrack, and can its composition inform the state of marine habitats? How does it affect sandy beach socio-ecosystems, and can such a citizen science program contribute to change the perception and management of beach wrack? Several monitoring protocols and studies were designed to answer these questions. Here, we focus on the first question and the "ALAMER" monitoring protocol that aims to address it. This protocol, that was co-constructed with several partners to be adapted to different audiences, from school children to experts, consists of identifying and quantifying the abundance of macroalgae and seagrass in five 1 m2 quadrats along a 25 m transect. In parallel with the development of the citizen science component of this protocol (creation of identification tools, training of participants, establishment of an observation network), the expert version of this protocol has been implemented since 2017 on approximately 650 beaches along

the Channel and Atlantic French coast in order to ensure that beach wrack can be used as an indicator of proximate benthic habitats. The first results are promising as they indicate that the composition of macrophyte communities in beach wrack can inform changes in the diversity, thermal affinity, and sensitivity to eutrophication of proximate benthic macrophyte communities. Extending this protocol to new audiences, such as conservation practitioners, although challenging, could strengthen our ability to inform the dynamics of benthic macrophyte communities under global change, and contribute to raise awareness of conservation issues in coastal and beach wrack ecosystems among other target communities.

POSTER SESSION

1

Impacts of beach nourishment on the crab Ocypode quadrata: a case study on the southeast coast of Brazil

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Beach nourishment efforts have become increasingly frequent to mitigate coastal erosion. One potentially affected species is the ghost crab (*Ocypode quadrata*), which inhabits the Atlantic coast and is already utilized as an indicator of beach-related impacts. The objective of this study was to investigate how beach nourishment activities can affect the population of O. quadrata, and whether this species serves as a potential bioindicator for such impacts. Sampling was conducted on two adjacent beaches in the state of Espírito Santo, southeastern Brazil, spanning from June 2022 to February 2024, totaling eleven campaigns. Four sampling points were selected, following a gradient of distance from the nourishment event and urbanization. The first point was located directly at the site of the event, while the second point was in an adjacent urbanized area without any erosion control strategies. The remaining points were situated in less urbanized areas with preserved restinga vegetation. At each sampling point, we assessed the population density and individual size by counting and measuring the diameter of burrows along five continuous, three-meter-wide transects perpendicular to the waterline. The abundance and average diameter of burrows were significantly smaller ($p < 0.005$) where the nourishment had taken place, consistent with findings from other studies. The first records of burrows at the nourishment site appeared three months after completion (abundance = 10/transect; diameter = 11 mm), indicating the population's resilience. Following four sampling events, the average number of burrows in the location where the nourishment occurred remained at 5/transect, with an average diameter of 21 mm, like the adjacent point where no nourishment had been carried out. In contrast, the most distant areas (points 3 and 4) exhibited higher burrow numbers (12 and 9 burrows/transect, respectively) and a larger average diameter (25 mm). The results indicate that this species is sensitive to beach nourishment activities and could be used in beach monitoring strategies for its protection as an umbrella species, thereby promoting the conservation of other species. Therefore, continuous monitoring is recommended to identify the effects of these activities in the medium and long term.

2

From open sea to into the bay: changes on sandy beaches morphodynamics and macrofauna

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Sandy beaches are typical habitats in estuaries and bay. However, these low-energy beaches have received less attention than those exposed ocean beaches. In this study, we analyzed changes in both beach morphodynamics and macrofauna composition along a continuum from open sea to estuarine beaches. The sampling was carried out at Peças Island, which its south portion corresponds to the north board of the Paranaguá Bay, south Brazil. In this place, two sectors facing the open sea and two sectors

facing into the bay were analyzed and compared regarding morphodynamics and macrofauna composition. In each sector three transects with 10 macrofaunal samples equidistantly distributed along intertidal zone were established. Data about wave energy, beach profile, sedimentary composition and water salinity were also recorded to each sector. Salinity and sediment composition was similar among beaches. There was observed a reduction in wave energy followed by an increase of tidal influence from open sea to into the bay, resulting at narrower and steeper estuarine beaches. Macrofauna richness and density values drastically dropped from the open sea (20 spp and 2,902±605 ind./m2) to estuarine beaches (11 spp and 731±15 ind./m). Observed changes in the macrofauna composition were mainly related to both reduction of the dominant species (the polychaete *Scolelepis goodbodyi*) and disappearance of some species (from open sea sector to estuarine ones. Reduction of wave energy into the bay results in narrow and steeper estuarine beaches. As a consequence, the reduction in the beach area limits the number of species and abundance of macrofauna, resulting in a poorest community in the estuarine beaches.

3

Automated Detection of Characteristic Beach and Dune Ecosystem Features Using PlanetScope Imagery

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Sandy beach and dune ecosystems can be important elements of coastline resilience to climate change. Beaches linked with dunes can provide nature-based protection against the threats of sea level rise, including heightened storm surge and increased risk of coastal flooding. Dunes can also act as sand storage reservoirs which actively maintain sandy beach ecosystems as they erode. Dunes also provide much needed habitat for a variety of unique native plants and animals which contribute to coastal biodiversity. Excessive coastal erosion due to sea level rise, increasingly intense storm surges, and human encroachment of natural areas for recreation are diminishing the extent and resilience of coastal dunes across California. Understanding the impacts of this variety of threats on these dynamic ecosystems requires reliable data with high spatial and temporal resolution. This type of information on the dynamics of our coastlines is essential for understanding and planning to increase dune resilience in the face of these threats has been challenging to obtain. To address this gap, we developed an automated classification method which provides rapid high-resolution data on dynamic shoreline features, such as beach width and the seaward extent of dune vegetation using a combination of high resolution PlanetScope/Dove imagery (3m, daily). These two metrics provide accurate daily data on both the location and extent of dry upper beach and the seaward advance or retreat of the foredunes for the California coast. Using classifications obtained for these features, we are evaluating how coastlines are changing across a range of timescales, from daily tidal cycles to climatic cycles (e.g., El Niño) and sea level rise as well as being able to isolate coastline responses to specific storm/wave events. The automated classification workflow we developed for the California coast is widely applicable to any coastal imagery utilizing the Planet platform. Our model can be readily applied to study the dynamic shoreline characteristics of any coastline with high spatial and temporal resolution.

4

Intertidal patterns in macrophyte wrack consumption and invertebrate habitat use

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Many ecosystems benefit from allochthonous resource subsidies from other ecosystems which have positive direct and indirect effects on biodiversity and food webs through increased habitat and food provisioning. These bottom-up effects can positively affect consumers across multiple trophic levels. Inputs of macrophyte wrack from nearshore rocky reefs to sandy beaches exemplify the role of subsidies with strong responses of beach invertebrate community structure and species distributions to spatial variability in wrack inputs. Consumption of these subsidies is also an important beach ecosystem function. Variation in the consumption rates of different macrophyte wrack species suggests invertebrate wrack consumers have preferences for specific macrophytes. To further investigate spatial patterns in consumption and habitat use of wrack by invertebrates, we conducted an experiment measuring the relative consumption of three common species of macrophytes at different intertidal levels of a sandy beach. Each treatment consisted of a placing 32 pre-weighed pieces of each macrophyte wrack species (two kelps and surfgrass) placed one meter apart, beginning one meter above the high tide strandline, along four shore-perpendicular transects in the late afternoon. The next morning, we collected the remaining experimental wrack and surveyed the invertebrate community by taking sediment cores under each piece of experimental wrack. We also analyzed the nutritional quality of each macrophyte species by measuring the carbon and nitrogen content. For the two kelps, average consumption increased with abundance of consumers. For surfgrass, no relationship was evident. The local species richness, abundance, and biomass of wrack-associated invertebrates differed significantly with intertidal level but only abundance differed with wrack type. Our results suggest that impacts of disturbance from climate, invasive species, and fishing on kelp forests that alter kelp subsidies will impact biodiversity and ecological functioning of recipient sandy beaches.

5

The fall and rise of Diopatra in Southern Brazilian Sandy Beaches.

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Marine beach species undergone changes in their populations along time mainly due to global climatic changes. Here we studied changes in population of a marine worm tube-dweller known as *Diopatra*. Population densities of *Diopatra* species from Brazilian sandy beaches were followed for ca. 50 years. Data were accessed from papers, gray literature, images, and collections to verify time changes in South Brazilian Bight (SBB) from 1974-2024. We modeled maximum density along time at 15 beaches, observing very high densities (> 100 ind.m-2) in 1974 followed by a decrease (~ 10 ind.m-2) of three species of *Diopatra* until 1995 and a strong decline (1996-2002) when populations were almost regionally extinct (0-

1 ind. m-2). A slight recovery (3-4 ind.m-2) occurred after 2006 and a recovery after 2020 (~ 20 ind.m-2) of the group *D. marinae/D.victoriae*, associated with northern warmer waters and disappearance of *D. hannelorae*, associated withcolder southern waters. This pattern was associated with heatwaves linked to an El-Niño event (1988) and gradual SST surface warming of ca. 1oC since 1974. The usage of *Diopatra* spp. as fishing bait could also be associated to such reduction. After 2016, *D. neapolitana*, an alien species originally from Mediterranean Sea, was established in SBB in high densities. Projections from species distribution modeling (SDM) suggest the potential for invasion within the current range of known species of the *D. cuprea* complex along the Brazilian coast, despite the absence of apparent competition between native and alien species, as they have not yet been observed on the same beaches. This lights a warning sign about the possible combination of global warming and other human-mediated impacts as species introduction and fishing bait harvesting on the biodiversity of Brazilian sandy beaches.

6

Interactions of marine organisms with micro- and macroplastics of a tropical estuarine beach, Rio de Janeiro, Brazil

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Plastic contamination is prevalent in marine ecosystems, impacting organism health, ecosystem functioning, and human health. Plastic pollution originates from diverse sources and occurs in various sizes (macro-, micro-, and nanoplastic), influencing interactions with organisms. Beach plastic contamination is extensively studied due to easy access and collection. This study aimed to describe plastic contamination on an anthropized estuarine beach, focusing on i) interactions between microplastics (MPs) and macroalgae, and ii) organisms colonizing macroplastics. Eight collections of macroalgae and macroplastic were conducted at Engenhoca Beach, Guanabara Bay, through active search along the beach line. Microplastics were separated from the macroalgae, and densities were expressed in the number of MPs per gram of algae biomass (MPs g-1). Red macroalgae exhibited higher MPs density (1.48 MPs g-1) than green algae (0.27 MPs g-1). The high MPs densities in red algae seem to be associated with the algae morphology, which is more branched. MPs densities described in the Guanabara Bay algae were 3 to 67 times higher than those estimated in studies from other countries. The macroplastics found on the beach were mainly from packaging waste, single-use plastics, and toys. Only nine taxa were identified on macroplastics, and their frequency of occurrence (FO) was as follows: bryozoan *Bugula Neritina* (FO = 69%), barnacles *Amphibalanus Amphitrite* (FO = 33%) and *A. subalbidus* (FO = 51%), polychaetes *Hydroides* spp. (FO = 84.4%) and *Branchiomma* spp. (FO = 2.2%), mollusks *Perna Perna* (FO = 2.2%) and unidentified oysters (FO = 4.4%), and algae *Ulva* spp. (FO = 70%) and unidentified filamentous algae (FO = 6.7%). This study reveals a significant presence of micro- and macroplastics interacting differently with organisms, potentially contaminating organisms foraging either on macroalgae turfs or on macroplastics. Moreover, organisms settling on macroplastics may face survival challenges as drifting plastics can transport them to unsuitable habitats, affecting survival, growth, and reproduction.

7

The neglected and wasted diversity of epibionts on Ulva spp. stranded on a tropical estuarine beach, Rio de Janeiro, Brazil

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Large biomass of macroalgae reaches estuarine beaches, carrying a high density and diversity of epibiont invertebrates. Due to both natural and artificial processes of eutrophication, algal bloom events have increased and, consequently, elevating beach wrack. The aim of the study was to describe the spatial-temporal variation in alpha, beta, and trophic diversities of the macrofauna associated with Ulva spp., which reaches an estuarine beach in Guanabara Bay, a highly anthropized ecosystem. During six months we conducted samplings of *Ulva* spp. fragments and the associated fauna in three locations along Engenhoca Beach through active search along the waterline. A total of 178 fragments of Ulva spp. were collected, with associated organisms (N = 10,591) on 164 fragments. The groups with the highest contributions to densities were crustaceans (81.3%) with 35 species, polychaetes (14.3%) with 22 species, and mollusks (2.5%) with 18 species. The majority (82%) of identified taxa comprised rare species with a frequency of occurrence < 20%. Spatial-temporal analyses revealed significant differences in density, richness, and alpha diversity between collections; however, the high variability of data between beach regions influenced the comparisons. High species substitution values (> 50%) occurred between consecutive months of collection (beta diversity). Macroinvertebrates were grouped into 8 trophic categories, and the trophic functional diversity (GT) was higher in July (dry period) compared to other months. The dominant trophic groups were deposit-feeders and suspension-feeders, but the trophic diversity index did not vary over the months, despite species replacement (i.e., beta diversity). This study is the first to determine the diversity of epibionts on *Ulva* spp. wracked on a beach in Guanabara Bay. The results highlight the important role of *Ulva* spp. as a habitat that sustains high density and taxonomic and trophic diversities of macrofauna. Due to the extremely high levels of pollution in Guanabara Bay, every day the beach is cleaned and the biomass and diversity of macrofauna are completely removed and wasted by the city's cleaning company. Therefore, studies identifying the impact of this removal on the ecosystem, especially on rare species, are urgently needed.

8

Tidal phase mediates sandy beach prey resources available to a surf zone fish

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In temperate regions, food webs of sandy beaches rely on cross-ecosystem subsidies of phytoplankton and kelp to fuel highly productive trophic intermediates, including invertebrates that are prey for birds and fish. Surf zone fish support recreational, artisanal and commercial fisheries worldwide but their trophic relationships with open coast beaches are not well quantified. For California beaches, intertidal suspension-feeding sand crabs are known as an important prey resource for surf zone fish. However the role of abundant intertidal kelp wrack-associated invertebrates and other beach invertebrates as prey resources for surf zone fish is poorly understood. To explore these trophic relationships, we compared

the availability of phytoplankton- and kelp wrack-dependent invertebrates to the diet of an abundant surf zone fish species, the barred surfperch (*Amphistichus argenteus*), across lunar tide phases. Lunar tide phases predictably modify patterns of beach inundation that redistribute intertidal invertebrates and can resuspend wrack deposits harboring kelp wrack-associated invertebrates. We hypothesized that these tidal shifts alter the variety and distribution of beach invertebrate prey available to barred surfperch. We expected a greater diversity and abundance of kelp-dependent beach invertebrates in fish diet during spring tides that sweep more of the intertidal beach than during neap tides. Barred surfperch diet was more diverse, with more kelp wrack-dependent taxa consumed, including talitrid amphipods, and a reduced dominance of sand crabs during spring tides compared to neap tides. Overall the diversity of prey observed in fish diets was correlated with the diversity of invertebrates on the beach. Our results suggest that when spring tide inundation or wave events affect the intertidal distributions of kelp-dependent beach invertebrates they experience enhanced predation by surf zone fish. Our finding of tidal mediation of fish diet expands our understanding of the dynamics of trophic connectivity between sandy beaches and surf zones. Our results provide new insights on reciprocal subsidy pathways in food webs of coastal ecosystems and the potential effects of climate change driven erosion and loss of beaches on surf zone fish prey resources.

9

Monitoring litter distribution by geospatial data in a marine protected island in southeast Brazil

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Marine litter (ML) is a major issue of global concern that impact coastal environments and human activities. Therefore, investigate litter distribution and their source is required for an efficient ecosystem management. Remote Sensing allow obtain systematic data of ML distribution at different temporal and spatial scales. This is especially important for Marine Protected Areas (MPA) that many times have difficult accesses. The Santana Archipelago is a MPA 8 km off the coast of Macaé City, Rio de Janeiro, Brazil. The pocket beach at the Francês Island is 100m long and the unique area that tourism is allowed, although no regulation accesses. This work aimed mapping macro-litter at Francês Beach using an unmanned aerial system (UAS, aka drone). Two multirotor quadcopters were used, DJI Mavic Air and the DJI Mavic 3M (RTK position system). The images were three times recorded with 80% front and 75% side overlaps in March, June and December 2023. The flight altitude was in March and June of the Mavic Air drone was set to 10 m above ground level, while the flight altitude of Mavic 3M was of 15 m on December. The image nominal spatial resolution, expressed in ground sample distance (GSD), was of 4.3 mm. The Digital Surface Model (DSM) and the orthomosaic map were generated applying a Structure from Motion - MultiView Stereo (SfM-MVS) photogrammetric processing on Agisoft Metashape. All litter was also sampled, quantified, weighed and categorized. On images ML was manually screened, and density maps were produced using Kernel Density Estimation. A total of 35.87 kg and 1096 items were sampled, mainly composed by plastic, glass, metal, paper, wood and rubber.

In images screening we recorded 42%, 40% and 12% of the sampled items respectively in the three months. Differences in image percentage detections are related to the characteristic of litter size and burial conditions. ML densities models revealed spatial patterns of accumulation, probably related with climatic conditions and the area used by beachgoers. This work provides the first insights of ML monitoring using UAS-based images in the Brazilian coast.

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Monitoring ghost crab (Ocypode quadrata) burrows distribution on sandy beach by geospatial analysis

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The ghost crab *Ocypode quadrata* is the only species inhabiting the east coast of the Americas. Diameters and spatial distribution of burrows are used to investigate population structure and habitat preference. Studies suggest that the prevalence of adult burrows at the upper zone of the sandy shore is due to the stability of the sediment and the protection offered by the adjacent vegetation. On the other hand, young individuals prefer to occupy the mesolittoral zone due to their lower resistance to dehydration, digging ability or exclusion by adults. The aim of this work was to use geospatial analysis to explicitly test the following hypotheses: (i) diameters of burrows are negative related to the distance from backshore vegetation; (ii) diameters of burrows are spatially autocorrelated. Data were acquired in June and December 2023 at the Francês Beach, Macaé, Rio de Janeiro, Brazil. The pocket beach, with 100 m extension, is a Marine Protected Area at the Santana Archipelago Municipal Park. All ghost crab burrow diameters were measured with a digital caliper (0.01mm) and their positions geolocated using a pair of GNSS receivers or with a target in a drone orthoimage. The distances of burrows from backshore were determined by geospatial tools in QGIS Program. Digital layers of burrows diameters were generated by kriging interpolation methods and the density maps were generated by Kernel Density Estimation. Moran's Eigenvectors Maps (MEMs) were obtained by the diagonalization of the doubly-centered Spatial Weighed Matrices using burrows locations. A total of 111 burrows were found in June and 37 in December. The diameters varied between 10 and 55 mm. The digital layer of burrow densities revealed estimated values between 0 and 0.09 burrow/m2. The highest densities values occurred in the supralittoral zone and were more prevalent at the ends of the beach arch, indicating a habitat preference. Prevalence of larger burrows occurred at one end of the beach arch. However, we rejected the hypothesis of the relationship between burrow diameters and the distance from backshore vegetation. MEMs explained 26% of the spatial patterns of burrow diameters in June and indicated significant autocorrelation. In December autocorrelation hypothesis was rejected. Herein we highlight the potential use of geospatial data to explicitly test ecological hypotheses in sandy beach ecosystems.

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Trophic ecology of the ghost crab *Ocypode quadrata* on beaches with different levels of human disturbance

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The ghost crab *Ocypode quadrata* inhabit sandy beaches of the Western Atlantic coast and plays a key role in the food webs of beach ecosystems. Here, we describe and compare the trophic ecology of *O. quadrata* on four beach arcs with different levels of urbanization in the north coast of Rio de Janeiro, Brazil. We used a combination of stomach content analysis of 107 individuals and stable isotopes (SI) data of δ15N and δ13C of *O. quadrata* and the main prey sources. Diet composition was analyzed using Non-metric Multidimensional Scaling and SI by evaluate isotopic niche and mixing models. We found differences in the stomach contents of the ghost crabs between beach arcs. Higher Insecta prevalence in stomach composition occurred in less urbanized beaches, indicating the influence of the backshore vegetation. High plastic rates in stomach contents were positively related with the urbanization level. The isotopic niches indicated similar diets and habitat use between beaches. However, individuals from less urbanized locations have larger niches, indicating greater variety in the use of food resources. There was a high isotopic niche overlap indicating a nested pattern. Mixing models revealed greater assimilation of the mole crab *Emerita brasiliensis* in all beaches, demonstrating a preference for more caloric sources when available. Moreover, the dietary composition of adults and juveniles of *O. quadrata* differ. Prevalence of insects was found in juveniles' diet and higher frequencies occurrence of *E. brasiliensis* were recorded in adults. These results are congruent with SI analyses since adults had a greater isotopic niche amplitude than juveniles. More enriched 13C values corroborated the adults' association with marine sources. The trophic ecology of *O. quadrata* and additional knowledge about its diet at different stages of life can provide valuable information for studies on the connectivity between biological and adjacent ecosystems.

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Drift line composition from beaches in northern coast of Rio de Janeiro is influenced by anthropogenic and environmental variables

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Sandy beaches are dynamic ecosystems that link the ocean and land. Allochthonous subsidies of stranded organic matter mainly represent important resources. Wrack, carrion and other detritus can be deposited in a strip and have a pivotal function in the trophic web. Here we investigated the spatiotemporal variability in the composition of drift lines from three beach arcs with different urbanization levels in northern Rio de Janeiro, Brazil. From April 2023 to October 2023 beaches were sampled monthly and from November 2023 to January 2024 sampling occurred biweekly. Along the drift line of each beach arc we sampled the superficial sediment (2cm) using five randomly spaced quadrats (50cm x 50cm) and sieved samples using a 1mm mesh. All organic material was identified to the lowest possible taxonomic level and inorganic material classified using OSPAR (2010). Dry items were weighted using a digital balance (0,01g). Tidal range, wave height, wave period, wave direction, wind speed and wind direction were acquired from tide table and the Aqualink dataset https://aqualink.org/). The relationships between the weight of litter, macroalgae, terrestrial plants, tubes of Polychaeta and shells with beach and climatic variables were assessed using multiple regressions. Variability in the composition of drift line samples was tested using PERMANOVA analysis. The most frequent items sampled was Polychaeta tubes followed by shells, terrestrial plants, litter and macroalgae. The frequency of litter in the most touristic beach arc was higher and represented 15,3% of the total weight. Litter weight was related to interaction of beach-tidal range and beach-wave height. The macroalgae weight was not related to beach arc or to environmental variables. Weight of terrestrial plants was related to wind direction, the interaction of beach-wave, beach-wave direction and beach-tidal range. Polychaeta tubes were only influenced by the beach arc and shells by the interactions beach-wave height and beach-wave direction. Finally, PERMANOVA analysis indicated clear differences in the drift line compositions. Our data highlighted the influence of anthropogenic disturbance and potential transformation on the role of sandy beach in ecosystems connectivity due climate changes.

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Citizen science and Beach clean-up actions for subside environmental awareness

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Sandy beaches are social-ecological systems on which management depends on the interaction of a numerous key players in society. Therefore, issues facing sandy beach ecosystems need to highlight three main goals: (1) science, (2) society's understanding and (3) political guidelines. Citizen science (CS) can be defined as actions that particularly involve science and society in producing scientific information. Marine litter (ML) is as major issue of global concern that impact coastal and marine environment, as well human well-being. Beach clean-ups are collective actions to collect data and raise awareness of environmental problems in society. The objective of this study was present the experience of a monitoring program of macro-litter in a beach on northern Rio de Janeiro, Brazil, involving scientists, students, players of the civil society and stakeholders. Fondly called as “Little Princess of the Atlantic” the city of Macaé has 23 kilometers of shore, mainly composed by sandy beaches. During the last two decades the city experienced an industrial boom and about 80% of Brazilian oil and 47% of natural gas production comes from Campos Basin, having an economical growth of 600%. Cavaleiros Beach is the principal touristic point in the city and receives thousands of beachgoers during summer high season. The beach has a number of hotels and restaurants and hosts numerous cultural festivals. Four clean-ups events during the years 2023 and 2024 were done including undergraduate students, high school students and beachgoers, in which actions were publicized and data shared with local managers. All macro-litter was sampled from a 100m transect parallel to the shoreline and sorted according to a standardized protocol by undergraduate students. An average of 20.2kg and a total of 7474 items were sampled, mainly composed by paper (71%-84%), plastic (10%-19%) and metal (3%-12%). Cigarette butt was the most sampled item. Data was subsequently used during undergraduate statistics classes and disseminated on social media, including local government public portals. Also, clean-ups data are systematically presented in high schools and cultural events, highlighting environmental awareness and education, particularly addressing the local society.

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Challenge your knowledge on sandy beaches: a web platform-based competition for schools in Italy.

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Information technologies have reshaped teaching and learning in schools, and the revolution in information technologies is changing the ways we think about education. Nowadays, schools make significant use of instructional technologies as a support for inclusive learning. In Italy, ecology is not a

study topic in itself but is embedded in civic educational curricula for both primary and secondary school cycles. Here is described an opportunity, based on a web platform, for schoolkids to participate to a non-formal learning path about ecological issues. The initiative "EcoLogicaCup" is a national online competition open to students from primary to high schools, aiming to stimulate the interest of youngest generations towards ecosystems and ecological sustainability. It is organized yearly by the University of Salento, Museum on Mediterranen Ecosystems' Ecology, LifeWatch Italy, sponsored by the Italian Society of Ecology (S.It.E.) and the Network of Universities for Sustainable Development (RUS). It is the first national competition on ecology held online: every year several ecological topics are available on the LifeWatch platform for participants to study, exercise and finally challenge themselves to be the winners. Schools have to officially join the competition, though they can enroll single classrooms, organized in teams, depending on teachers' availability to engage in the challenge. The topic proposed for 2024 edition is 'Sandy Beach'. Participants must learn about this topic, fix key concepts and answer questions with five difficulty levels in the shortest time to get the highest score (https://training.lifewatchitaly.eu/en/education-and-schools-2/ecologicacup/). Sandy beaches are fascinating ecosystems connecting land and sea; they provide several ecosystem services yet are highly impacted by anthropogenic pressures. EcoLogicaCup would contribute to disseminate the knowledge of this type of ecosystems, engaging young citizens and supporting teachers in the civic education and sustainable use of ecological resources. Given the large coastal extension of Italy (about 8,000km), sandy beaches are key ecosystems to be protected for their ecological value as well as being an economic resource.

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Does the expansion of the tufted ghost crab *Ocypode Cursor* in the Mediterranean Sea jeopardize the nesting sites of the loggerhead turtle *Caretta caretta*?

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The tufted ghost crab Ocypode cursor (Linnaeus, 1758) is the only representative of the genus *Ocypode* occurring in the Mediterranean Sea, and is included in the list of threatened taxa of the Barcelona Convention. The species mainly occurs in the Levantine and Aegean Sea and to a minor extent in Greek Ionian islands; the Ionian coasts of the Puglia Region (SE Italy) represent the northernmost limit of its distribution. Here we provide a comprehensive review of the occurrence of the species in the Mediterranean, emphasizing its progressive spread towards the northwestern sectors of the basin,. A number of recent, previously unpublished records from the Salento Peninsula (SE Italy) are included, collated during monitoring activities focused on nesting sites of the loggerhead turtle *Caretta caretta* (Linnaeus, 1758). A considerable spatial overlap in the distribution of *O. cursor* populations and C. caretta nesting sites along the Salentine coasts of the Ionian and Adriatic Sea is highlighted; furthermore, a number of direct and indirect observations of predation by the crab on turtle eggs and nestling are reported. These preliminary results suggest that *O. cursor* might negatively interact with *C. caretta* in the Salento Peninsula, as repeatedly indicated in other studies performed in the Atlantic Ocean. The potential effects of climate warming in promoting the crab's range expansion is discussed, along with the necessity

of a thorough assessment of the actual distribution of the crab in the Mediterranean Sea and of an in-depth assessment of its predatory and competitive relationships with other inhabitants of sandy beach ecosystems, including species of conservation interest.

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Community structure of the Western Gulf of Thailand's intertidal macrofauna in sandy beaches with different grain sizes

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Sandy beach ecosystems are very important tourism resources in tropical countries. This study aimed to compare the macrobenthic invertebrates in the sandy beaches of Ko Samui and Ko Phangan, the Western Gulf of Thailand in relation to density and species diversity. Macrobenthos and sediment samples have been collected since 2017 along transects perpendicular to the shorelines with a 0.09 m 2 quadrat sampler. The sandy beach profile and grain size of the sandy beaches were also measured. The median grain size at Ko Samui was 1.00 mm. which was much higher than that at Ko Phangan (0.38 mm) The macrofauna density at Ko Samui (7.9 individuals/m 2) was significantly lower than that at Ko Phangan (13.0 individuals/m 2). The species diversity of macrofauna at Ko Samui was also lower than that at Ko Phangan. The dominant macrobenthic invertebrates at Ko Samui were gastropods and bivalves, while the dominant microbenthic invertebrates at Ko Phagnan were polychaetes and amphipods. The polychaetes in the family Capitellidae were the most dominant group. Several macrobenthic invertebrates in the sandy beaches at these study sites have high potential to be bioindicators for environmental impact assessment in the intertidal sandy beach ecosystems.

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Netnography on the beach: Instagram depiction of values for nature and ecological features related to #sandybeach

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When considering beaches as social-ecological systems (SESs), Netnography (i.e. the ethnographic perspective applied to the internet users, basically "watching people online") seems an excellent tool to approach people' insights. Beaches are in fact highly exposed on social media, yet their iconic representation in images is highly dependent on ecosystem assets (sun, sea and sand" triad). A conceptualization of beaches as SESs draws attention towards those elements which are at the same time granting beach ecological functionality, are essential to ecosystem services, and are iconic in representations: sand grain size, beach slope, and dune or coastal vegetation integrity. A preliminary analysis of Instagram posts with hashtag #sandybeach, carried out in Summer 2021, however points at the fact that an average of 30% of them do not include beach (sand, dune, profile) nor water (color) ecological features. In addition, less than 3% of those posts relates to actions of stewardship, such as

beach clean-ups or wildlife protection. For instance, when comes to beach wildlife, resident macroinvertebrates are clearly less appreciated by beachgoers than large-bodied vertebrates (think e.g. a beach flea vs. a sea turtle hatchling or a plover). However, pets representation is higher than resident fauna representation. In summary, Instagram pictures seem to perpetrate the insight of beaches as sites of high recreational value, and we suggest monitoring eventual changes to the perception of beaches through Netnography. In particular by applying the concept of Littoral Active Zone to pictures, hence including the surf zone, surfers emerge as a specific group of users, more connected to environmental features and likely more engaged in transformative change actions.

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Evaluation of tourist carrying capacity to support recreational beaches management

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The overexploitation of sandy beaches by tourism reduces ecological integrity, rendering natural conditions unsatisfactory for the needs of the population and resulting in negative socio-economic impacts. In this context, the assessment of tourist carrying capacity aims to support beach management from a social, environmental, and economic perspective. The objective of this study was to estimate the tourist carrying capacity at nine beaches in the states of Rio de Janeiro (RJ) and Espírito Santo (ES), southeastern Brazil. The physical carrying capacity was calculated based on the available space for recreation in scenarios of one user per 5 m2 and 10 m2. Subsequently, limiting environmental factors for recreational use such as sunlight, precipitation, strong winds, tidal range, and temperature were considered, supporting the calculation of the tourist carrying capacity. For the calculation, management conditions (infrastructure and services) were estimated based on the scoring of 69 indicators, included in the international beach quality program called Blue Flag and in the main instrument for coastal management in Brazil, the Orla Project. At RJ beaches, the carrying capacity was not exceeded in the scenario of one user per 10 m2, except in the central region with a higher tourist appeal. In ES state, the results indicated overload for all beaches in the central southern region; for example, one received six times more users than its tourist capacity. Overall, the highest percentages of management capacity were recorded at beaches with Blue Flag certification. The beaches that require the most improvements in coastal management are those located in regions with lower Human Development Index (HDI) and farther from major urban centers. The results suggest priority management actions and guide efforts towards potential beach certification. The management of services, infrastructure, and overload highlights the need for preventive measures to avoid the tourism paradox, including loss of environmental quality and revenue. Moreover, the flexibility of this evaluation tool allows for its application in beaches of any country. The integration of tourist carrying capacity and assessment of the coastal scenario provides a more comprehensive and effective framework for the sustainable management of beaches.

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Restoring Dunes as Nature-Based Solutions for California Shorelines

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Climate change impacts including sea level rise, beach erosion, and flooding are increasingly affecting coastal communities globally. Natural features, such as coastal dunes can be part of climate change adaptation approaches along urban and natural shores. Compared to traditional hard engineering approaches such as armoring, nature-based solutions using coastal dune restoration can be sustainable and resilient, while providing a myriad of ecological benefits and services. This project, funded by a UC Office of the President Climate Action Seed Grant, evaluates California's coastal dunes for their potential to enhance resilience to climate change impacts. The primary objectives include: (1) classifying sites where protective dunes exist(ed), their current condition, and key geomorphic features by conducting a state-wide inventory for dunes; (2) identifying opportunities for restored dunes to improve shoreline resilience by developing and evaluating a suitability assessment and performance framework; 3) assessing performance of selected dune restoration projects spanning the geographic and social-economic diversity of the state by compiling existing data and extending monitoring; and 4) developing state-wide guidance for monitoring, implementation, maintenance, and performance assessment of protective dunes using collaborator workshops and outcomes from existing projects. Here we summarize the project scope and progress to date, including surveys of pilot dune restoration sites and the engagement of end-user groups in co-development of products.