Capítulo 16.

Evaluación cualitativa de los servicios ambientales del litoral norte del municipio de Ilheus, Bahia, Brasil

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Resumen

El municipio de Ilhéus, zona sur del estado de Bahía, presenta ecosistemas de gran relevancia. Sin embargo, el municipio viene sufriendo una gran especulación inmobiliaria, principalmente debido a la expansión urbana de la ciudad de Ilhéus, al crecimiento del turismo, y más recientemente, al proyecto de instalación del Complexo Porto Sul (puertos, ferrocarril y aeropuerto). El objetivo principal del presente estudio fue valorar cualitativamente servicios ambientales costeros en este importante sector del litoral de Brasil utilizando un conjunto de indicadores ambientales estandarizados.

Los servicios fueran divididos de acuerdo con sus funciones ecosistémicas y agrupados en tres clases generales: Servicios de Regulación y Soporte, Servicios de Provisión, y Servicios de Información y Culturales. Cada servicio fue valorado como bajo (valor 1), medio (valor 2) o alto (valor 3). El estudio muestra que la mayoría de las playas presentó buenos índices de servicios ambientales (medio y alto). La playa de Ponta da Tulha (sector 2) fue una excepción, donde los servicios de soporte y regulación fueron bajos, lo que repercutió en la reducción de la oferta de servicios de provisión, información y culturales. Correlacionando los índices de servicios ambientales con lo uso actual y ocupación del suelo, se observó también que la urbanización suprimiendo los ambientes naturales resultó en menor variedad y cualidad de los servicios ambientales disponibles. Por último, este estudio evidenció la eficiencia de valorar servicios ambientales utilizando un conjunto estandarizado y flexible de indicadores ambientales.

Introduction

The study of natural capital and ecosystem services has gained considerable attention from the scientific community over the past years. In fact, an exponential increase in the number of publications on this theme was observed by Fisher et al. (2009) particularly after the publication of the Millennium Ecosystem Assessment in 2005, a global initiative of the United Nations (UN) combining the work of more than 1360 researchers.

While traditional environmental management strategies may tend to consider human activities and social preferences alone, without taking into account the value of the benefits obtained from the natural environment, the emerging trend towards a more ecosystem-based management framework allows a more integrative approach. As discussed by Elliff and Kikuchi (2015), decision-makers that value natural capital and respect the carrying capacity of their areas are able to reach long-term and fair benefits to a wider population.

The management of coastal and marine ecosystems is slowly changing, but most issues are still dealt without integration and without the necessary transdisciplinarity (Clarke et al., 2013). Although coastal zones are generally considered as strategic areas for the exploitation of marine resources, they offer much more than only their privileged location. Coastlines host a mosaic of highly relevant and diverse ecosystems that represent the transition between terrestrial and marine environments. Beaches, for example, represent one of the most valued coastal ecosystems, supporting various forms of economic activity, such as "sun, sea and sand" tourism.

However, the natural capital of beaches and other ecosystems depends above all on resilient ecological systems that are able to promote ecosystem functions and services. The irresponsible use of these resources may irreversibly reduce carrying capacity and resilience. Therefore, the appropriation of these spaces by society should be preceded by caution in order to provide adequate incentives to protect natural system resilience (Souza Filho et al., 2014a). Thus, the inherent fragility of these carefully balanced ecosystems requires special attention from the government (Brazil, 1998).

A common obstacle to achieve efficient ecosystem-based management strategies consists of not having a full understanding of the natural capital and ecosystem services being delivered in a given area. Moreover, the variety of classifications and methodologies to survey and valuate ecosystem services can hinder more robust analyses (Elliff and Kikuchi, 2015).

Thus, the objective of the present investigation was to conduct a baseline qualitative study of the coastal ecosystem services delivered in an important sector of the Brazilian coast using a standardized set of environmental indicators, generating an ecosystem services index.

Material and methods

Study site

The beaches of the northern sector of the municipality of Ilhéus, southern coast of the state of Bahia, Brazil, were assessed in the present study (Figure 1). Combining ecological richness and easy access to its approximately 34 km of beaches, the northern shoreline of the municipality of Ilhéus represents an important area for tourism growth and development in the state of Bahia. The area has experienced high real estate speculation over the past years mainly due to the urban expansion of Ilhéus and, more recently, the installation project of the Porto Sul Complex, which will combine port, railroad and airport constructions.

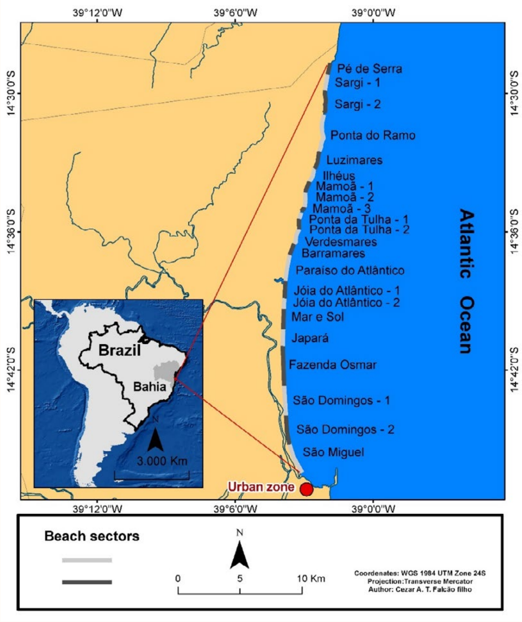

Figure 1. Location of the beaches studied along the northern shoreline of the municipality of Ilhéus, state of Bahia, Brazil.

Though this new transportation enterprise is thought to improve the economy in the region, there is much concern regarding the possible impacts of this complex to the socio-environmental dynamics of the area. This coastal area, known as the Cacao Coast, presents various ecosystems of high environmental sensitivity. Sandy beaches, mangrove forests, wetlands and *restinga* vegetation are found along the shoreline with different levels of preservation (Figure 2).

Figure 2. Examples of coastal ecosystems found along the northern shoreline of the municipality of Ilhéus, state of Bahia, Brazil. **A) sandy** beaches and *restinga* vegetation. B) Wetlands and mangrove forests.

Ecosystem service survey

Field campaigns took place during the summer and winter months of 2013-2014 and 2016-2017 for a complete overview of the seasonal conditions found in the study area. Surveys were conducted on foot along the beaches of Pé de Serra, Sargi, Ponta do Ramo, Luzimares, Ilhéus, Coqueiros, Mamoã, Ponta da Tulha, Verdes Mares, Barramares, Paraíso do Atlântico, Jóia do Atlântico, Mar e Sol, Japará, Fazenda de Osmar, São Domingos, and São Miguel (see Figure 1). Most beaches were quite homogeneous regarding their natural characteristics and infrastructure. However, the beaches of Sargi, Mamoã, Ponta da Tulha, Jóia do Atlântico, and São Domingos were more heterogeneous and were therefore segmented for the analysis.

Beaches and associated ecosystems were qualitatively valuated in the present study. To do so, surveys encompassed the beach and 200 m of the adjacent inland coastal zone, allowing a broader and more integrated analysis of the ecosystem services offered.

The methodology applied for the qualitative valuation of ecosystem services was based on the Millennium Ecosystem Assessment (2005) and on adaptations made by Santos and Silva (2012) and Souza Filho et al. (2014b). Ecosystem services were grouped into three categories: provisioning services, regulating and supporting services, and information and cultural services. Each ecosystem service was ranked from 1 to 3 (low to high) according to the occurrence of their respective environmental indicators (Tables 1, 2 and 3). For example, regarding natural food production, the absence of activities such as fisheries, shellfish gathering or gathering wild plants in the sampling site would indicate a low value of this service, while the occurrence of at least one activity would indicate a medium value, and the occurrence of more than one of these activities in the same site would represent a high value for this service. The scores obtained for each beach studied were then added to generate an ecosystem service index.

Table 1.
Indicators for the valuation of regulating and supporting ecosystem services.

Regulating and Supporting Service	Low (1)	Medium (2)	High (3)
Natural sediment retention	Absence of vegetation in the backshore or along the beach ridge	Occurrence of vegetation in the backshore or along the beach ridge over at least 50% of the shoreline	Occurrence of vegetation in the backshore or along the beach ridge over more than 50% of the shoreline
Aquifer recharge	Absence of sandy terraces or terraces with waterproofed surface	Occurrence of sandy terraces in at least 50% of the shoreline	Occurrence of sandy terraces in over 50% of the shoreline
Water control and storage	Absence of wetlands or mangrove forests	Occurrence of wetlands or mangrove forests in less than 50% of the shoreline	Occurrence of wetlands or mangrove forests in over 50% of the shoreline

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Regulating and Supporting Service	Low (1)	Medium (2)	High (3)
Pollutant assimilation and recycling	Absence of wetlands or mangrove forests	Occurrence of wetlands or mangrove forests in less than 50% of the shoreline	Occurrence of wetlands or mangrove forests in over 50% of the shoreline
Wave energy dissipation	Absence of surf zone	Surf zone with up to 3 breakers	Surf zone with more than 3 breakers
Foreshore zone natural protection	Absence of coral reefs and/ or sandstone banks	Occurrence of coral reefs and/ or sandstone banks in less than 50% of the shoreline	Occurrence of coral reefs and/ or sandstone banks in less than 50% of the shoreline
Backshore zone natural protection	Absence of beach ridge	Occurrence of beach ridge in less than 50% of the shoreline	Occurrence of beach ridge in over 50% of the shoreline
Marine refuge and/or nursery	Absence of estuaries, coral reefs or sea turtle nesting areas	Occurrence of at least one refuge/nursery area (estuaries, coral reefs or sea turtle nesting areas)	Occurrence of more than one refuge/nursery area (estuaries, coral reefs or sea turtle nesting areas)
Terrestrial or transitional refuge and/or nursery	Absence of mangrove forests, restinga or Atlantic Rainforest	Occurrence of at least one refuge/ nursery area (mangrove forests, restinga, Atlantic Rainforest)	Occurrence of more than one refuge/ nursery area (mangrove forests, restinga, Atlantic Rainforest)

Table 2.
Indicators for the valuation of provisioning ecosystem services.

Provisioning Service	Low (1)	Medium (2)	High (3)
Natural food production	Absence of activities such as fisheries, shellfish gathering or gathering wild plants	Occurrence of at least one activity (i.e. fisheries, shellfish gathering or gathering wild plants)	Occurrence of more than one activity (i.e. fisheries, shellfish gathering or gathering wild plants)
Food production in farmed areas	Absence of activities such as crops, animal breeding, fish farming, etc.	Occurrence of at least one activity (i.e. crops, animal breeding, fish farming, etc.)	Occurrence of more than one activity (i.e. crops, animal breeding, fish farming, etc.)
Water resources	Absence of surface water bodies or aquifers	Occurrence of at least one source of water (i.e. surface water bodies or aquifers)	Occurrence of more than one source of water (i.e. surface water bodies or aquifers)
Ornamental resources	Absence of ornamental resources (i.e. dead wood, oysters, plants, fish, rocks, minerals)	Occurrence of at least one ornamental resource (i.e. dead wood, oysters, plants, fish, rocks, minerals)	Occurrence of more than one ornamental resource (i.e. dead wood, oysters, plants, fish, rocks, minerals)
Genetic resources	Occurrence of anthropized areas, pastures or monocultures	Occurrence of restinga or agroforestry systems	Occurrence of forests, coral reefs, estuaries or mangrove forests

Table 3.
Indicators for the valuation of information and cultural ecosystem services.

Information and cultural service	Low (1)	Medium (2)	High (3)
Ecotourism	Absence of locations with quality for ecotourism, such as hiking and diving	Occurrence of at least one location with quality for ecotourism, such as hiking and diving	Occurrence of more than one location with quality for ecotourism, such as hiking and diving
Historical/cultural tourism	Absence of buildings or areas with known historical value	Occurrence of at least one building or area with known historical value	Occurrence of more than one building or area with known historical value
Recreation and leisure	Low recreational quality	Medium recreational quality	High recreational quality
Scenic quality	Absence of natural attractions (e.g. cliffs)	Occurrence of at least one natural attraction (e.g. cliffs)	Occurrence of more than one natural attraction (e.g. cliffs)

Results

The results of the qualitative valuation of ecosystem services delivered by the beaches and associated coastal ecosystems of the northern shoreline of the municipality of Ilhéus are listed in Table 4. Most beaches assessed presented medium to high ecosystem service index (>30), as shown in Figure 3. The highest values were observed for Sargi (sector 2), Ponta do Ramo and Mamoã (sector 3), which were 42, 43 and 42, respectively. These three beaches presented high diversity of associated coastal ecosystems, including estuaries with great potential for various ecosystem services (Figure 4a). Ponta da Tulha (sector 2) was the only beach that did not reach an index value of at least 30 (index = 25), therefore being considered as having a low ecosystem service index. In the case of this beach, supporting and regulating services were mostly ranked as low, which reflected in a reduced offer of provisioning and information and cultural services.

Natural sediment retention and recharge of aquifers were the ecosystem services most frequently valued as high. Most beaches presented considerable vegetation cover over the backshore and beach ridge and presence of sandy terraces, even in more urbanized sites. In turn, foreshore zone natural protection and historical/cultural tourism were valued as low for all beaches. Ecotourism was also valued as low in most beaches, only reaching medium values in Pé de Serra, Sargi (sector 1) and Ponta do Ramo, and one high value in Sargi (sector 2), all neighboring beaches. Strong coastal erosion was observed in São Domingos (sector 2) (Figure 4b), which presented low foreshore and backshore natural protection values and medium wave energy dissipation value.

Table 4. Values attributed to each ecosystem service evaluated along the northern shoreline of the municipality of Ilhéus, state of Bahia, Brazil, and resulting ecosystem service index. Beach names were abbreviated as follows: PS: Pé de Serra; S1: Sargi – sector 1; S2: Sargi – sector 2; PR: Ponta do Ramo; L: Luzimares; C: Coqueiros; M1: Mamoã – sector 1; M^2: Mamoã – sector 2; M3: Mamoã – sector 3; PT1: Ponta da Tulha – sector 1; PT2: Ponta da Tulha – sector 2; V: Verdesmares; B: Barramares; PA: Paraíso do Atlântico; JA1: Jóia do Atlântico – sector 1; JA2: Jóia do Atlântico – sector 2; MS: Mar e Sol; J: Japará; FO: Fazenda de Osmar; SD1: São Domingos – sector 1; SD2: São Domingos – sector 2; SM: São Miguel.

Table 4.
Ecosystem service & value attributed to each service evaluated.

Ecosystem service	Show the values attributes for each service evaluated																					
	PS	S1	S2	PR	L	C	M1	M2	M3	PT1	PT2	V	B	PA	JA1	JA2	MS	J	FO	SD1	SD2	SM
REGULATING AND SUPPORTING SERVICES																						
Natural sediment retention	3	3	2	3	3	3	3	2	3	3	2	3	3	3	3	3	3	3	3	3	2	2
Aquifer recharge	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2
Water control and storage	2	2	2	2	2	2	2	2	3	2	1	1	1	2	2	2	2	2	2	1	2	2
Pollutant assimilation and recycling	2	2	2	2	2	2	2	2	3	2	1	1	1	2	2	2	2	3	2	1	2	2
Wave energy dissipation	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Eco-system service	Show the values attributes for each service evaluated																					
	PS	S1	S2	PR	L	C	M1	M2	M3	PT1	PT2	V	B	PA	JA1	JA2	MS	J	FO	SD1	SD2	SM
Foreshore zone natural protection	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Backshore zone natural protection	3	2	2	2	2	2	3	1	3	3	1	2	2	3	2	2	3	2	3	3	1	1
Marine refuge and/or nursery	2	2	3	3	2	2	2	1	2	2	1	1	1	2	2	1	2	2	1	1	1	2
Terrestrial or transitional refuge and/or nursery	2	2	3	3	1	2	2	2	3	3	1	2	2	2	3	2	3	3	2	3	2	2
TOTAL	20	19	20	21	18	19	20	16	23	21	13	16	16	20	20	18	21	21	19	18	15	16
PROVISIONING SERVICES																						
Natural food production	2	2	3	3	2	2	2	2	3	3	2	2	2	2	2	2	2	2	2	2	3	3
Food production in farmed areas	2	2	2	3	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	3	1	1
Water resources	2	3	3	3	3	3	2	2	3	2	1	2	2	3	3	2	3	3	2	2	2	2
Ornamental resources	2	2	2	2	1	1	1	2	2	2	1	2	2	2	2	1	2	2	3	2	3	3
Genetic resources	3	2	3	3	2	2	2	2	3	2	1	2	2	2	2	2	3	3	2	2	1	1
TOTAL	11	11	13	14	10	10	8	10	13	11	7	10	10	11	11	9	12	12	11	11	10	10
INFORMATION AND CULTURAL SERVICES																						
Ecotourism	2	2	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Historical/cultural tourism	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Recreation and leisure	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2
Scenic quality	3	1	3	3	1	1	1	1	2	2	1	1	1	2	2	1	2	2	1	1	1	1
TOTAL	8	6	9	8	5	5	5	5	6	6	5	5	5	6	7	5	6	6	5	5	5	5
Ecosystem services index	39	36	42	43	33	34	33	31	42	38	25	31	31	37	38	32	39	39	35	34	30	31

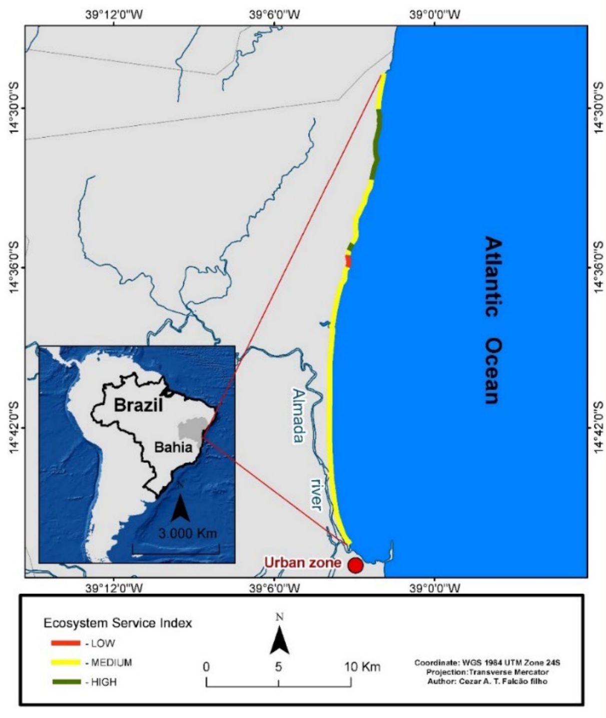

Figure 3. Ecosystem service index obtained for the northern shoreline of the municipality of Ilhéus, state of Bahia, Brazil.

Figure 4. Field observations in Ilhéus, state of Bahia: A) Overview of the mouth of the Sargi River at the border between the municipalities of Ilhéus and Uruçuca from the Ponta do Ramo Beach; B) High vulnerability to coastal erosion, São Domingos Beach (sector 2).

Discussion

As expected for such a rich stretch of coastline, ecosystem services reached medium to high values in most of the beaches analyzed. The presence and maintenance of regulating and supporting services in the area greatly influenced the occurrence of provisioning and information and cultural services, as also indicated by Santos and Silva (2012). Although regulating and supporting services may seem somewhat disconnected from some major economic benefits obtained from natural ecosystems (e.g. food, mineral resources, tourism), these classes of ecosystem services are responsible for maintaining the balance in ecosystem functions and supporting the delivery of the full range of services available (Millennium Ecosystem Assessment, 2005). For example, Ponta do Tulha (sector 2) presented the lowest value of regulating and supporting services and also the lowest values for provisioning and information and cultural services. With over 70% of its shoreline occupied by human-made structures, which decreased the presence of vegetation, scenic attractions and associated ecosystems, sector 2 of Ponta do Tulha presented a highly contrasting profile in comparison to sector 1 of this same beach. The occurrence of two adjacent areas with opposing characteristics and levels of use could be concerning if urban expansion continues without consideration towards the carrying capacity of the system and natural resilience.

While the list of ecosystem services used is not exhaustive, it includes services of all categories and addresses some of the main uses of beach ecosystems. As shown by Elliff and Kikuchi (2017), the list is flexible and can be applied to a diverse range of coastal environments. In addition, as discussed by Daily et al. (1997), classifications tend to be arbitrary due to the interconnectivity of services, which can at times allow the same service to be placed in more than one category for example, therefore this issue should not be a limiting factor for researchers.

The methodology applied allows the identification of ecosystem services and areas that require priority attention and action by ranking the value of services as low, medium or high. Ecotourism and historical/cultural tourism, for example, were mostly ranked as having low value along the northern portion of the municipality of Ilhéus. This finding indicates that these forms of tourism could be better explored in the whole area, potentially indicating an untouched source of revenue for the local population. Tourism is one the most highly valued ecosystem service in coastal areas (Moreno and Amelung, 2009). However, this same service that can improve the regional economy and support livelihoods can also potentially lead to negative impacts, threatening the ecosystem from which it originates (Arkema et al., 2015). Other services, particularly provisioning services, when overexploited can also cause environmental degradation. Thus, any form of exploitation of natural capital should respect the limits imposed by environmental parameters, keeping within the carrying capacity of the ecosystem (Malone et al., 2014).

Long et al. (2015) identified stakeholder involvement, interdisciplinarity, appropriate monitoring, use of scientific knowledge and adaptive management among the key principles of marine ecosystem-based management. As discussed by Fernandino et al. (2018), by including "adaptive management" as one of these key principles, Long et al. (2015) recognize the importance of decision-makers and stakeholders to consider climate change within management action plans, either for mitigation or adaptation purposes. Sea-level rise, increased frequency of storm surges and wave climate alterations can lead to different responses along the study area due to the variety of ecosystems and morphological features observed. Cliffed coasts, for example, may recede depending on sea-level rise rate (Trenhaile, 2011), threating properties and compromising current land use and occupation patterns. Moreover, the ecosystem services offered by the mangrove forests present in the study area, which were shown to greatly influence the ecosystem service index of the beaches assessed, may become seriously threatened, especially in areas which are already under pressure from human activities (Woodroffe et al., 2016). In turn, water resources can eventually be compromised through the salinization of aquifers due to sea-level rise (Mascиopinto and Liso, 2016).

Although the problems triggered by climate change impacts may occur at global and regional scales, as highlighted by Fernandino et al. (2018), decisions should be made at a local level, taking into account resource limitations and environmental particularities.

Conclusions

The northern shoreline of the municipality of Ilhéus, state of Bahia, presented mostly a medium level of ecosystem service offer. Only one beach assessed was classified as low, while three beaches were classified as having high offer of ecosystem services. Regulating and supporting services were found to greatly influence the supply of provisioning and information and cultural services, thus emphasizing the importance of preserving these services even though they may not be directly connected to current economic activities.

The use of a list of indicators to qualitatively valuate ecosystem services presented several advantages, serving as a guideline for field observations in an area that had not been assessed previously regarding its potential delivery of services.

An ecosystem-based management strategy would allow the region to better take advantage of ecosystem services that are currently not well explored, such as tourism, while still remaining within the carrying capacity limits of the environment. Moreover, decision-makers and stakeholders should be aware of future environmental changes that the region will come to experience (i.e. implementation of the Porto Sul Complex, climate change effects, etc.). Coastal management should take on a participatory and interdisciplinary character, seeking sustainable development within the carrying capacity limits of the area.

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