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Spatial models of suitable sandy substrates for brittle star community conservation in Sancang Coast, West Java, Indonesia

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Abstract. *Suprapto PK, Husna IR, Meylani V, Basukriadi A, Wibowo AA, Nurdin E. 2022. Spatial models of suitable sandy substrates for brittle star community conservation in Sancang Coast, West Java, Indonesia. Indo Pac J Ocean Life 6: 87-93.* The brittle star is known as one of the echinoids with the largest members. Currently, brittle star species are threatened due to harvests for fulfilling decorative species demands in aquariums. This study aims to determine suitable sandy substrates for the brittle star community in Sancang Coast, West Java, Indonesia, in three representative stations. Brittle star presences and environmental variables were surveyed using belt transect methods, and sandy substrate suitability was determined using scoring and an interpolation method aided by GIS. Results show three species belong to the Ophiocomidae, with *Ophiocoma scolopendrina* (Lamarck, 1816) (brittle lagoon star) being the most abundant. About 394,631 m^2 of sandy substrates were available, and an estimated 47.52% is considered very suitable for brittle stars. Most suitable sandy substrates were located on the West side, characterized by low water temperature, high salinity, and alkaline water. In contrast, less suitable sandy substrates were located on the coast's east side, characterized by high water temperature, low salinity, and acidic water. To conclude, this research has identified which parts of the Sancang Coast should be prioritized to conserve brittle stars.

Keywords: Environment**,** *Ophiocoma scolopendrina,* Ophiocomidae, Sancang, suitable

INTRODUCTION

The Ophiuroidea, or brittle stars, snake stars (euryalids with non-branching arms), and basket stars (euryalids with branching arms), are the biggest group of extant echinoderms, with 2,064 documented species found in all seas from the intertidal to the deepest depths (Stöhr et al. 2012). The 2,064 ophiuroid species described range from the intertidal to the hadal depths and from the equator to the polar regions. Regarding brittle star biogeography, the Indo-Pacific area has the highest overall species richness (825 species at all depths). Because of the existence of many Indo-Pacific species that partially spread into these regions, adjacent regions were also quite species-rich, including the Indian (316), South Pacific (355), and North Pacific (398). The West Atlantic was a secondary region with increased species diversity (335). The regions with relatively low species richness include the Arctic (73 species), East Atlantic (118), South America (124), and Antarctica (126) (Martín-Ledo and González 2013; Lau et al. 2021). Some of the Indo-Pacific species richness could be attributed to its vast area (99.3 million km^2). Around 64% of species (1,316) were restricted to a single region, and the highest proportion of endemic species included the East Pacific (63%) and West Atlantic, with 61% of endemic species found here (O'Hara et al. 2011).

Indonesian waters were also reported to have significant brittle star biodiversity within the Indo-Pacific region. In Pandaratan Beach of Sumatra Island, brittle stars accounted for 9.15%–14.71% of the echinodermata community registered for *Ophiocoma erinaceus* (Müller & Troschel, 1842) species (Susetya 2019). Even on Java Island (Pakpahan et al. 2020), brittle stars are known to dominate the intertidal zones. According to Muzaki et al. (2019), the most dominant species in Pidakan Beach of East Java are brittle stars, represented by *Ophiocoma dentata* (Müller & Troschel, 1842) (Family Ophiocomidae), which accounted for 52.50%, and *Ophiomastix annulosa* (Lamarck, 1816), which accounted for 17.46%. Due to their occurrence in all marine habitats, brittle stars have emerged as a key taxonomic group for biogeographic or macro-ecological studies. They have a variety of life history strategies and trophic and are diverse and abundant enough to be statistically analyzed without becoming a major taxonomic exercise with every survey. Since their skeletal parts occur in large numbers as microfossils in most marine sediments and are taxonomically identifiable, including deep-sea cores, brittle stars have a high potential to serve as model organisms to assess the impact of palaeoceanographic events and macro-evolutionary patterns on the composition and diversity of past communities.

Although humans rarely harvest brittle stars, some *Ophioderma* and *Ophiarachna* species are harvested and sold as marine aquarium species. On the other hand, as brittle stars are a dominant component of seafloor fauna, they can be impacted by other human activities such as mining or trawling. Anthropogenic activities occurring in coastal areas, including trampling, tourism, or harvesting marine biota in sandy substrates, have been reported to have a negative impact on the local fauna. Even though there are no or limited studies on the direct impact of trampling on echinoderms, the lower species richness of echinoderms could be related to decreasing food sources in an area with higher anthropogenic activities. In addition, anthropogenic activity has been reported to cause a decrease in bivalves, gastropods, and crustaceans, which are the food source for many brittle stars considering that brittle stars were omnivorous predators that preyed on at least 24 taxa representing foraminiferans, crustacean fragments, and sediment particles (Lafite et al. 2021).

Recently, a sandy ecosystem that is an important habitat for brittle stars was threatened due to sand mining (Nishi et al. 2015). Then this condition demands a study to select the remaining sandy substrates suitable for conserving brittle stars in the future. Therefore, this study aims to determine suitable habitats for brittle stars in sandy substrates in the Sancang Coast intertidal zones, West Java, Indonesia.

MATERIALS AND METHODS

Study area

This research was conducted on the sandy substrate of the intertidal zones of Sancang Coast, Garut District, West Java, Indonesia, on July 19-21, 2020. The study area was part of the Leuweung Sancang Natural Reserve. The research location consists of 3 stations, namely station 1, located in Ciporeang on the East side with geocoordinates of 7°44′19″ S and 107°52′9″ E, station 2, located in Cikujangjambe on the middle side with geocoordinates of 7°44′19″ S and 107°52′38″ E, and station 3, located in Cibako on the West side with geocoordinates of 7°44′24″ S and 107°52′26″ E. The intertidal zones comprised seagrass in the middle and surrounded by sandy substrates. The sandy substrates were bordered by a natural reserve and Sandy Beach recreational area on the North side, the Indian Ocean on the south side, and Karang Gajah Rivermouth on the East side near Ciporeang. The research location is shown in Figure 1. These sample sites were selected due to the presence of sandy substrates.

Procedures

Brittle star surveys

Brittle star samplings were carried out using the belt transect method, in which a transect was drawn perpendicularly from the coast to the sea for 100 m. Sampling was carried out at 3 stations (Figure 1), and each station contained 100 plots per station with a size of 1 x 1 m per plot. Identification of brittle stars was carried out by comparing the morphology of the brittle star species obtained with the morphological characteristics in the book Identification, "A Guide to Common Echinoderms of Andaman and Nicobar Islands," by Raghunathan et al. (2013), and scientific articles based on shape, color, spines, and patterns of brittle stars. The survey was carried out during the low tide to get a better view while surveying the brittle star community.

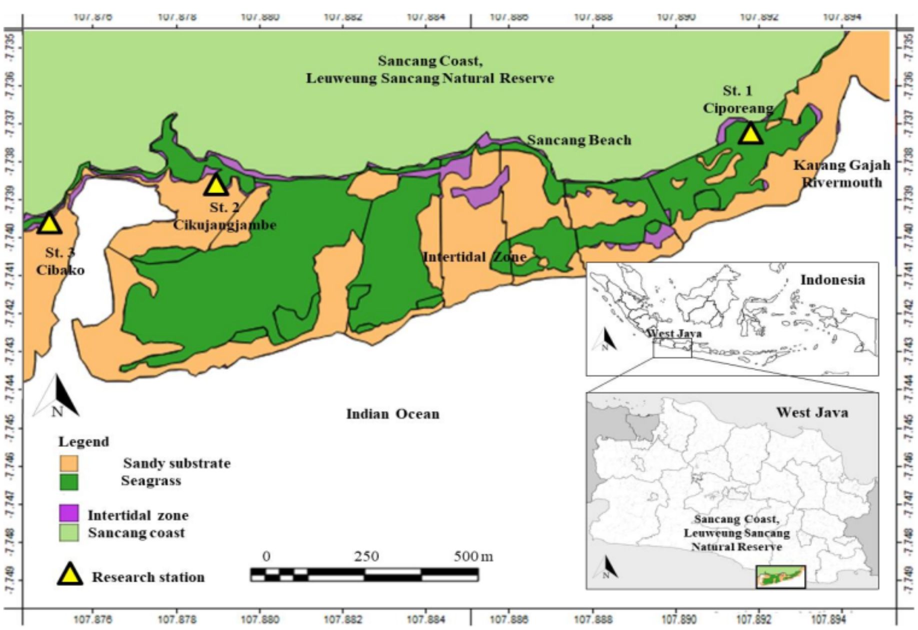

Figure 1. Location of the study area, research station, and sandy substrates at intertidal zones of Sancang Coast, Garut District, West Java, Indonesia

Environmental variable assessments

Assessments of the environmental variable at each station were conducted around 07.00-09.00 AM following low tide on all sampling days. Measured environmental variables included pH, salinity (‰), dissolved oxygen (DO, mg/L), and water temperature (^{0}C). All variables were assessed in situ using digital multiparameter devices. Those devices include a refractometer, a DO meter, and a digital thermometer. Following the presence of brittle stars, the environment variables were measured at the surface of sandy substrate depth.

Suitable sandy substrates analysis

Estimations of suitable habitats for brittle stars followed the workflow (Figure 2) and method described by Meixler and Bain (2012) and Boitt et al. (2021). The suitability method used was the scoring and overlay of environmental variables and brittle star individual numbers mapped into a sandy substrate map. First, all the environmental variable values, including pH, salinity, dissolved oxygen, and water temperature, were tested for their correlations using Principal Component Analysis (PCA) and then scored from lowest to highest. The variable with the lowest score was considered the least suitable, and the one with the highest score was considered the most suitable. Then all the score values were tabulated into the Geographical Information System (GIS) table along with their geocoordinates.

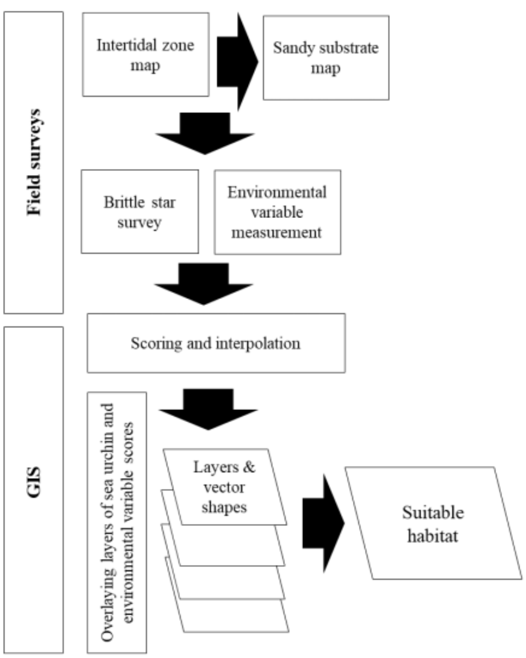

Figure 2. Workflow for determining suitable sandy substrates at Sancang Coast, Garut District, West Java, Indonesia intertidal zones

The tabulated GIS tables contained environmental variables and brittle star individual numbers that were used and interpolated to create GIS layers and vector shapes. Next, all the layers were overlaid, and the score values in each environmental variable layer and vector shape were summed to create composite layers. The final step was to classify score values in composite layers. The vector shapes with the highest score values were classified as the most suitable habitat and high-very-high classes. While the vector shapes with the lowest score values were classified as least suitable for sandy substrate and low-very low classes. This process was conducted using GIS software (ArcView 3.3).

Data analysis

The correlations of environmental variables with the brittle star community were analyzed using Principal Component Analysis (PCA). This analysis was also used to observe and compare the values and quantities of environmental variables and Brittle Star individuals in stations 1, 2, and 3. Besides, Chi-square (x^2) was used to test the differences between environmental variables and the brittle star community among locations, with the significance level at $P < 0.05$. All sample sites were tested equally.

RESULTS AND DISCUSSION

Brittle star community

Based on the study results, 3 brittle star species were observed on the sandy substrates of the Sancang Coast that belonged to the family Ophiocomidae, *Ophiocoma* genus, which included *O. aethiops* (Lütken, 1859), *O. echinata* (Lamarck, 1816), and *O. scolopendrina* (Lamarck, 1816). Based on the statistical test (Table 1, x^2 = 249.4992, P =0.00001), the numbers of individuals of each species were significantly different among stations, indicating the effects of locations on the brittle star community. The *O. aethiops* was abundant in Cikujangjambe, followed by Cibako and Ciporeang. Abundances of *O. echinata* and *O. scolopendrina* followed similar patterns as Cibako > Cikujangjambe > Ciporeang. That indicates that, in general, the brittle star community is high in Cibako compared to other locations. The *O. scolopendrina* were brittle star species found frequently in every location and dominated the brittle star community.

PCA results have confirmed this brittle star community pattern (Figure 3). Cibako was characterized by the dominance of *O. echinata* and *O. scolopendrina*. While Cikujangjambe was characterized by the dominance of only the *O. aethiops* species, Besides that, Ciporeang was characterized by a low number of members of the brittle star community.

Environmental variable patterns

The results of environmental variable assessments (Table 1) show the spatial pattern and distribution of measured environmental variables. Based on the result, the water temperature increased toward the Ciporeang site, or station 1, on the East side. The highest water temperature measured at station 1 was 28.3°C, and the lowest at station 3 was 27.9°C. A similar pattern can be observed for DO. The DO was also rising along the Sancang Coast's sandy substrates. The highest water DO observe in station 1 was equal to 5.64 mg/L, and the lowest water DO in station 3 was equal to 5.54 mg/L. In contrast, pH and salinity showed the opposite pattern. According to the result, pH declined towards the Ciporeang site, or station 1, on the East side, with the lowest pH value at 8.33. While pH increased toward station 3 and made the water in here alkaline. Similarly, salinity was also observed declining towards the Ciporeang site, or station 1, on the east side, with the lowest salinity values at 32.2‰. At the same time, salinity increased towards station 3 and made the water in here more saline with a salinity of 34‰. This condition makes the sandy substrates at Cibako in the West have colder water, alkaline water, high salinity, and less DO. While the sandy substrates at Ciporeang on the East side have warmer water, acidic water, low salinity, and oxygen-rich water.

The current environmental variable patterns were confirmed by PCA results (Figure 3). Based on the results, Ciporeang was significantly characterized by temperature increases. While increases in salinity and pH characterize the Cibako and Cikujangjambe, increases in DO do as well.

Table 1. Statistical results (Chi-square) of environmental variables with the brittle star community across all 100 plot samples at sandy substrates of intertidal zones of Sancang Coast, Garut District, West Java, Indonesia

Variables	Units	Stations			Chi-square	
		1 Ciporeang (East)	2 Cikujangjambe (Middle)	3 Cibako (West)	x^2	P
O. aethiops	Individuals	35	712	207	249.4992	0.00001*
O. echinata	Individuals	29	277	279		
O. scolopendrina	Individuals	152	715	755		
Water temperature	^{0}C	28.3	27.8	27.9	0.5154	0.999991
Dissolved oxygen	mg/L	5.64	5.72	5.54		
Salinity	‰	32.2	33.7	34		
pH		8.33	8.4	8.38		

Note: *Statistical significance level at <0.05

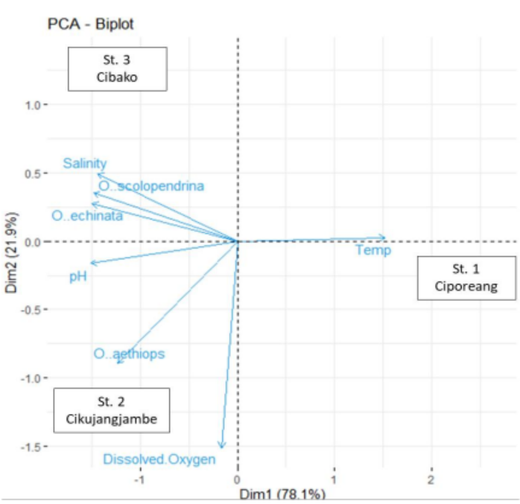

Figure 3. PCA of environmental variables with the brittle star community at sandy substrates of intertidal zones of Sancang Coast, Garut District, West Java, Indonesia

Brittle star community correlations with environmental variables

The PCA results explained brittle star community correlations with environmental variables (Figure 3). In this study, there were both converse and inverse correlations. Positive correlations were mostly observed in Cibako. In this study, abundances and increasing individuals of *O. echinata* and *O. scolopendrina* were positively correlated with increases in salinity and pH. It indicates that in Cibako, brittle stars increased when the water became more saline. Besides, it will increase the brittle star population when water becomes alkaline. The positive correlations of environmental variables were also observed in Cikujangjambe. Here, the number of brittle stars will increase when water is enriched with oxygen. Compared to Cibako and Cikujangjambe, negative community-level correlations with environmental variables were observed in Ciporeang. Here, the absence of brittle stars was caused by water temperature increases. The rise in temperature in Ciporeang has also contributed to the reductions in salinity, pH, and DO and led to the declining brittle star community.

Suitable sandy substrates

Based on the analysis, an estimated 394,631 m2 of sandy substrates were available on Sancang Coast, spanning from Ciporeang in the East to Cibako in the West (Figure 4). From those areas, between 22,529 m^2 (5.7%) to 187,559 m^2 (47.52%) were considered to have a high or very high suitability level. In greater detail (Figure 5), Cibako, located on the West, has the largest sandy substrates classified as very suitable. Sandy substrate suitability in the middle at Cikujangjambe was more heterogeneous. In this case, the sandy substrate suitability was considered low to moderate. The Ciporeang site, located in the East, was considered unsuitable, considering that almost 75% of its sandy substrates were classified as very unsuitable.

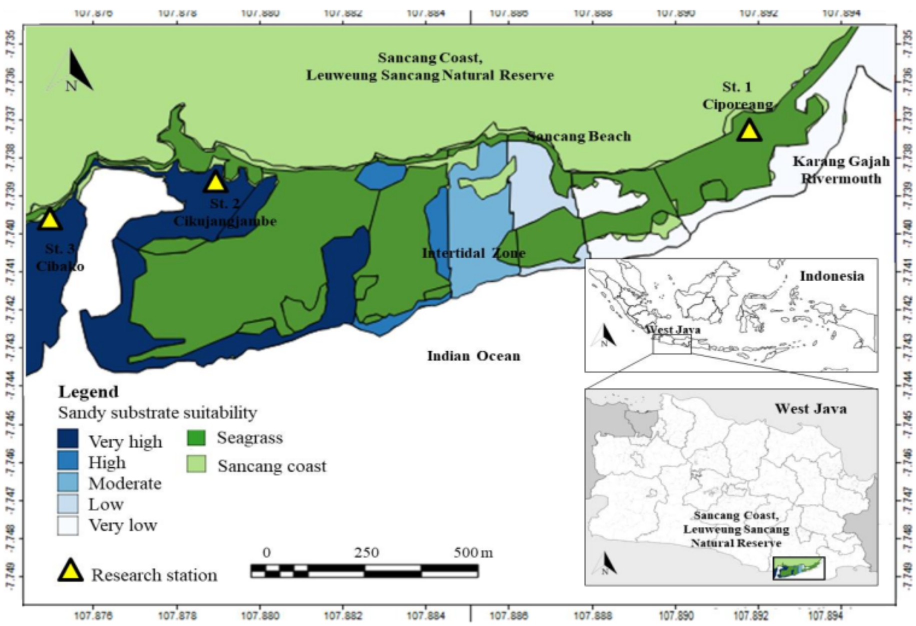

Figure 4. Sandy substrate suitability for brittle star community at intertidal zones of Sancang Coast, Leuweung Sancang Natural Reserve, West Java, Indonesia

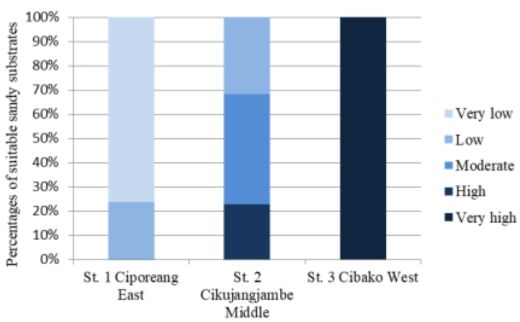

Figure 5. Area compositions of suitable sandy substrate classes (very low, low, moderate, high, very high) for brittle star community in stations 1, 2, and 3 at intertidal zones of Sancang Coast, Leuweung Sancang Natural Reserve, West Java, Indonesia

Discussion

This study elaborated on the importance of brittle star conservation by elaborating on the suitable habitats for conserving the brittle star community in the sandy substrates at intertidal zones of the Sancang Coasts. That agrees with previous studies highlighting current threats to brittle stars and the importance of designating conservation areas by determining suitable habitats. The determination of suitable habitat will lead to the establishment of Marine Protected Areas (MPA) that have proven to be a successful tool for the conservation of marine forests and the control of brittle star populations. That is because information about suitable habitats will guide and inform which parts of the habitats should be protected and can yield significant results in conservation efforts. Here, *O. scolopendrina* was a brittle star species that is very common and abundant in comparison to other brittle star species. This condition is in agreement with the results from nearby coastal in Rancabuya Coast, West Java (Paujiah et al. 2018). In Rancabuaya, *O. scolopendrina* was present in every location, including sandy substrates with high numbers. That confirms that the sandy substrates of the West Java Coast are suitable and potentially support brittle star conservation practices. Despite its current geographical distribution, the records of *O. echinata* in this study were in agreement with the results from Paujiah et al. (2018) and a recent study by Bahtiar et al. (2020) that confirm the presence of *O. echinata* within Indonesia's tropical waters. Similar to *O. echinata*, *O. aethiops* is present within Indonesia's tropical waters with a density of 0.045 indv/m^2, as confirmed by Katili (2011)

In this study, the sandy substrates of the Sancang Coasts were the point of interest to be recommended for brittle star-suitable habitats. That agrees with the previous study (Geraldi et al. 2016). According to Muzaki et al. (2019), most brittle star species were found only in the bottom substrates, composed of coarse to fine sand. Brittle stars prefer soft bottom substrates that enable them to burrow themselves and hide during low tide or high light intensity. That is due to the negative phototaxis properties of brittle stars, as observed by Muyassaroh et al. (2021). The selected sandy substrates in this study indicate that brittle stars prefer lower temperatures and avoid substrates with warm water. According to Angreni et al. (2017) and Susetya (2019), Brittle star abundance was negatively correlated with temperature because high temperatures would cause high evaporation, increasing salinity. An increase of 3 in salinity would lead to flaking skin or even death in extreme conditions (Fang et al. 2014).

Less suitable sandy substrates were identified on the East side of the studied coast in Ciporeang. This site is characterized by very distinct environmental variables and low abundances of brittle stars in comparison to other locations. This condition is related to the locations of Ciporeang that are close to the river mouth. The presence of a river mouth and anthropogenic activities nearby (Scherner et al. 2013; Souza et al. 2013; Cabral et al. 2019) has the potential to discharge pollutants and nutrients that can contaminate the pristine coastal ecosystems nearby and affect the populations of marine organisms (Brauko et al. 2016), including brittle stars. Eutrophication originating from the land is a common problem among coastal ecosystems near river mouths that greatly affects the diversity of organisms, from fish to small benthic invertebrates (Brauko et al. 2020). Eutrophications contribute to altering the pristine sandy beaches by creating drifting algae mats that induce episodic hypoxia (Barros et al. 2017) that may affect brittle star species. Eutrophication processes in the form of increased phytoplankton production may increase the accumulation of organic pollutants in benthic sediment-ingesting fauna, including brittle stars. This condition explains the lower abundance of brittle stars in Ciporeang, which makes the sandy substrates in this site classified as unsuitable.

Another distinct environmental variable of unsuitable sandy substrates is the declining pH values, which indicate ocean acidification. This condition is considered unsuitable since acidification (Wood et al. 2011) has adverse effects on brittle stars, as documented in previous studies (Kroeker et al. 2013; Hu et al. 2014). Furthermore, acidic water and lowering pH values have been reported to decrease the dry weight of both intact and regenerating brittle stars (Christensen et al. 2017). Besides that, lowering pH values has also been reported to cause increased mortality and a reduced growth rate of brittle larval stars as observed under low pH conditions. For example, according to Yu et al. (2015), brittle larval stars appeared more sensitive and experienced over 80% mortality after 7-day exposure to pH 7.7.

To conclude, this study has determined the sandy substrates of the Sancang Coast that are suitable for conserving brittle stars. In the future, it is recommended to elaborate more on the environmental variables of brittle stars to obtain a more comprehensive understanding of the brittle star habitat requirements. Considering that brittle stars are substrate dwellers, further research should encompass all aspects of substrates and sediments. In addition, those environmental variables should cover physico-chemical aspects of sediments ranging from sediment sizes and types to sediment organic matters (Geraldi et al. 2016).

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