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A description of the ecosystem on and around the breakwater in Benin (Arrondissement Avlékété)

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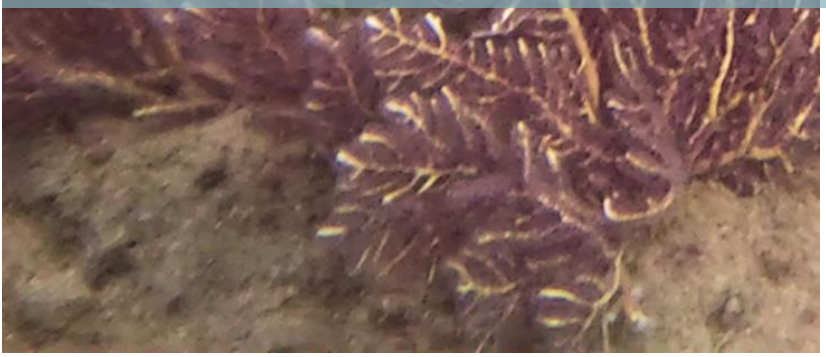

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Content

1 Summary

This study has the aim to give a description of the ecosystem on and around a nearshore breakwater in Benin (Arrondissement Avlékété). The benthic and fish fauna around the submerged breakwater and a sandy reference location were investigated, respectively with Van Veen grab samples, fishnet surveys and eDNA monitoring. The fauna on the breakwater was investigated by taking scrape samples.

Taxonomic identifications of the Van Veen Grab and scrape samples revealed over 200 benthic morpho-species, including 90 at species level. The benthic infauna in the sediment around the breakwater is more diverse compared to the sandy reference location. The seaward side Van Veen samples host the highest number of taxa (60 taxa), compared to the leeward site of the breakwater (47 taxa) and the reference (28 taxa). The most dominant taxa groups are the Crustacea, Mollusca, and Polychaeta. Polychaeta are clearly dominating at the reference location, while Mollusca dominate at the seaward site. At the leeward side of the breakwater the Mollusca and Polychaeta are equally dominating. The species found on the hard substrates of the breakwater depict a different community composition compared to the benthos in the sediment. A total of 127 morpho species were identified of which 50 at species level. On the breakwater, sponges, soft corals, and oysters are the most abundant of the larger taxa. Associated with these reef-building species are a range of smaller organisms such as polychaetes, crustaceans (amphipods, tanaidaceans, isopods, crabs, and shrimps), a few brittle stars, flatworms, mollusks (bivalves and gastropods) and minor groups (sipunculid worms, pycnogonids)

Of the 50 fish species morphological recorded in the area over time (2021-2024), 22 were also detected by eDNA metabarcoding and in addition to that eDNA detected an additional 30 species. The lower comparability is due to a lack of reference sequences. The majority of the detected fish species were shared between breakwater and reference locations. Seven species were exclusively detected in leeward locations, six species were detected exclusively in seaward locations, and two species were exclusively detected in reference locations. Following the IUCN red list classification, from the species found exclusively near the breakwater, one species was near threatened, three species were vulnerable, and one species was endangered.

This study shows that the breakwater has successfully established a thriving new habitat, supporting a wide range of marine species across various taxa. By providing essential hard substrates, the breakwater has encouraged the growth of diverse reef building communities, resulting in significantly greater biodiversity compared to the reference location, which lacks such substrates. These findings highlight the ecological benefits of the breakwater as it not only fosters habitat creation but also contributes to enhancing species diversity in the area.

2 Introduction

Beach erosion is a well-known phenomenon along the West African coast. This is caused by an almost permanent ocean swell coming from direction 200°-210° (SSW). Due to the angle of the wave attack to the coastline, important sand volumes are being transported from west to east. Man-made structures such as groynes constructed along the coastline, interrupt this sand transport, provoking sedimentation on the west side of the structure and erosion on the east side. This erosion, in combination with climate change and sea-level rise, threatens urbanization, villages and development along the coastline.

In early 2018, the Government of Benin awarded Jan De Nul with a design-and-build contract to protect a 5 km long stretch of coastline in the district of Avlékété. The concept design consists of a 5.2 km long submerged breakwater parallel to the coast at 150 m off the existing low-water coastline. The breakwater comprises a 1 to 500 kg foundation layer and a core of 1 to 3 tonnes of locally quarried rock units. The top of the breakwater is situated at approximately -6 m CD water depth. Inspiration for the design was sought in nature's most effective wave breaking structures: coral reefs. These natural structures combine three key functions: 1) they absorb wave energy; 2) they redirect it perpendicular to the coast; and 3) they host a rich ecosystem.

Figure 2-1. Side stone dumping vessel Pompei installing the submerged breakwater

This study has the aim to give a description of the ecosystem on and around a breakwater in Benin (Arrondissement Avlékété). The breakwater was built between 2018–2021 as a coastal protection measure (Figure 2-1). Fauna characterization before construction of the breakwater (September 2017) identified 217 benthic organisms of 34 distinct species. A dominance of mollusks was found. Identification to species level was unsuccessful due to the absence of relevant literature. Surprisingly, few annelids or crustaceans were identified in the samples.

The fishery resources of Benin's continental shelf are extremely diverse. Species diversity and plankton abundance are linked to seasonal variations in the oceanographic regime, while the

rapid development of plankton has a ripple effect on the fish population (Farahani & Kasraei, 2024). Fish production in the Gulf of Guinea is high and the migration of important fish stocks depends on upwelling phenomena, movements of climatic fronts and ocean currents (Table 1).

Table 1. Species caught by artisanal and industrial fisheries

Species by tonnage by artisanal fishery	
Sardinella maderensis	16%
Carangidae	11%
Sciaenidae	10%
Ilisha africana	9%
Engraulis encrasicolus	9%
Trichiurus lepturus	7%
Galeoides decadactylus *Scomber scombrus* *Chloroscombrus chrysurus* *Sphyraena afra*	37%

Species by tonnage by industrial fishery	
Sciaenidae	15%
Galeoides decadactylus	6%
Penaeus	6%
Dasyatidae	4%
Cynoglossus spp	3%
Dentex sp	3%
Ephippion guttifer	3%
Balistes spp	2%
Sphyraena afra	2%
Lagocephalus laevigatus	2%
Other species	41%-52%

The breakwater acts as a protective barrier against waves and creates a less energetic environment, allowing the growth of aquatic fauna and flora. The presence of the breakwater will foster a more sheltered and stable environment conducive to the growth and diversity of marine flora and fauna. By providing hard substrates, the breakwater may enhance the establishment of algal communities and reef builders such as oysters, sponges and possibly corals, creating suitable habitats that serve as nurseries and feeding grounds for various aquatic organisms, including fish and crustaceans. To assess these ecological impacts over time, three sampling campaigns (2020, 2021, and 2024) were conducted to monitor the benthic fauna colonizing the breakwater, the benthic infauna in surrounding sediments, and fish diversity through experimental fishing. In 2024, environmental DNA (eDNA) analysis was additionally employed to gain deeper insights into fish diversity.

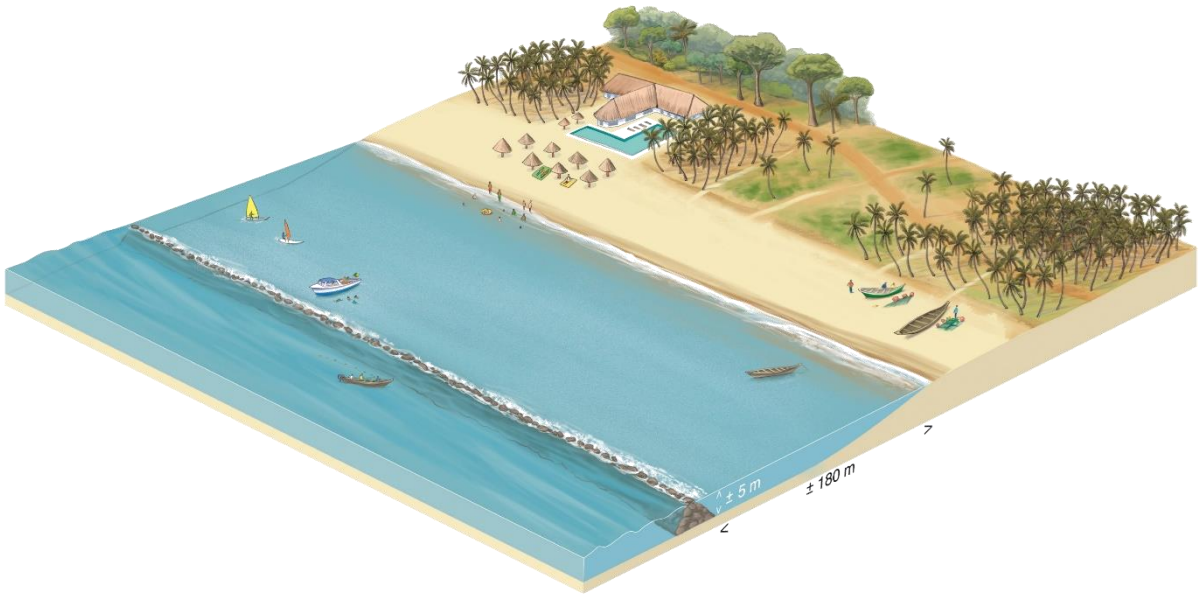


Figure 2-2. Drawing of the study site (© Hendrik Gheerardyn) with indication of the breakwater position.

3 Material and Method

3.1 Sampling

The same sampling locations were chosen for the different methods of sampling (Van Veen, scrape samples and eDNA samples) (Figure 3-1). Along the breakwater, a total of six locations were sampled. Three locations on the seaward side and three locations on the leeward side. Sampling was focused on the first 1.5 km section on the western side of the breakwater since this is the oldest section installed in 2018. Additionally, three Van Veen grabs and eDNA samples were taken at a sandy reference site located 2 km east from the breakwater. 10 × 2 L Van Veen Grabs were sampled from each location to obtain sufficient material for benthic infauna analysis. The material was sieved through a 1 mm mesh sieve and preserved in a 7% formaldehyde/seawater solution. Epifauna was sampled at the same locations by scrape samples from the breakwater by divers. No reference samples were taken for the scrape samples due to the absence of hard substrate in the sandy reference area.

Water samples for eDNA were taken at the six locations along the breakwater (seaward, leeward) and the reference site. At the reference location three random water samples were taken at 1 km distance from each other. Water samples were taken by pumping approximately 1 L of water through a Sterivex™ filter until the filter clogged. Subsequently 2 ml Longmire's buffer was added to the filter for preservation.

Figure 3-1. Overview of the sampling locations (Google map).

Experimental fishing was conducted in 2021 and 2024 to sample marine fauna near the breakwater. For reference, a timeline to summarize the sampling campaigns is shown in Figure 3-3.

Gillnets of the "Tohounga" and "Sovi" type were deployed leeward and seaward of the breakwater, and 2 km further east outside the zone of influence of the breakwater (sandy reference zone). The nets were set along the breakwater, parallel to the coast. The nets were set around 17:00 the previous day and retrieval started at 8:00 the next morning and ended around 12:00 (GMT +1). The recovery of the nets began with the first nets placed towards the last. A total of 18 gillnets were set, including eight seaward, eight nets leeward and two nets in the reference zone (Figure 3-2, Table 2). It is worth noting that many nets were concentrated in the oldest part of the breakwater (the western part).

Table 2 Specifications of the fishing nets

Campaign	2021		2024	
Gillnet	Tohounga	Sovi	Tohounga	Sovi
Length	200 m	200 m	200 m	200 m
Mesh	4.0 cm	1.5 cm	9.0 cm	2.5 cm
Drop	1.5 m	1.5 m	1.8 m	2.5 m

Figure 3-2. Schematic representation of the position of the gillnets during the experimental fishery

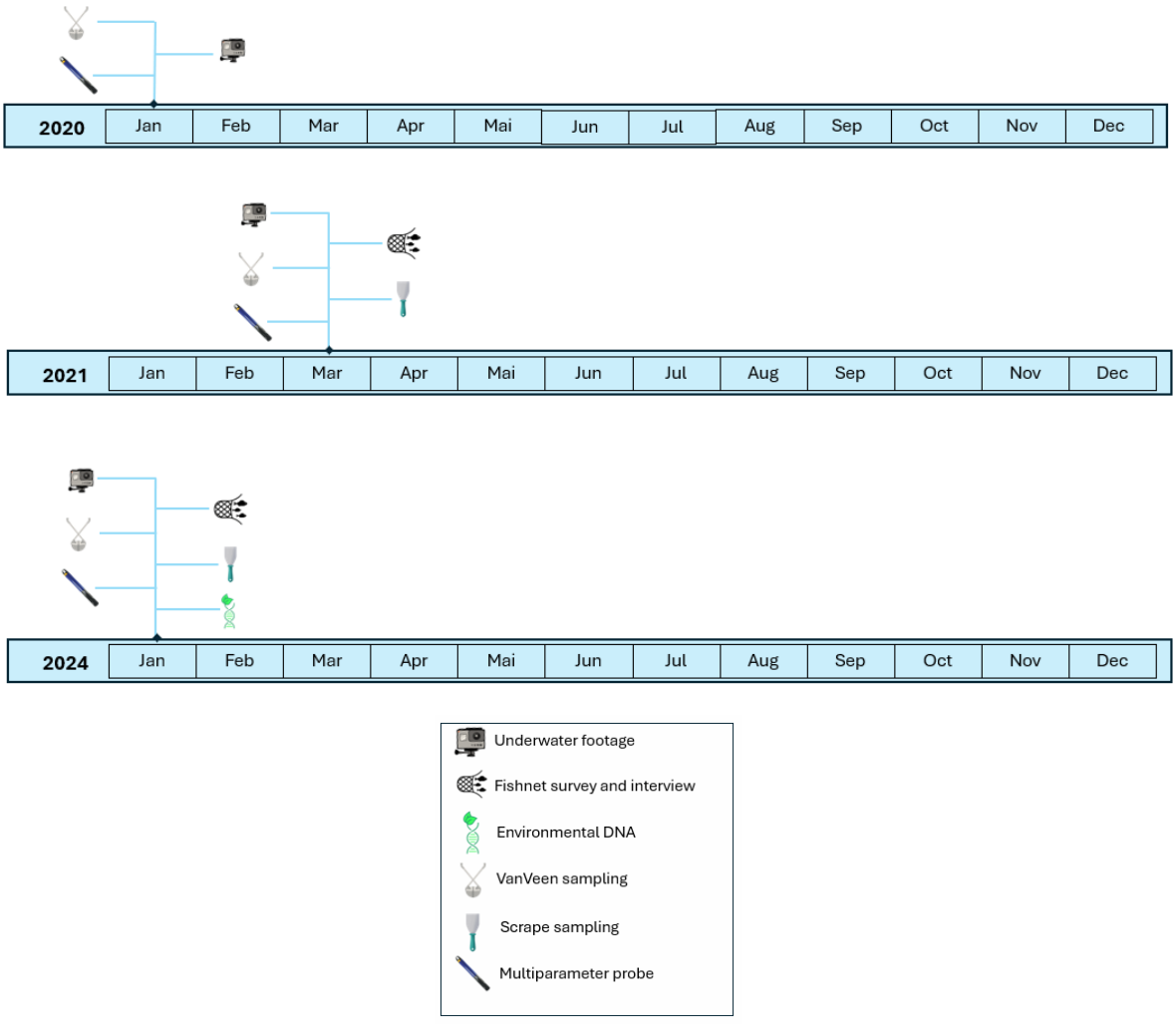


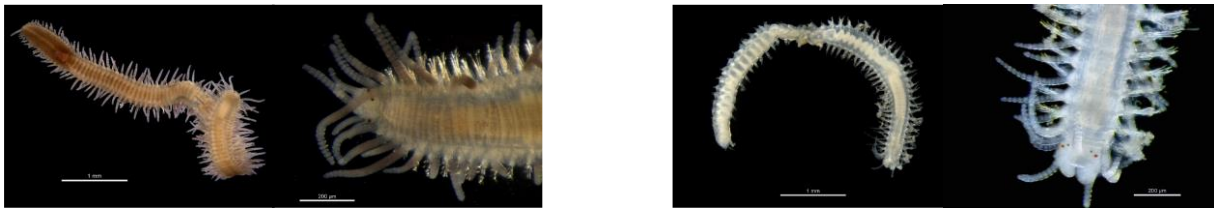
Figure 3-3 Timeline of sampling

3.2 Morphological data analysis

3.2.1 Benthos

The biota were identified to the lowest possible taxonomic level using a binocular stereo microscope (Leica M205C) and identification keys (Bivalvia: Ardovini & Cossignani, 2004; Von Cosel, 1995; Annelida: Day, 1968; Crustacea: Henriksen, 2009; Kensley, 1978; Griffiths, 1973; Echinodermata: Olbers, 2016; Cnidaria: Wirtz & d'Udekem-d'Acoz, 2001; Wirtz & De Grave, 2010; Sánchez, 2007). Additionally, more than two hundred original journal articles were consulted for species where no keys were available. A complete list of the consulted literature can be found in Annex 8

Organisms are defined by a genus name and a species name. Sometimes it is not possible to identify up to species level for several reasons and then we can define a morphospecies. This is a species that is distinct from other species found in the study area, but cannot be determined to species level. Morphospecies are proven by photographic evidence. The organism is then catalogued under a higher taxonomic level (Genus, Family, Order or even higher). See Figure 3-4.



Syllidae sp1 Syllidae sp3

Figure 3-4. Syllidae sp1 and Syllidae sp3 are two distinct species that could not be identified beyond family level (Photographs © Hans Hillewaert)

Reasons for using morphospecies may be the lack of relevant literature or identification keys; the occurrence of undescribed species; incomplete organisms (e.g., no head, no antennae, no tail, ...). All these issues, but especially the lack of relevant literature and keys, apply to these morphological analyses.

3.2.2 Fish identification

Specimens of marine organisms caught in the gillnets were identified using the FAO identification guides for the Gulf of Guinea (Schneider, 1992) and the Central-Eastern Atlantic (Carpenter & De Angelis, 2014). Following identification, the specimens were photographed, counted and fin samples were taken for molecular analyses. The currently accepted nomenclature of each identified species was confirmed using the World Register of Marine Species (WoRMS) "Taxa" tool available at: https://www.marinespecies.org/index.php.

3.3 Genetic data analyses

eDNA extraction, PCR amplification using 12S rDNA MiFish_U/E degenerate primers and library preparation were performed at Flander Research Institute for Agriculture, Fisheries and Food (ILVO), in dedicated pre- and post-PCR laboratories. Illumina NovaSeq sequencing was conducted by Admera Health Biopharma Services (New York, US). Demultiplexing of the sequences was conducted using cutadapt v2.3. Error modeling and the creation of Amplicon Sequencing Variants (ASVs) were performed using the DADA2 v1.10.1 bioinformatics pipeline. Taxonomic assignment was initially conducted based on the custom-made reference database, which was previously created according to the morphologically identified species by Jan De Nul in Benin. This database consists of partial 12S reference sequences of 35 fish species from the study area. Unassigned ASVs were subjected to a further query against the custom reference database and NCBI database using BLAST+ v2.12.0. Since the negative control samples returned very few reads, the data were not subjected to decontamination.

All downstream analyses were performed using the VEGAN package v 2.6.4 in R. The samples were categorized into three zones: seaward (three samples), leeward (three samples) and reference (three samples). A Venn diagram was constructed with the presence/absence data of the species using the VENNDIAGRAM package in R to compare fish species detected by eDNA and morphology, as well as the fish species detected in seaward, leeward and reference locations. For the alpha diversity analysis, we implemented coverage-based rarefaction to ensure the equal completeness of the samples for diversity comparison. To test for differences in species richness (S) and Shannon diversity index (H') of eDNA data per zone (leeward, seaward, reference), a one-way Analysis of Variance (ANOVA) was conducted. We used robust linear model instead of a linear model for Shannon diversity index since the normality assumption were not met for that measurement. Post-hoc Tukey HSD (Honestly Significant Difference) tests were conducted for the significant main effects. For beta diversity analysis, we first standardized the unrarefied community data by implementing "eDNA index" method based on Wisconsin double transformation (Kelly et al., 2019). Briefly, eDNA read count proportions were calculated, followed by scaling the abundances from 1 to 0 based on the species with the highest eDNA proportion. Beta diversity was then calculated based on a Bray-Curtis dissimilarity matrix and a Non-metric Multidimensional Scaling (NMDS) plot was used to visualize the ordination of the data grouped by sampling zones (Leeward, Seeward and Reference). The statistical significance of the zone factor on community composition was evaluated with permutational multivariate analysis of variance (PERMANOVA), followed by pairwise multilevel comparison of the groups.

4 Results

4.1 Benthic infauna near the breakwater (Van Veen)

The comparison between the samples taken at the reference, seaward and leeward site of the breakwater shows 5 taxa in common (Figure 4-1). The seaward side samples host the highest number of taxa (60 taxa), compared to the leeward site of the breakwater (47 taxa) and the reference (28 taxa). 17 taxa are in common between the Van Veen samples at both sides of the breakwater. The species in common with the reference site is lower for both and 6 and 9 taxa for the leeward and seaward, respectively. This indicates that the sediments around the breakwater are enriched in fauna compared to the reference location.

Figure 4-1. Venn diagram of the three types of Van Veen samples: Reference, seaward and leeward (towards the coast). (Photographs © Hans Hillewaert)

The most dominant groups are the Crustacea, Mollusca and Polychaeta (Figure 4-2). Polychaeta are clearly dominating at the reference location with 13 taxa, followed by 4 taxa for both Mollusca and Crustacea. At the seaward site, the Mollusca are dominating with 21 taxa, followed by 14 taxa of Crustacea and 13 of Polychaeta. At the leeward side of the breakwater the Mollusca and Polychaeta are equally dominating with 6 taxa, closely followed by the Crustacea with 5 taxa.

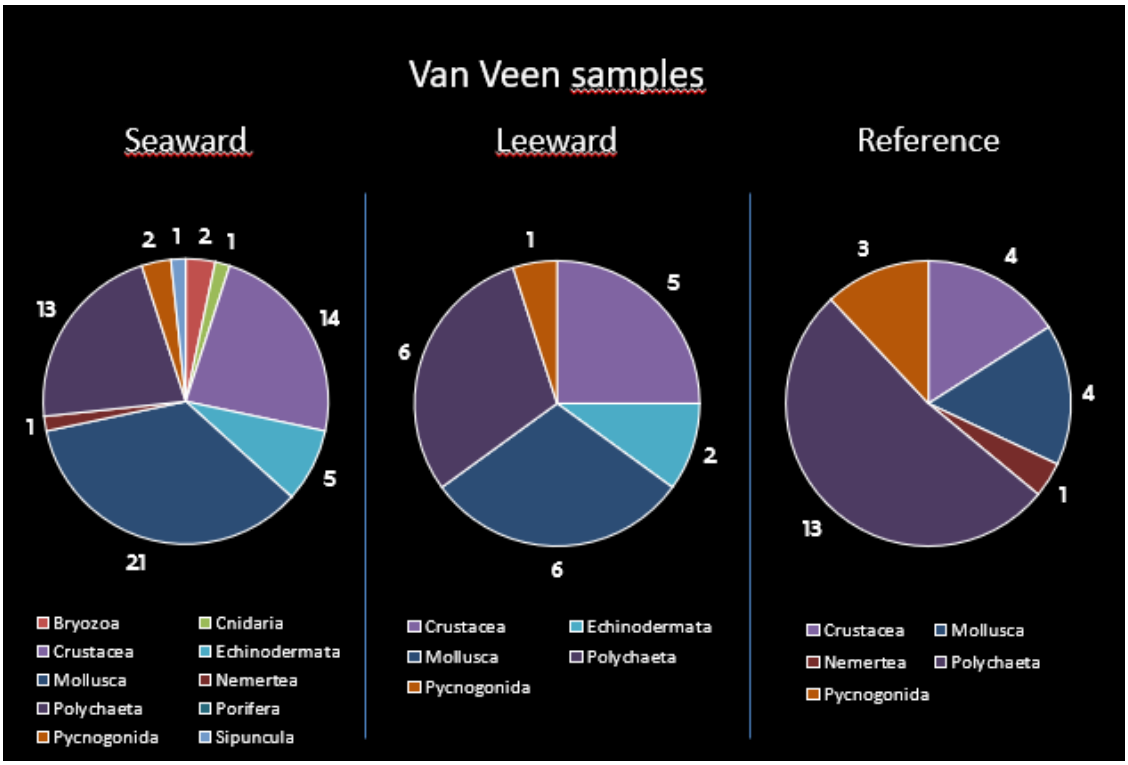


Figure 4-2. Overview of the relative dominance of the different taxa groups at the three Van Veen sample locations

4.2 Benthic epifauna on the breakwater (scrape samples)

127 morphospecies were found, of which 50 were identified to species level. Sponges, soft corals, and oysters are the most abundant of the larger taxa. Associated with these reef-building species are a range of smaller organisms such as polychaetes, crustaceans (amphipods, tanaidaceans, isopods, crabs and shrimps), a few brittle stars, flatworms, mollusks (bivalves and gastropods) and minor groups (sipunculid worms, pycnogonids) (Figure 4-3).

Figure 4-3. Photo impression of the main species in the scraping samples. (Photographs © Hans Hillewaert)

Crustacea are the dominant taxonomic group (46 taxa), followed by Polychaeta (28 taxa), Mollusca (15 taxa) and Cnidaria (14 taxa). Among the latter, there were also some hard coral species. The overview of the taxa from the breakwater shows the presence of many different taxonomic groups (Figure 4-4). Most of these morphospecies differ from those found in the Van Veen samples, showing a clear increase in biodiversity due to the introduction of a new substrate type.

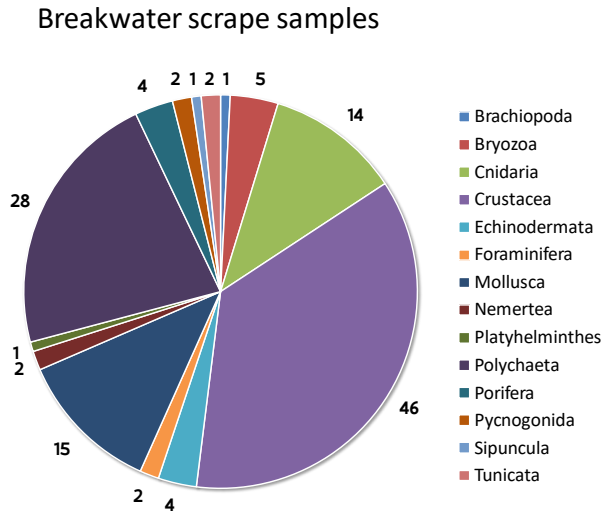


Figure 4-4. Overview of the relative dominance of the taxa groups on the breakwater (scrape samples)

4.3 General diversity

The major taxonomic groups in the area are Crustacea, with several species of crabs, amphipods, isopods, and shrimps (Figure 4-5). The Mollusca exist mostly of bivalve and gastropod species (Figure 4-6). The Annelida consist of many Syllidae taxa, along with tube-building polychaetes (Figure 4-7). Some other interesting groups are the Echinodermata, Brachiopoda and Bryozoa (Figure 4-8).

Figure 4-5. Overview of the major Crustacea taxa (with inclusion of Pycnogonida). (Photographs © Hans Hillewaert)

Figure 4-6. Overview of the major Mollusca taxa. (Photographs © Hans Hillewaert)

Figure 4-7. Overview of the major Annelida taxa. (Photographs © Hans Hillewaert)

Figure 4-8. Overview of other important taxa groups (Bryozoa, Brachiopoda, Echinodermata). (Photographs © Hans Hillewaert)

4.4 Comparison with the 2021 sampling for benthos

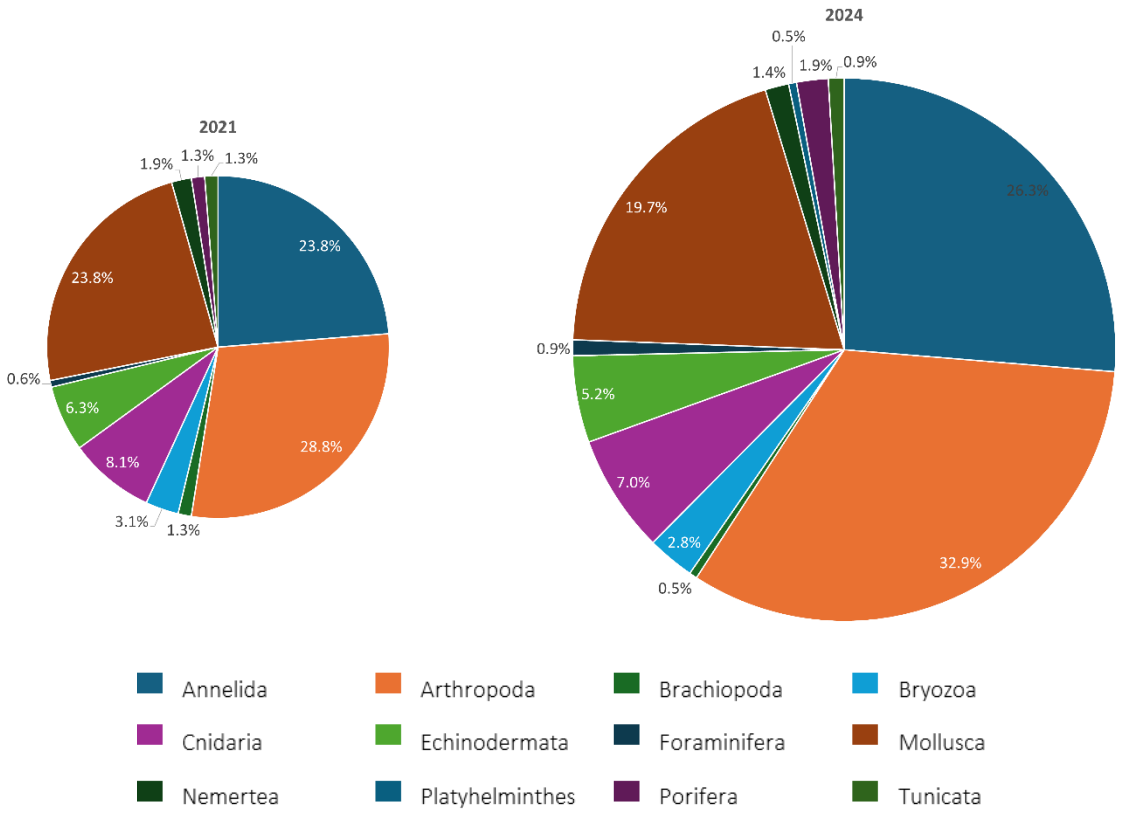


Figure 4-9. Comparison between Phyla 2021 - 150 valid morphospecies, 39 fully identified species; 2024 - 213 valid morphospecies, 96 fully identified species.

A comparison between the two sampling periods is not straightforward. In the initial sampling, no morphospecies were defined and most organisms were not reliably identified beyond the family level. This was due to a lack of detailed identification literature and expertise, so the number of distinct species cannot be precisely determined. In general, 2021 had 150 valid morphospecies, including 39 fully identified species. In 2024, we found 213 valid morphospecies, of which 96 are fully identified species. In 2021 a thanatocoenosis was also used for the Mollusca to determine species richness. After deducting these empty shells as well as species that may not occur in the study area, only a comparison at the phylum level could be made. There is a general proportional similarity in the main phyla. The differences mainly reflect the number of Polychaeta and Crustacea identified to species level in the follow-up sampling in 2024 (Figure 4-9).

4.5 Fishing net survey

4.5.1 Diversity of species from experimental fishing

Experimental fishing allowed a total of 24 species, belonging to 19 genera and 18 families, to be inventoried on the seaward and leeward side of the breakwater and at a reference site further away.

Among the 18 families, the Carangidae family is the most diverse, comprising two genera (*Caranx* and *Trachinotus*). All other fish families encountered (Balistidae, Cynoglossidae, Drepanidae, Ephippidae, Serranidae, Dasyatidae, Muraenidae, Muricidae, Lethrinidae, Lutjanidae, Kuhliidae, Psettodidae, Sciaenidae, and Scaridae) each include one genus. From the Mollusca one genus each from Melongenidae and Strombidae and from the Crustacea one species of crab (Portunidae).

Among the 19 genera, the most diverse are the genera *Pseudotolithus* and *Lutjanus* each represented by three species (*P. epipercus, P. senegallus* and *P. senegalensis* for *Pseudotolithus*) and

(*L. dentatus*, *L. fulgens* and *L. goreensis* for *Lutjanus*). They are followed by the genus *Caranx* containing two species (*C. crysos* and *C. hippos*). All the other 16 genera are each represented by a single species.

In terms of spatial distribution, species diversity seaward and leeward of the breakwater showed no significant difference. A total of 16 species were caught leeward compared to 15 species seaward. No species were caught by the nets placed in the sandy reference area. *Pseudotolithus epipercus* (Sciaenidae) is the most abundant species with a relative abundance of 20.4%. It is followed by *Lutjanus goreensis* of the Lutjanidae family with a relative abundance of 16.3%. The species *Caranx crysos* (Carangidae) and *Lutjanus fulgens* (Lutjanidae) both having the same relative abundance of 14.3%. The species *Caranx hippos* (Carangidae) with a relative abundance of 5.1% and the species *Pseudotolithus senegallus* (Sciaenidae) and *Ephippus goreensis* (Ephippidae) with an identical relative abundance of 4.0% complete this list. The other species have a low relative abundance ranging from 3% to 1%. (Figure 4-10).

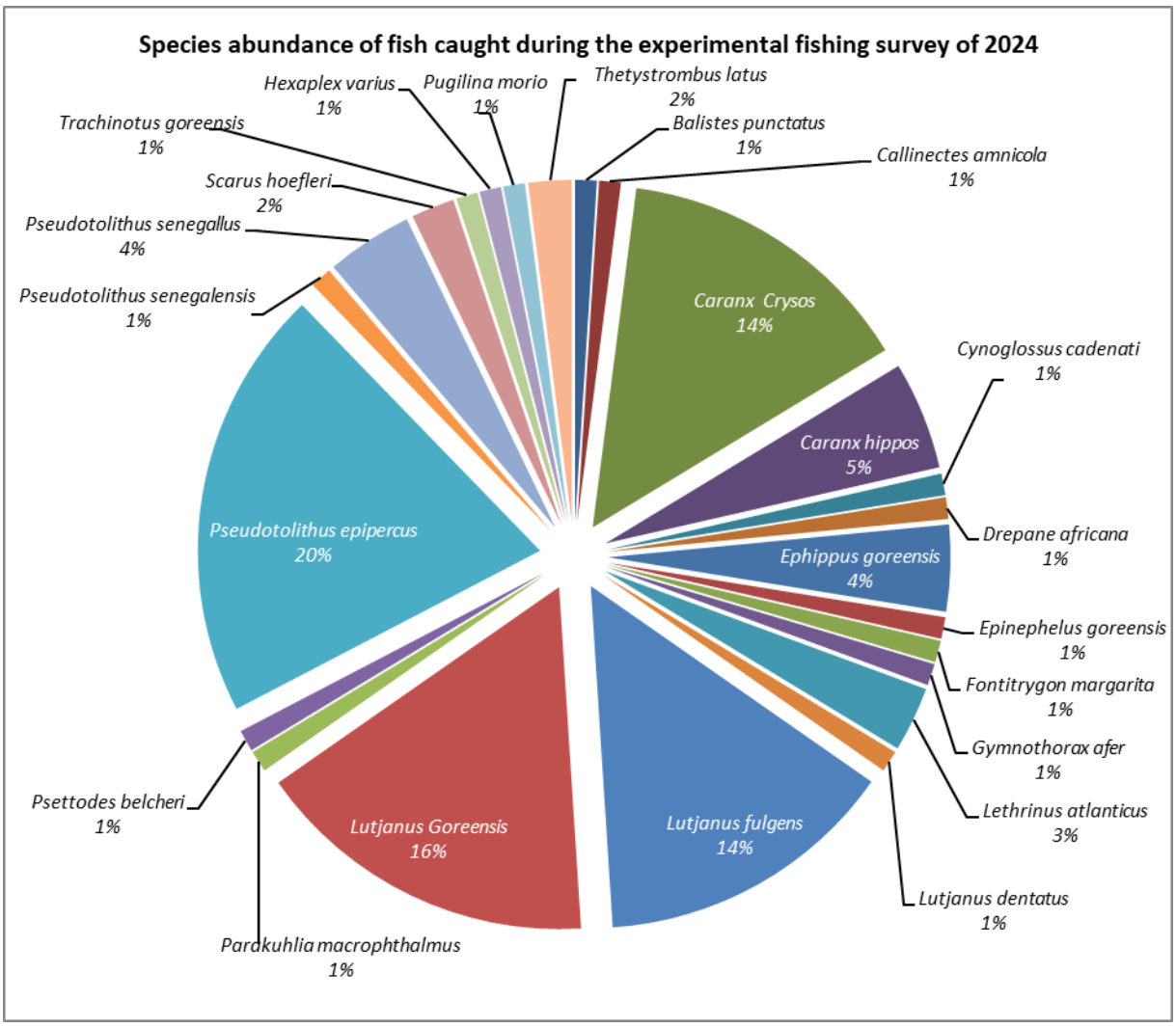


Figure 4-10: Species abundance of fishing net survey 2024

4.5.2 Comparison 2021 & 2024 surveys

The results of the two campaigns show that there is a small difference in terms of species around the breakwater between the two years.

24 species belonging to 19 genera and 18 families were counted in the catches of the 2024 experimental fishery compared to 27 species belonging to 22 genera and 19 families for the experimental fishery conducted in 2021.

It should be noted that the most abundant species in both experimental fisheries remained the same (*Pseudotolithus epipercus* of the Sciaenidae family). However, it was noted that other species that were abundant in the catches of the 2021 fishery were not caught at all (*Galeoides decadactylus* of the Polynemidae; *Callinectes pallidus* a crab of the Portunidae family) or were caught in small numbers in 2024 (*Caranx hippos*). On the contrary, some species found in small numbers in the catches of the 2021 experimental fishery are abundant in the 2024 catches (*Lutjanus goreensis*; *L. fulgens* and *Caranx crysos*.).

This difference between the results of the two experimental fisheries can have several explanations. One of them is the current intensity of fishing around the breakwater. In 2021, there was no strong fishing pressure on the breakwater. Over time, local fishermen have come to understand that the breakwater has created favourable habitat for the reproduction and development of several marine species, especially many commercial species. The most likely explanation for small differences in species composition is the increase in the mesh sizes of the nets used for the two campaigns. Mesh sizes in 2021 were 4 cm and 1.5 cm as opposed to 9 cm and 2.5 cm in 2024 (Tohounga and Sovi gillnets). Larger mesh sizes probably induced by the application of fishing legislation in the Republic of Benin were observed during the survey on the characteristics of the gear used by fishermen. Both campaigns were also performed during different months of the year which can explain the presence or absence of certain species.

4.6 Genetic observations

The sequencing event generated 14,042,135 forward and reverse reads in total. After the demultiplexing and DADA2 step, biological samples included 693,300 reads per sample on average (± SD 955,884) (Table 3).

Table 3. Number of read counts, ASVs and species in the samples after DADA2 step. Note that each species in the negative controls were represented by only one read, making decontamination unnecessary.

Sample ID	# Reads	# ASVs	# Fish species
AL_1000_2024	524,070	138	43
AL_1500_2024	103,719	103	34
AL_500_2024	318,584	108	27
AS_1000_2024	152,751	105	41
AS_1500_2024	52,911	77	27
AS_500_2024	1,185,185	107	21
REF_R1_2024	170,321	78	28
REF_R2_2024	3,233,231	193	37
REF_R3_2024	198,933	121	37
DNA_Neg_1	-	-	-
Filter_Neg1	85	9	6
Filter_Neg2	14	8	3

Out of 332 Amplicon Sequencing Variants (ASVs) generated from Illumina sequencing after demultiplexing, 185 were identified as fish ASVs. These ASVs accounted for 52 species-level, 12 genus-level, and 7 family-level fish detections in total (Supplementary information). The higher taxonomic level assignments are mostly due to identical 12S MiFish fragment sequences of closely related species, such as *Pseudolithus senegalensis* and *P. typus*. Likewise, when an ASV was assigned to a species that is not a resident of West Africa or the Gulf of Guinea, those assignments were grouped under a higher taxonomic level indicating a relative of that species in West Africa that has not yet been sequenced. For example, if an ASV was assigned to *Scarus iseri*, *S. dimidiatus* or *S. taeniopterus*,

assignments were grouped to *Scarus* sp. since none of these species are resident to West Africa. *Butis koilomatodon*, an Indo-Pacific species, was found to be introduced to Guinea (Vreven et al., 2007). Among the species detected by eDNA *Engraulis encrasicolus*, *Ethmalosa fimbriata*, *Scarus* sp., and *Sardinella maderensis* accounted for the highest read counts, with 28%, 13%, 10% and 7% of the total read counts, respectively (Supplementary information).

Of the 50 species detected by morphological identification reported by Jan De Nul, 22 were also detected by eDNA metabarcoding. In addition, another 30 species were detected by eDNA (Figure 4-11). Of the species identified solely by morphological identification, only nine had available 12S reference sequences, either from tissue samples or from the NCBI database. For the remaining 19 species, no 12S reference sequences were available. This highlights the importance of improving the reference sequence database of fish in the area to improve eDNA biodiversity analysis.

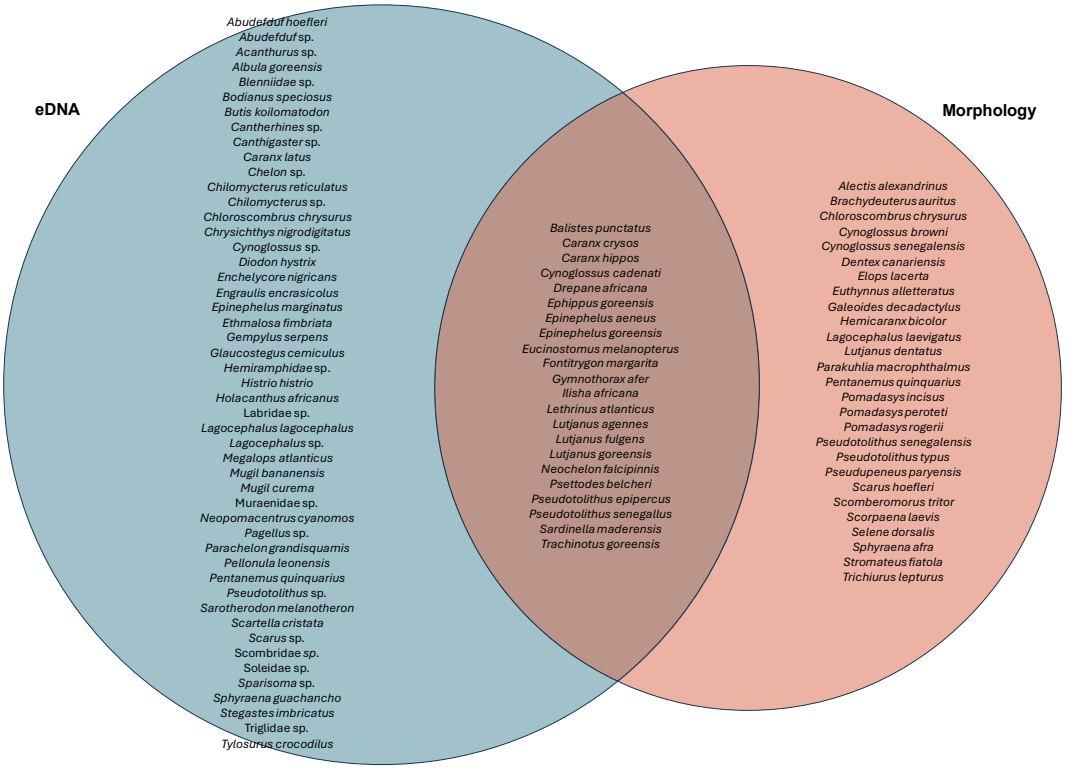


Figure 4-11. Venn diagram of the species based on the detection method. The full list of the species including all detection intersects is given in Table 1.

The majority of the detected species were shared between breakwater and reference locations (Figure 4-12). Seven species were exclusively detected in leeward locations, six species were detected exclusively in seaward locations, and two species were exclusively detected in reference locations.

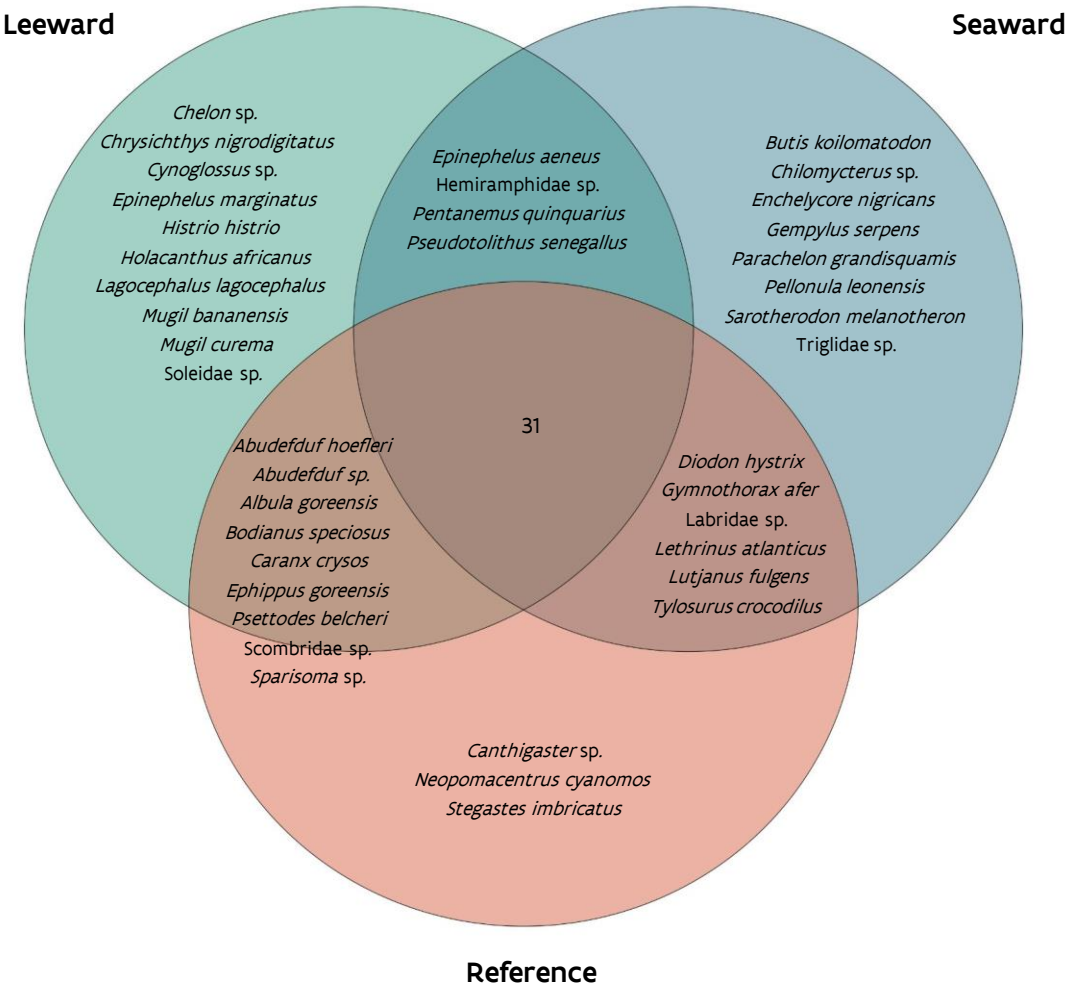


Figure 4-12. Venn diagram of the species based on the sampling zone.

In terms of alpha diversity indices, seaward locations exhibited the highest variability (Figure 4-13). The ANOVA results for the species richness, performed after fitting a linear model, revealed that the richness was not significantly different between the three zones ($p > 0.05$). In contrast, ANOVA after fitting a robust linear model for the Shannon diversity index indicated a significant effect of the zone factor ($p = 0.013$). Post-hoc Tukey HSD test showed that the seaward was significantly different from both the leeward ($p = 0.0008$) and reference samples ($p = 0.0002$). However, there was no significant difference between the reference and leeward samples.

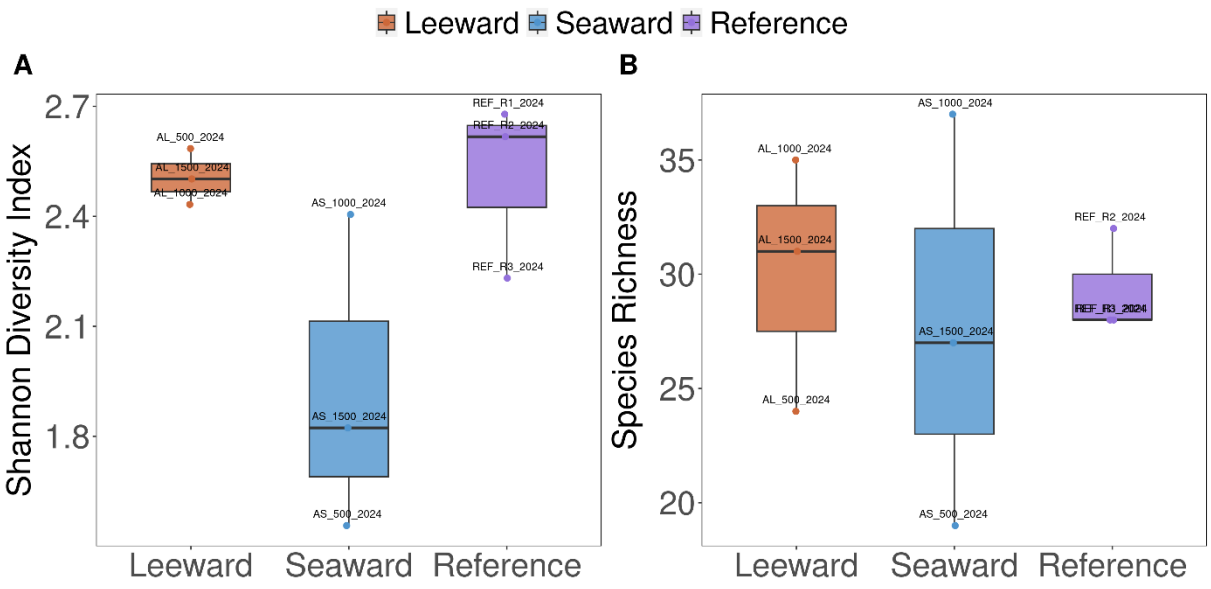


Figure 4-13. Box plots for alpha diversity measurements per zone comparing eDNA samples. A) Shannon Diversity Index B) Species richness.

Non-parametric Multidimensional Scaling (NMDS) plot revealed a separation between breakwater and reference communities (Figure 4-14). PERMANOVA analysis revealed a significant effect of zone factor on fish communities (pseudo-F = 1.88, p = 0.013). The R^2 values suggest that the zone factor explains a considerable proportion of the variation in community composition between each pair of zones (ranging from 27.303% to 34.981%). However, the lack of statistical significance in the pairwise comparisons (p-value = 0.1) suggests that, after adjusting for multiple comparisons, there is no compelling evidence to conclude that these differences are statistically significant. This might be due to the small sample size, which can limit the power of the test to detect significant differences. In future sampling campaigns, including more sampling locations or replicates to the sampling design may enhance the robustness of the data analysis.

When the seaward and leeward zones were combined and considered as a single breakwater zone, PERMANOVA analysis revealed borderline significance between reference and breakwater zones (pseudo-F = 1.87, p = 0.0483), explaining 21% of the variations between these zones.

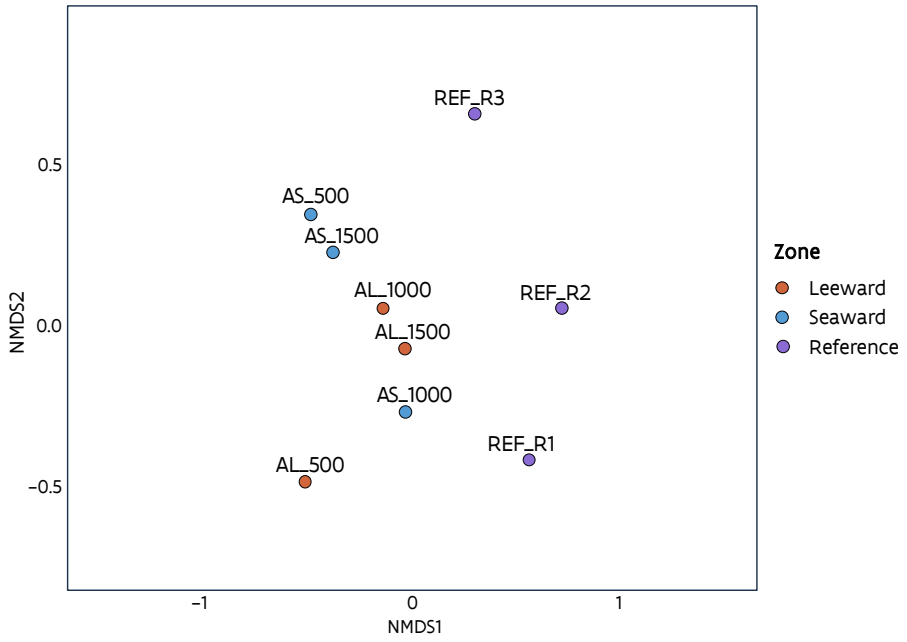


Figure 4-14. Non-parametric Multidimensional Scaling (NMDS) plot for the fish community (Stress value = 0.0587). Groups are defined for the zones.

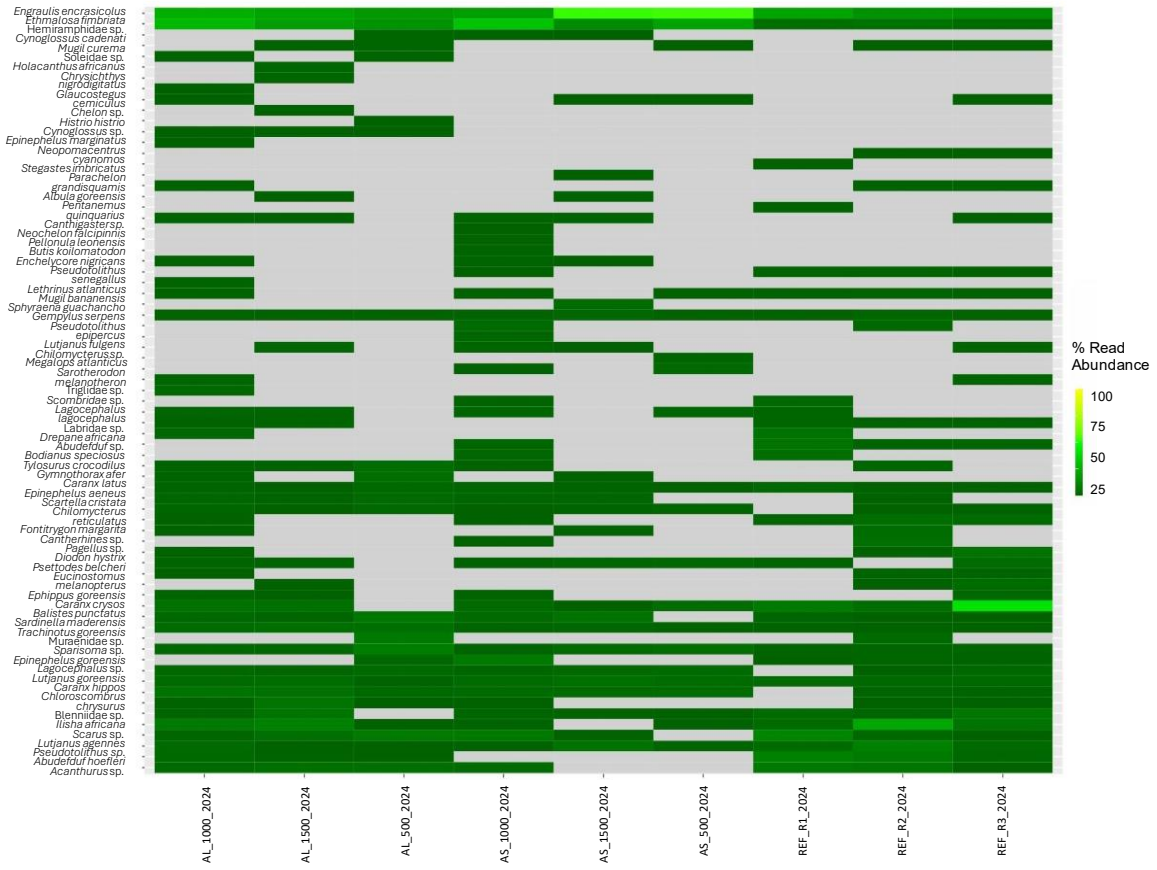


Figure 4-15. Heat map for the relative read abundance of fish species.

4.7 Interest for Conservation

The species identified during the experimental fishing surveys of 2024 have different conservation statuses on the IUCN Red List (IUCN, 2024). It should be noted that the status of some species deserves special attention. *Pseudotolithus senegallus* and *P. senegalensis* are respectively Vulnerable and Endangered globally. *Fortitrygon magarita* and *Balistes punctatus* are vulnerable on the IUCN Red List. *Epinephelus goreensis* is listed as Near Endangered. Most of the species fished except those mentioned above have a "Data Deficient" status on the IUCN Red List.

To add to the experimental fishing survey of 2024, eDNA analysis identified a total of 71 species. By combining the experimental fishing technique with DNA analysis, 11 species were recorded in the IUCN Red List as Near Threatened or higher, of which 5 species were only found around the breakwater. The critically endangered *Glaucostegus cemiculus* was detected in all eDNA samples.

eDNA samples further revealed the presence of *Sardinella maderensis*, *Megalops atlanticus*, *Pentanemus quinquarius* and *Epinephelus marginatus* that are listed as vulnerable. Lastly *Epinephelus aeneus* was also detected and is listed as near endangered. All red-listed species detected in the fishing nets were also detected using eDNA. (Annex 3 and Annex 5). See Figure 4-16 for an overview of all detected IUCN listed fish species.

The breakwater designed to function as a coral reef and sheltering a significant diversity of marine organisms, contributes to the conservation of marine biodiversity in Beninese marine waters.

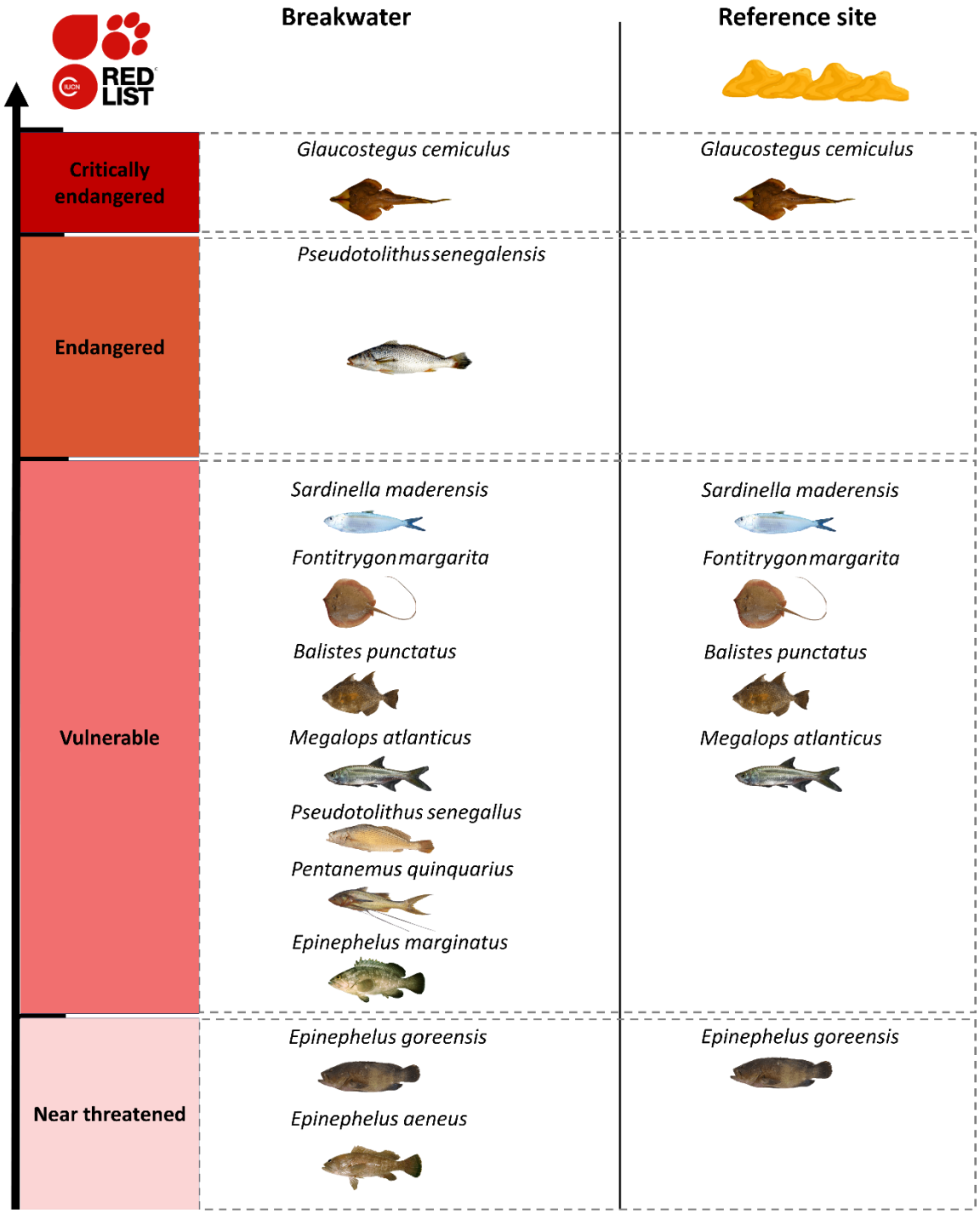


Figure 4-16 Schematic overview of IUCN listed fish species identified morphologically and/or via eDNA for the breakwater and reference site.

5 Discussion and conclusion

In this study, the benthic and fish fauna on and around the breakwater and a reference location were investigated, respectively by means of Van Veen grab samples, scrape samples, fishnet surveys and eDNA monitoring. The 2024 campaign was the most comprehensive study on the fish and benthic fauna in the area with the breakwater. It was also on a more detailed taxonomic level than in previous studies and the different sampling techniques delivered complementary information. The aim of the monitoring is to evaluate the effect of the breakwater on the marine ecosystem within the area. The results of this study confirm that the breakwater hosts additional

fauna, and in such way enriches the biodiversity. All sampling and monitoring strategies showed that the breakwater hosts a far greater diversity when comparing it to a sandy reference area lacking hard substrates. Based on the eDNA samples, it was shown that the fish community is divers, most at the leeward side of the breakwater. Fish net surveys and morphological identification did not show any significant difference between the seaward or leeward side. In the Van Veen samples, the benthic infauna diversity was lower at the leeward side of the breakwater compared to the seaward side, possibly due to courser material being found leeward compared to seaward. The overall benthic infauna diversity around the breakwater was far richer compared to the sandy reference site which suggests that the breakwater has a spillover effect and enriches the surrounding benthic infauna. . The breakwater itself host a very divers benthic epifauna and the larger taxa were sponges, soft corals, and oysters. These are important reef-building species, which host a range of smaller organisms such as polychaetes, crustaceans, brittle stars, mollusks, seaspiders and flatworms. Therefore, the effects of the breakwater on the marine ecosystem in the area is as expected.

The major conclusions can be summarized as follows. First, comparing the outcomes with previous monitoring studies is not easy, due to some differences in sampling strategy and level of taxonomical determination between the campaigns. Second, the implementation of a new strategy, eDNA monitoring, helped to improve the monitoring of fish diversity, but can be further improved by continuing the effort to enlarge the reference database in possible future sampling campaigns. . Third, the hard substrates that make up the breakwater have created a new and unique habitat that influences the marine ecosystem in the area by attracting and supporting a wide range of marine taxa that enrich the overall marine biodiversity in the surrounding area, in line with what was expected.

To gain a full understanding of the reef ecosystem developing on the breakwater, continued monitoring is essential. Long-term follow-up will allow for the observation of trends in biodiversity and ecosystem structure over time, as well as the early detection of any shifts in species composition. Such monitoring will provide insights into the development and resilience of reef-building species and their associated fauna, further supporting conservation and management efforts. Figure 5-1 gives an artistic impression of the potential ecosystem development on the long-term.

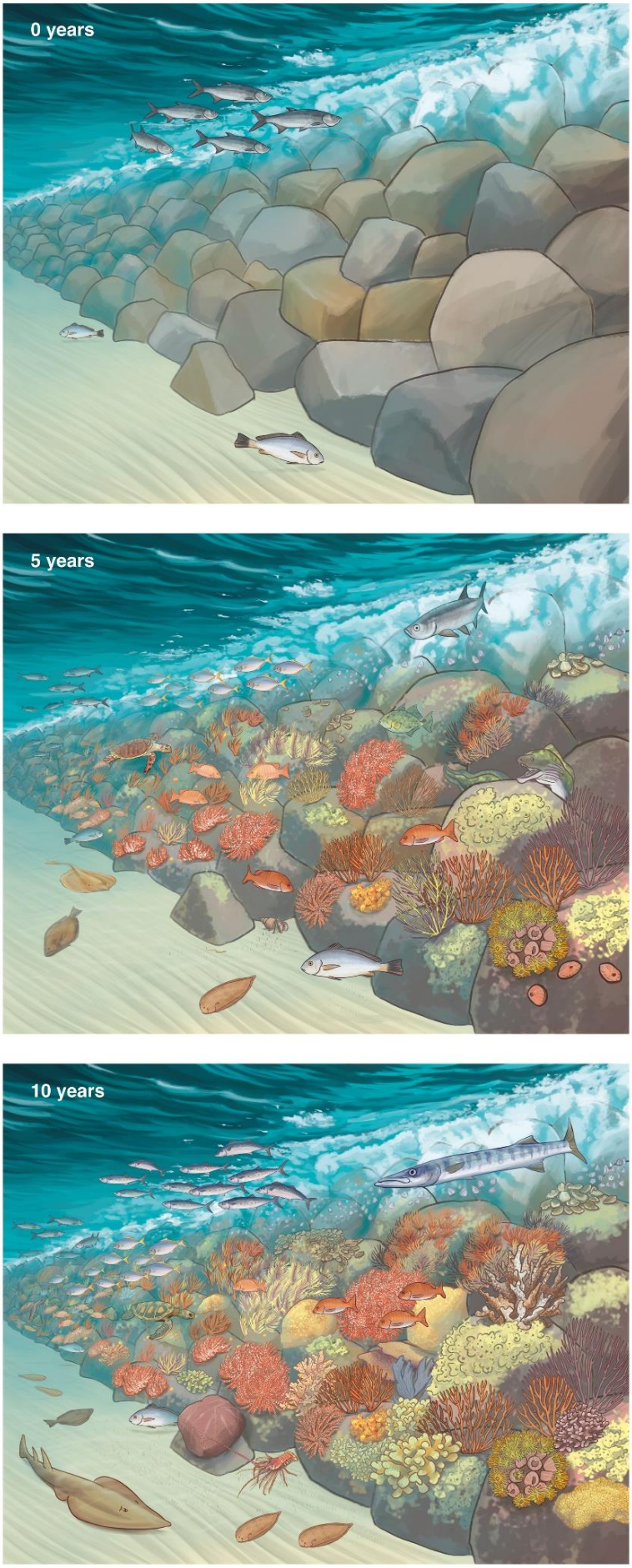


Figure 5-1: Long-term evolution of the marine biodiversity of the underwater breakwater ©Hendrik Gheerardyn

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6.3 Benthos identification

A complete list can be found in Annex 8.

Annex 1 Species list 2021

Caveat: included are dead shells (thanatocoenosis) and some doubtful identifications due to lack of identification literature.

Class	Order	Family	Genus	Species
Anthozoa	Actinaria			Actinaria sp.1
Anthozoa	Actinaria			Actinaria sp.2
Anthozoa	Actinaria			Actinaria sp.3
Anthozoa	Actinaria			Actinaria sp.4
Ascidiacea				Ascidiacea sp.1
Ascidiacea				Ascidiacea sp.2
Asteroidea	Paxillosida	Astropectinidae	*Astropecten*	*Astropecten jarli*
Bivalvia	Adapedonta	Hiatellidae	*Panopea*	*Panopea sp.*
Bivalvia	Adapedonta	Solenidae	*Solen*	*Solen guinensis*
Bivalvia	Arcida	Arcidae	*Mosambicarca*	*Anadara geissei*
Bivalvia	Arcida	Arcidae	*Anadara*	*Anadara gibbosa*
Bivalvia	Arcida	Arcidae	*Arca*	*Arca sp.*
Bivalvia	Arcida	Glycymerididae	*Glycymeris*	*Glycymeris concentrica*
Bivalvia	Cardiida	Cardiidae	*Acanthocardia*	*Acanthocardia echinata*
Bivalvia	Cardiida	Cardiidae	*Laevicardium*	*Laevicardium senegalense*
Bivalvia	Cardiida	Cardiidae	*Parvicardium*	*Parvicardium scabrum*
Bivalvia	Cardiida	Donacidae	*Donax*	*Donax sp.*
Bivalvia	Cardiida	Semelidae	*Abra*	*Abra sp.1*
Bivalvia	Cardiida	Semelidae	*Abra*	*Abra sp.2*
Bivalvia	Cardiida	Semelidae	*Semele*	*Semele lamyi*
Bivalvia	Cardiida	Solecurtidae	*Tagelus*	*Tagelus adansonii*
Bivalvia	Cardiida	Tellinidae	*Arcopagia*	*Arcopagia sp.*
Bivalvia	Cardiida	Tellinidae	*Tellina*	*Tellina sp.*
Bivalvia	Carditida	Carditidae	*Cardiocardita*	*Cardiocardita lacunosa*
Bivalvia	Carditida	Carditidae	*Cardita*	*Cardita calyculata*
Bivalvia	Galeommatida	Lasaeidae	*Kellia*	*Kellia suborbicularis*
Bivalvia	Lucinida	Lucinidae	*Divaricella*	*Divaricella sp.*
Bivalvia	Lucinida	Lucinidae	*Lucina*	*Lucina adansoni*
Bivalvia	Lucinida	Thyasiridae	*Thyasira*	*Thyasira sp.*
Bivalvia	Myida	Corbulidae	*Corbula*	*Corbula sulcata*
Bivalvia	Mytilida	Modiolidae	*Modiolus*	*Modiolus lulat*
Bivalvia	Mytilida	Modiolidae	*Jolya*	*Modiolus martorelli*
Bivalvia	Mytilida	Mytilidae	*Aulacomya*	*Aulacomya atra*
Bivalvia	Mytilida	Mytilidae	*Brachidontes*	*Brachidontes sp.*
Bivalvia	Mytilida	Mytilidae	*Mytilus*	*Mytilus edulis*
Bivalvia	Nuculanida	Nuculanidae	*Lembulus*	*Lembulus bicuspidatus*
Bivalvia	Nuculanida	Nuculanidae	*Nuculana*	*Lembulus gruveli*
Bivalvia	Nuculanida	Nuculanidae	*Lembulus*	*Lembulus montagui*
Bivalvia	Ostreida	Margaritidae	*Pinctada*	*Pinctada sp.*
Bivalvia	Pectinida	Anomiidae	*Anomia*	*Anomia sp.*
Bivalvia	Pectinida	Pectinidae	*Aequipecten*	*Aequipecten flabellum*
Bivalvia	Pectinida	Pectinidae	*Lissochlamys*	*Lissochlamys exotica*
Bivalvia	Venerida	Mactridae	*Scissodesma*	*Scissodesma* juv.
Bivalvia	Venerida	Mactridae	*Scissodesma*	*Scissodesma acutissima*
Bivalvia	Venerida	Mactridae	*Scissodesma*	*Scissodesma spengleri*
Bivalvia	Venerida	Veneridae	*Petricolaria*	*Petricolaria sp.*
Bivalvia	Venerida	Veneridae	*Pitar*	*Pitar nicklesi*
Bivalvia		Cuspidariidae	*Cuspidaria*	*Cuspidaria sp.*
Bivalvia		Pandoridae	*Pandora*	*Pandora albida*
Echinoidea	Arbacioida	Arbaciidae	*Arbacia*	*Arbacia lixula*
Echinoidea	Camarodonta	Echinometridae	*Echinometra*	*Echinometra lucunter*
Echinoidea	Echinolampadacea	Rotulidae	*Rotula*	*Rotula deciesdigitatus*

Class	Order	Family	Genus	Species
Gastropoda	Lepetellida	Fissurellidae	*Fissurella*	*Fissurella mutabilis*
Gastropoda	Lepetellida	Fissurellidae	*Fissurella*	*Fissurella nubecula*
Gastropoda	Littorinimorpha	Calyptraeidae	*Calyptraea*	*Calyptraea chinensis*
Gastropoda	Littorinimorpha	Charoniidae	*Charonia*	*Charonia lampas*
Gastropoda	Littorinimorpha	Eratoidae	*Erato*	*Erato sp.*
Gastropoda	Littorinimorpha	Eulimidae	*Eulima*	*Eulima glabra*
Gastropoda	Littorinimorpha	Eulimidae	*Melanella*	*Melanella sp.*
Gastropoda	Littorinimorpha	Naticidae	*Natica*	*Natica sp.*
Gastropoda	Littorinimorpha	Naticidae	*Sinum*	*Sinum concavum*
Gastropoda	Littorinimorpha	Tonnidae	*Tonna*	*Tonna galea*
Gastropoda	Neogastropoda	Buccinidae	*Neptunea*	*Neptunea contraria*
Gastropoda	Neogastropoda	Buccinoidea in. sed.	*Afrocominella*	*Afrocominella capensis*
Gastropoda	Neogastropoda	Clavatulidae	*Clavatula*	*Clavatula sp.*
Gastropoda	Neogastropoda	Columbellidae	*Columbella*	*Columbella adansoni*
Gastropoda	Neogastropoda	Cystiscidae	*Gibberula*	*Gibberula miliaria*
Gastropoda	Neogastropoda	Drilliidae	*Drillia*	*Drillia pyramidata*
Gastropoda	Neogastropoda	Muricidae	*Stramonita*	*Stramonita haemastoma*
Gastropoda	Neogastropoda	Olividae	*Agaronia*	*Agaronia biraghii*
Gastropoda	Neogastropoda	Olividae	*Olivella*	*Olivella pulchella*
Gastropoda	Neogastropoda	Volutidae	*Volutocorbis*	*Capensisvoluta lutosa*
Gastropoda	Trochida	Calliostomatidae	*Calliostoma*	*Calliostoma granulatum*
Gastropoda	Trochida	Trochidae	*Gibbula*	*Steromphala cineraria*
Gastropoda		Acteonidae	*Acteon*	*Acteon monterosatoi*
Gastropoda		Cerithiidae	*Cerithium*	*Cerithium guinaicum*
Gastropoda		Epitoniidae	*Scala*	*Gyroscala commutata*
Gastropoda		Patellidae	*Patella*	*Patella aspera*
Gastropoda		Patellidae	*Patella*	*Patella piperata*
Gastropoda		Patellidae	*Patella*	*Patella rustica*
Gastropoda		Pyramidellidae	*Eulimella*	*Eulimella sp.*
Gastropoda		Pyramidellidae	*Turbonilla*	*Turbonilla sp.*
Gastropoda		Turritellidae	*Mesalia*	*Mesalia brevialis*
Gastropoda		Turritellidae	*Turritella*	*Turritella annulata*
Gastropoda		Turritellidae	*Turritella*	*Turritella ligar*
Gymnolaemata	Cheilostomatida	Watersiporidae	*Watersipora*	*Watersipora sp.*
Hydrozoa	Anthoathecata	Tubulariidae	*Ectopleura*	*Ectopleura dumortierii*
Hydrozoa	Leptothecata	Sertulariidae	*Tridentata*	*Amphisbetia distans*
Malacostraca	Amphipoda	Ampeliscidae	*Ampelisca*	*Ampelisca sp.*
Malacostraca	Amphipoda	Ampithoidae	*Ampithoe*	*Ampithoe sp.*
Malacostraca	Amphipoda	Caprellidae	*Caprella*	*Caprella sp.*
Malacostraca	Amphipoda	Corophiidae	*Corophium*	*Corophium sp.*
Malacostraca	Amphipoda	Ischyroceridae	*Cerapus*	*Cerapus sp.*
Malacostraca	Amphipoda	Ischyroceridae	*Ericthonius*	*Ericthonius sp.*
Malacostraca	Amphipoda	Ischyroceridae	*Ischyrocerus*	*Ischyrocerus sp.*
Malacostraca	Amphipoda	Maeridae	*Elasmopus*	*Elasmopus sp.*
Malacostraca	Amphipoda	Photidae	*Photis*	*Photis sp.*
Malacostraca	Amphipoda	Podoceridae	*Podocerus*	*Podocerus sp.*
Malacostraca	Amphipoda	Stenothoidae	*Stenothoe*	*Stenothoe sp.*
Malacostraca	Cumacea	Bodotriidae	*Iphinoe*	*Iphinoe sp.*
Malacostraca	Decapoda	Albuneidae	*Albunea*	*Albunea paretii*
Malacostraca	Decapoda	Alpheidae	*Alpheus*	*Alpheus sp.*
Malacostraca	Decapoda	Grapsidae	*Pachygrapsus*	*Pachygrapsus gracilis*
Malacostraca	Decapoda	Grapsidae	*Pachygrapsus*	*Pachygrapsus transversus*
Malacostraca	Decapoda	Majidae	*Maja*	*Maja sp.*
Malacostraca	Decapoda	Ocypodidae	*Ocypode*	*Ocypode africana*
Malacostraca	Decapoda	Palaemonidae	*Palaemonella*	*Palaemonella rotumana*
Malacostraca	Decapoda	Panopeidae	*Panopeus*	*Panopeus harttii*
Malacostraca	Decapoda	Pilumnidae	*Pilumnus*	*Pilumnus sp.*

Class	Order	Family	Genus	Species
Malacostraca	Decapoda	Polybiidae	*Liocarcinus*	*Polybius zariquieyi*
Malacostraca	Decapoda	Processidae	*Processa*	*Processa edulis*
Malacostraca	Decapoda	Sesarmidae	*Metagrapsus*	*Metagrapsus curvatus*
Malacostraca	Mysida	Mysidae	*Gastrosaccus*	*Gastrosaccus sp.*
Octocorallia	Malacalcyonacea	Alcyoniidae	*Parerythropodium*	*Alcyonium sp.*
Octocorallia	Malacalcyonacea	Carijoidae	*Carijoa*	*Carijoa riisei*
Octocorallia	Malacalcyonacea	Gorgoniidae	*Leptogorgia*	*Leptogorgia sp.1*
Octocorallia	Malacalcyonacea	Gorgoniidae	*Leptogorgia*	*Leptogorgia sp.2*
Ophiuroidea	Amphilepidida	Amphiuridae	*Amphiura*	*Amphiura grandisquama*
Ophiuroidea	Amphilepidida	Ophiactidae	*Ophiactis*	*Ophiactis sp.*
Ophiuroidea	Amphilepidida	Ophiotrichidae	*Ophiothrix*	*Ophiothrix cotteaui*
Polychaeta		Orbiniidae	*Scoloplos*	*Scoloplos sp.*
Polychaeta	Eunicida	Onuphidae	*Onuphis*	*Onuphis eremita*
Polychaeta	Spionida	Poecilochaetidae	*Poecilochaetus*	*Poecilochaetus sp.*
Polychaeta	Terebellida	Flabelligeridae	*Pherusa*	*Pherusa sp.*
Polychaeta		Magelonidae	*Magelona*	*Magelona sp.*
Polychaeta		Orbiniidae	*Naineris*	*Naineris sp.*
Polychaeta		Oweniidae	*Galathowenia*	*Galathowenia africana*
Scaphopoda	Dentaliida	Dentaliidae	*Dentalium*	*Dentalium congoense*
Thecostraca	Balanomorpha	Balanidae	*Balanus*	*Balanus trigonus*
Thecostraca	Balanomorpha	Balanidae	*Megabalanus*	*Megabalanus tintinnabulum*

Annex 2 Pelagic study species list 2021

1 – *Fontitrygon margarita*
2 – Pastenague marguerite
3 – Ozoun

1 – *Pomadasys incisus*
2 – Grondeur métis
3 – Gbowui

1 – *Galeoides decadactylus*
2 – Petit capitaine
3 – Fanvi, Tikué, Shikoué

1 – *Neochelon falcipinnis*
2 – Mulet à grandes nageoires
3 – Wétin

1 – *Euthynnus alletteratus*
2 – Thonine commune
3 – Kpokoun

1 – *Sphyraena afra*
2 – Bécune guinéenne
3 – Acouta, Lizi

1 – *Stromateus fiatola*
2 – Fiatole
3 – Zohè, Kobigla

1 – *Cynoglossus browni*
2 – Sole-langue nigérienne
3 – Offohomin

1 – *Lagocephalus laevigatus*
2 – Compère lisse
3 – Ako

1 – *Caranx crysos*
2 – Carangue coubali
3 – Tchii

1 – *Chloroscombus chrysurus*
2 – Sapater
3 – Zozrovi

1 – *Scomberomorus tritor*
2 – Thasard blanc
3 – Zalou, Agbonmadui

1 – *Alectis alexandrinus*
2 – Cordonnier bossu
3 – Plapla

1 – *Scorpaena laevis*
2 – Racasse du sénégal
4 – Kapita, Oloulou-osso-non

1 – *Pseudotolithus senegallus*
2 – Otolithe gabo
3 – Djoké

1 – *Eucinostomus melanopterus*
2 – Blanche drapeau, Friture
3 – Friti, Noutouivi

1 – *Dentex canariensis*
2 – Denté à points rouges
3 – Sika-sika

1 – *Selene dorsalis*
2 – Musso africain
3 – N'gogban

1 – *Pomadasys rogerii*
2 – Grondeur nez de cochon
3 – Kokouin

1 – *Sardinella maderensis*
2 – Grande allache
3 – Déyi

1 – *Hemicaranx bicolor*
2 – Carangue bicolore
3 – Zanlan

1 – *Epinephelus aenus*
2 – Mérou blanc
3 – Toboko

1 – *Trichiurus lepturus*
2 – Poisson sabre commun, Ceinture
3 – Nimpa

1 – *Psettodes belcheri*
2 – Turbot épineux tacheté
3 – Offohomin

1 – *Pseudupeneus prayensis*
2 – Rouget du Sénégal
3 – Rouget

1 – *Trachinotus goreensis*
2 – Pompaneau tacheté
3 – Adjagboé, Cobi

1 – *Brachydeuterus auritus*
2 – Lippu pelon
3 – Degbenomadu, Ngugbu, Hahoui

1 – *Cymbium cymbium*
2 – Volute trompe de cochon
3 – Hounmin Boboè

1 – *Thetystrombus latus*
2 – Strombe d'afrique occidentale
3 – Escargot

1 – *Calappa gallus*
2 – Migraine Jaune
3 – Crabe

1 – *Calappa rubroguttata*
2 – Migraine maculée
3 – Crabe

1 – *Sanquerus validus*
2 – Étrille lisse du Sénégal
3 – Ossron

1 – *Parapenaeopsis atlantica*
2 – Cevette guinéenne
3 – Olouho

1 – *Squilla aculeata calmani*
2 – Squille de Guinée
3 – Djo

Annex 3 Fisheries results 2024

IUCN categorization as follows: EN endangered, VU vulnerable, NT near threatened, LC least concern, DD data deficient.

	Family	Scientific name	French name	Vernacular	IUCN
Seaward	Balistidae	*Balistes punctatus*	Baliste à tâche bleues	Silyvou/Tapol assu	VU
	Carangidae	*Caranx crysos*	Carangue coubali	Kpankpan	LC
	Carangidae	*Caranx hippos*	Carangue crevalle	Kpankpan	LC
	Ephippidae	*Ephippus goreensis*	Chèvre de mer	Hounmin kpavi	LC
	Kuhliidae	*Parakuhlia macrophthalma*	Crocro à gros yeux	Youki	DD
	Lethrinidae	*Lethrinus atlanticus*	Empereur atlantique	Sinkplin	LC
	Lutjanidae	*Lutjanus fulgens*	Vivaneau doré	Kploloé	LC
	Lutjanidae	*Lutjanus goreensis*	Vivaneau de Gorée	Agnanto	DD
	Muraenidae	*Gymnothorax afer*	Murène Obscure	Houmin todan	LC
	Muricidae	*Hexaplex varius*	Murex varié	Houmin wouissoé	DD
	Portunidae	*Callinectes amnicola*	Crabe bicorne	Ossron	DD
	Scaridae	*Scarus hoefleri*	Perroquet de Guinée	Houmin gbato	LC
	Sciaenidae	*Pseudotolithus epipercus*	Otolithe Guinéen	Tchotchovi	DD
	Sciaenidae	*Pseudotolithus senegallus*	Otolithe gabo	Djoké	VU
	Serranidae	*Epinephelus goreensis*	Mérou Doungat	Mérou	NT
	Strombidae	*Thetystrombus latus*	Strombe d'Afrique Occidentale	Houmin wouissoé	DD
Leeward	Carangidae	*Caranx crysos*	Carangue coubali	Kpankpan	LC
	Carangidae	*Caranx hippos*	Carangue crevalle	Kpankpan	LC
	Carangidae	*Trachinotus goreensis*	Pompaneau tâcheté	Kobi	LC
	Cynoglossidae	*Cynoglossus cadenati*	Sole-langue de Ghana	offohomin	DD
	Dasyatidae	*Fontitrygon margarita*	Pastenague marguerite	Ozouin	VU
	Drepanidae	*Drepane africana*	Forgeron ailé	Gbagba	LC
	Lutjanidae	*Lutjanus dentatus*	Vivaneau brun	Kploloé	DD
	Lutjanidae	*Lutjanus fulgens*	Vivaneau doré	Kploloé	LC
	Lutjanidae	*Lutjanus gorensis*	Vivaneau de Gorée	Agnanto	DD
	Melongenidae	*Pugilina morio*	Mélongène noire	Houmin wouissoé	DD
	Psettodidae	*Psettodes belcheri*	Turbot épineux tacheté	offohomin	DD
	Sciaenidae	*Pseudotolithus epipercus*	Otolithe Guinéen	Tchotchovi	DD
	Sciaenidae	*Pseudotolithus senegalensis*	Otolithe sénégalais	Djoké/ Ekan	EN
	Sciaenidae	*Pseudotolithus senegallus*	Otolithe gabo	Djoké	VU
	Strombidae	*Thetystrombus latus*	Búzio cabra	Houmin wouissoé	DD

Annex 4 Photographs of species caught within the perimeter of the breakwater 2024

Species photograph	Species
	*Lutjanus goreensis*
	*Ephippus goreensis*
	*Pseudotolithus senegallus*
	*Scarus hoefleri*

Species photograph	Species
	*Balistes punctatus*
	*Pseudotolithus epipercus*
	*Epinephelus goreensis*
	*Caranx crysos*

Species photograph	Species
	*Lutjanus fulgens*
	*Parakuhlia macrophthalmus*
	*Gymnothorax afer*
	*Cynoglossus cadenati*

Species photograph	Species
	*Fontitrygon margarita*
	*Psettodes belcheri*
	*Lutjanus agennes*
	*Drepane africana*

Species photograph	Species
	*Trachinotus goreensis*
	*Pseudotolithus senegalensis*
	*Caranx hippos*
	*Caranx crysos*

Species photograph	Species
	*Lethrinus atlanticus*
	*Lutjanus dentatus*
	*Callinectes amnicola*

Species photograph	Species
	*Hexaplex varius*
	*Thetystrombus latus*
	*Pugilina morio*

Annex 5 Fish species 2024

Fish species that were identified morphologically M, genetically (eDNA) E or both ME.
IUCN categorization as follows: CR critically endangered, EN endangered, VU vulnerable, NT near threatened, LC least concern, DD data deficient.

Order	Family	Scientific Name	M/E	English	French	IUCN
Myliobatiformes	Dasyatidae	*Fontitrygon margarita*	ME	Daisy stingray	Pastenague marguerite	VU
Rhinopristiformes	Glaucostegidae	*Glaucostegus cemiculus*	M	Blackchin guitarfish	Poisson-guitare fouisseur	CR
Acanthuriformes	Acanthuridae	*Acanthurus monroviae*	M	Monrovia doctorfish	Chirurgien chas-chas	LC
Acanthuriformes	Drepaneidae	*Drepane africana*	ME	African sicklefish	Forgeron ailé	LC
Acanthuriformes	Ephippidae	*Ephippus goreensis*	ME	East Atlantic African spadefish	Chèvre de mer	LC
Acanthuriformes	Pomacanthidae	*Holacanthus africanus*	M	Guinean angelfish	Poisson-ange africain	LC
Albuliformes	Albulidae	*Albula goreensis*	M	Senegal Bonefish	Banane de mer	DD
Anguilliformes	Muraenidae	*Enchelycore nigricans*	M	Viper moray	Murène noire	LC
Anguilliformes	Muraenidae	*Gymnothorax afer*	ME	Dark moray	Murène obscure	LC
Anguilliformes	Muraenidae	Muraenidae sp.	M	morray	murène	
Beloniformes	Belonidae	*Tylosurus crocodilus*	M	Hound needlefish	Aiguille crocodile	LC
Beloniformes	Hemiramphidae	Hemiramphidae sp.	M	halfbeak	demi-bec	
Blenniiformes	Blenniidae	Blenniidae sp.	M	blenny	blennie	
Blenniiformes	Blenniidae	*Scartella cristata*	M	Molly miller	Blennie chevelue	LC
Carangaria incertae sedis	Polynemidae	*Galeoides decadactylus*	E	Lesser African threadfin	Petit capitaine	NT
Carangaria incertae sedis	Polynemidae	*Pentanemus quinquarius*	ME	Royal threadfin	Capitaine royal	VU
Carangaria incertae sedis	Sphyraenidae	*Sphyraena afra*	E	Guinean barracuda	Bécune guinéenne	LC
Carangaria incertae sedis	Sphyraenidae	*Sphyraena guachancho*	M	Guachanche barracuda	Bécune guachanche	LC
Carangiformes	Carangidae	*Alectis alexandrina*	E	Alexandria pompano	Cordonnier bossu	LC
Carangiformes	Carangidae	*Caranx crysos*	ME	Blue runner	Carangue coubali	LC
Carangiformes	Carangidae	*Caranx hippos*	ME	Crevalle jack	Carangue crevalle	LC
Carangiformes	Carangidae	*Caranx latus*	M	Horse-eye jack	Carangue mayole	LC
Carangiformes	Carangidae	*Chloroscombrus chrysurus*	ME	Atlantic bumper	Sapater	LC
Carangiformes	Carangidae	*Hemicaranx bicolor*	E	Bicolor jack	Carangue bicolore	LC
Carangiformes	Carangidae	*Selene dorsalis*	E	African moonfish	Musso africain	LC
Carangiformes	Carangidae	*Trachinotus goreensis*	ME	Longfin pompano	Pompaneau tacheté	LC
Cichliformes	Cichlidae	*Sarotherodon melanotheron*	M	Blackchin tilapia	tilapia	LC
Clupeiformes	Dorosomatidae	*Ethmalosa fimbriata*	M	Bonga shad	Ethmalose d'Afrique	LC
Clupeiformes	Dorosomatidae	*Pellonula leonensis*	M	Smalltoothed pellonula	Spratelle de Guinée	LC
Clupeiformes	Dorosomatidae	*Sardinella maderensis*	ME	Madeiran sardinella	Grande allache	VU
Clupeiformes	Engraulidae	*Engraulis encrasicolus*	M	European anchovy	Anchois	LC
Clupeiformes	Pristigasteridae	*Ilisha africana*	ME	West African ilisha	Alose rasoir	LC
Elopiformes	Elopidae	*Elops lacerta*	E	West African ladyfish	Guinée d'Afrique occidentale	LC
Elopiformes	Megalopidae	*Megalops atlanticus*	M	Tarpon	Tarpon argenté	VU
Eupercaria incertae sedis	Gerreidae	*Eucinostomus melanopterus*	ME	Flagfin mojarra	Blanche drapeau	LC
Eupercaria incertae sedis	Haemulidae	*Brachydeuterus auritus*	E	Bigeye grunt	Lippu pelon	NT
Eupercaria incertae sedis	Haemulidae	*Parakuhlia macrophthalma*	E	Dara	Crocro à gros yeux	DD
Eupercaria incertae sedis	Haemulidae	*Pomadasys incisus*	E	Bastard grunt	Grondeur métis	LC
Eupercaria incertae sedis	Haemulidae	*Pomadasys perotaei*	E	Parrot grunt	Grondeur perroquet	LC
Eupercaria incertae sedis	Haemulidae	*Pomadasys rogerii*	E	Pigsnout grunt	Grondeur nez de cochon	LC
Eupercaria incertae sedis	Labridae	*Bodianus speciosus*	M	Blackbar hogfish	Porceau dos noir	DD
Eupercaria incertae sedis	Labridae	Labridae sp.	M	wrasse	labre	
Eupercaria incertae sedis	Lethrinidae	*Lethrinus atlanticus*	ME	Atlantic emperor	Empereur atlantique	LC
Eupercaria incertae sedis	Lutjanidae	*Lutjanus agennes*	ME	African red snapper	Vivaneau africain rouge	DD
Eupercaria incertae sedis	Lutjanidae	*Lutjanus dentatus*	E	African brown snapper	Vivaneau brun d'Afrique	LC
Eupercaria incertae sedis	Lutjanidae	*Lutjanus fulgens*	ME	Golden African snapper	Vivaneau doré	LC
Eupercaria incertae sedis	Lutjanidae	*Lutjanus goreensis*	ME	Gorean snapper	Vivaneau de Gorée	DD
Eupercaria incertae sedis	Scaridae	*Scarus hoefleri*	E	Guinean parrotfish	Perroquet de Guinée	LC
Eupercaria incertae sedis	Scaridae	*Scarus sp.*	M	parrotfish	perroquet	
Eupercaria incertae sedis	Scaridae	*Sparisoma sp.*	M	parrotfish	perroquet	
Eupercaria incertae sedis	Sciaenidae	*Pseudotolithus epipercus*	ME	Guinea croaker	Otolithe giuneèn	DD
Eupercaria incertae sedis	Sciaenidae	*Pseudotolithus senegalensis*	E	Cassava croaker	Otolithe sénégalais	EN

Order	Family	Scientific Name	M/E	English	French	IUCN
Eupercaria incertae sedis	Sciaenidae	*Pseudotolithus senegallus*	ME	Law croaker	Otolithe gabo	VU
Eupercaria incertae sedis	Sciaenidae	*Pseudotolithus sp.*	M	croaker	otolithe	
Eupercaria incertae sedis	Sciaenidae	*Pseudotolithus typus*	E	Longneck croaker	Otolithe nanka	LC
Eupercaria incertae sedis	Sparidae	*Dentex canariensis*	E	Canary dentex	Denté à tache rouge	LC
Eupercaria incertae sedis	Sparidae	*Pagellus sp.*	M	seabream	pageot	
Gobiiformes	Eleotridae	*Butis koilomatodon*	M	Mud sleeper	éleotridé	LC
Lophiiformes	Antennariidae	*Histrio histrio*	M	Sargassumfish	Pêcheur des Sargasses	LC
Mugiliformes	Mugilidae	*Chelon sp.*	M	mullet	mulet	
Mugiliformes	Mugilidae	*Mugil bananensis*	M	Banana mullet	Mulet banane	LC
Mugiliformes	Mugilidae	*Mugil curema*	M	White mullet	Mulet blanc	LC
Mugiliformes	Mugilidae	*Neochelon falcipinnis*	ME	Sicklefin mullet	Mulet à grandes nageoires	DD
Mugiliformes	Mugilidae	*Parachelon grandisquamis*	M	Largescaled mullet	Mulet écailleux	DD
Mulliformes	Mullidae	*Pseudupeneus prayensis*	E	West African goatfish	Rouget du Sénégal	VU
Ovalentaria incertae sedis	Pomacentridae	*Abudefduf saxatilis*	M	Sergeant-major	Sergent major	LC
Ovalentaria incertae sedis	Pomacentridae	*Abudefduf sp.*	M	sergeant-major	sergent major	
Ovalentaria incertae sedis	Pomacentridae	*Neopomacentrus cyanomos*	M	Regal demoiselle	demoiselle	LC
Ovalentaria incertae sedis	Pomacentridae	*Stegastes imbricatus*	M	Cape Verde gregory	grégoire	LC
Perciformes	Epinephelidae	*Epinephelus aeneus*	ME	White grouper	Mérou blanc	NT
Perciformes	Epinephelidae	*Epinephelus goreensis*	ME	Dungat grouper	Mérou de Gorée	NT
Perciformes	Epinephelidae	*Epinephelus marginatus*	M	Dusky grouper	Mérou noir	VU
Perciformes	Scorpaenidae	*Scorpaena laevis*	E	Senegalese rockfish	Rascasse du Sénégal	LC
Perciformes	Triglidae	Triglidae sp.	M	gurnard	grondin	
Pleuronectiformes	Cynoglossidae	*Cynoglossus browni*	E	Nigerian tonguesole	Sole-langue nigérienne	DD
Pleuronectiformes	Cynoglossidae	*Cynoglossus cadenati*	ME	Ghanian tonguesole	Sole-langue du Ghana	DD
Pleuronectiformes	Cynoglossidae	*Cynoglossus senegalensis*	E	Senegalese tonguesole	Sole-langue sénégalaise	NT
Pleuronectiformes	Cynoglossidae	*Cynoglossus sp.*	M	tonguesole	sole-langue	
Pleuronectiformes	Psettodidae	*Psettodes belcheri*	ME	Spottail spiny turbot	Turbot épineux tacheté	DD
Pleuronectiformes	Soleidae	Soleidae sp.	M	sole	sole	
Scombriformes	Gempylidae	*Gempylus serpens*	M	Snake mackerel	Escolier serpent	LC
Scombriformes	Scombridae	*Euthynnus alletteratus*	E	Little tunny	Thonine commune	LC
Scombriformes	Scombridae	*Scomberomorus tritor*	E	West African Spanish mackerel	Thazard blanc	LC
Scombriformes	Scombridae	Scombridae sp.	M	mackerel	maquereau	
Scombriformes	Stromateidae	*Stromateus fiatola*	E	Blue butterfish	Fiatole	LC
Scombriformes	Trichiuridae	*Trichiurus lepturus*	E	Largehead hairtail	Poisson-sabre commun	LC
Siluriformes	Bagridae	*Chrysichthys nigrodigitatus*	M	Belly up	Mâchoiron	LC
Tetraodontiformes	Balistidae	*Balistes punctatus*	ME	Bluespotted triggerfish	Baliste à taches bleues	VU
Tetraodontiformes	Diodontidae	*Chilomycterus reticulatus*	M	Spotted porcupinefish	Poisson-hérisson ponctué	LC
Tetraodontiformes	Diodontidae	*Chilomycterus sp.*	M	burfish	poisson-hérisson	
Tetraodontiformes	Diodontidae	*Diodon hystrix*	M	Spot-fin porcupinefish	Porc-épic boubou	LC
Tetraodontiformes	Monacanthidae	*Cantherhines sp.*	M	filefish	poisson-lime	
Tetraodontiformes	Tetraodontidae	*Canthigaster sp.*	M	sharpnose puffer	canthigaster	
Tetraodontiformes	Tetraodontidae	*Lagocephalus laevigatus*	E	Smooth puffer	Compère lisse	LC
Tetraodontiformes	Tetraodontidae	*Lagocephalus lagocephalus*	M	Oceanic puffer	Compère océanique	LC
Tetraodontiformes	Tetraodontidae	*Lagocephalus sp.*	M	puffer	compère	

Annex 6 List of (morpho)species 2024

Foraminifera

Miliolida

Quinqueloculina philippinensis

Rotaliida

Hanzawaia boueana

Bryozoa

Beania klugei

Biflustra sp1

Bryozoa sp1

Bryozoa sp4

Menipea triseriata

Watersipora subtorquata

Porifera

Porifera

Callyspongia tubulosa

Haliclona cinerea

Porifera sp1

Scypha sp1

Cnidaria

Actiniaria

Actiniidae sp1

Edwardsia kameruniensis

Hydrozoa

Diphasia sp1

Amphisbetia cf distans

Macrorhynchia phoenicea

Sertulariidae sp1

Octocorallia

Carijoa riisei

Leptogorgia gaini

Leptogorgia varians

Scleractinia

Caryophyllia smithii

Hexacorallia sp1

Hexacorallia sp2

Palythoa cf *caribaeorum*

Siderastrea siderea

Tubastraea coccinea

Crustacea

Ostracoda

Hemicytheridae sp1

Ostracoda sp1

Ostracoda sp2

Thecostraca

Balanidae sp1

Amphipoda

Ampelisca brevicornis

Ampelisca heterodactyla

Ampelisca rubella

Ampelisca tenuicornis

Amphipoda sp1

Amphipoda sp2

Amphipoda sp3

Amphipoda sp4

Amphipoda sp5

Amphipoda sp6

Apolochus neapolitanus

Cheirocratus sp1

Elasmopus sp1

Ericthonius punctatus

Latigammaropsis togoensis

Leucothoe occidentalis

Leucothoe sp2

Neoischyrocerus gorgoniae

Podocerus africanus

Podocerus variegatus

Pontogeneiidae sp1

Quadrivisio ? sp

Stenothoe adhaerens

Cumacea

Bodotria africana

Iphinoe brevipes

Isopoda

Anthuridae sp1

Arcturidae sp1

Arcturina rhomboidalis

Cyathura carinata

Idoteidae sp1

Joeropsis paulensis

Sphaeromatidae sp1

Uromunna powelli

Mysida

Mysidae sp1

Mysidae sp2

Tanaidacea

Apseudes sp1

Tanaidacea sp1

Tanaidacea sp2

Anomura

Albunea sp1

Anapagurus wolffi

Clibanarius sp1

Dardanus sp1

Diogenidae sp1

Petrolisthes monodi

Brachyura

Bathynectes longipes

Cronius ruber

Macropodia straeleni

Majidae sp1

Mebeli michaelseni

Menippe nodifrons

Paractaea margaritaria

Serenepilumnus pisifer

Caridea

Alpheidae sp1

Lysmata sp1

Ogyrides rarispina

Palaemonella atlantica

Processa sp1

Processa sp2

Pycnogonida

Achelia sp1

Ammotheidae sp1

Anoplodactylus sp1

Callipallenidae sp1

Callipallenidae sp2

Endeis straughani

Nymphonidae sp1

Pycnogonida sp2

Mollusca

Bivalvia

Anadara gibbosa

Arca bouvieri

Arcuatula senhousia

Bivalvia sp1

Bivalvia sp2

Cardiocardita lacunosa

Carditamera contigua

Corbula chudeaui

Costellipitar longior

Donax pseudacutangulus

Huberimactra grayi

Isognomon dunkeri

Lissochlamys exotica

Lucinella legouxi

Ostreidae sp1

Oudardia coseli

Pholadidae sp1

Pholadidea eborensis

Pteria atlantica

Semele modesta
Strigilla splendida
Striostrea denticulata
Tivela bicolor

Cephalopoda

Sepiola atlantica

Gastropoda

Claremontiella nodulosa
Clavatula coerulea
Eulima grimaldii
Fissurella nubecula
Glabella tyermani
Haminoea elegans
Hastula exacuminata
Lirularia canaliculata
Naytia glabrata
Olivella pulchella
Onoba sp1
Retusa truncatula
Stramonita canaliculata
Thais nodosa
Tritia goreensis
Turritella ligar
Vermetus afer
Volvarina exilis
Volvulella acuminata

Scaphopoda

Dentalium congoensis
Dischides politus
Episiphon sowerbyi

Nemertea

Nemertea

Linaeidae sp1
Nemertea sp1
Nemertea sp2

Platyhelminthes

Polycladida

Polycladida sp1

Polychaeta

Eunicida

Eunice filamentosa
Lumbrineridae sp1
Lumbrinerides aberrans
Nothria africana
Onuphidae sp1
Onuphis landanensis
Parougia sp1

Phyllodocida

Chrysopetalum debile
Eteone sp1
Eteone sp2
Glycera sp1
Nereiphylla castanea
Nerideidae sp1
Nerideidae sp2
Nerideidae sp3
Phyllodoce sp1
Odontosyllis guillermoi
Polynoidae sp1
Polynoidae sp2
Sigalion vazensis
Sigalionidae sp1
Syllidae sp1
Syllidae sp2
Syllidae sp3
Syllidae sp4
Syllidae sp5

Polychaeta incertae sedis

Magelona sp1
Oweniidae sp1

Sabellida

Serpulidae sp1
Spirobranchus tetraceros

Scolecida

Leiochone johnstoni
Leodamas dubius
Maldanidae sp2
Ophelina sp1
Orbiniidae sp1
Polyophthalmus pictus
Scoloplos sp1

Spionida

Poecilochaetus modestus
Spionidae sp1

Terebellida

Ampharetidae sp1
Amphictene souriei
Cirratulidae sp1
Cirratulidae sp2
Flabelligeridae sp1
Isolda wydahaensis
Lysilla sp1
Paratherochaeta africana
Pista sp1

unidentified Polychaeta

Polychaeta sp2
Polychaeta sp3
Polychaeta sp4
Polychaeta sp5
Polychaeta sp6
Polychaeta sp7
Polychaeta sp8

Sipuncula

Golfingia sp1
Phascolosma sp1

Tunicata

Tunicata

Molgulid sp1
Tunicata sp1

Echinodermata

Echinoidea

Echinocyamus pusillus
Rotula deciesdigitatus

Holothuroidea

Cherbocnus cabindaensis
Thyone sp1

Ophiuroidea

Acrocnida semisquamata
Amphipholis squamata
Amphiura grandisquama
Ophiactis luetkeni
Ophiactis lymani
Ophiothrix cotteaui
Ophiuroidea sp juv

Annex 7 Images of morphospecies 2024

Foraminifera

Hanzawaia boueana

Quinqueloculina philippinensis

Porifera

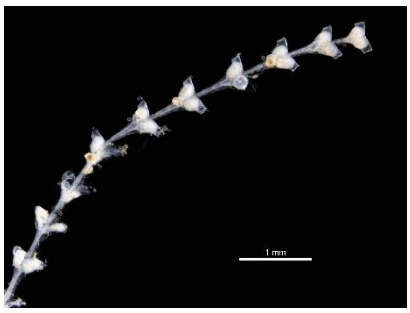
Callyspongia tubulosa

Porifera

Haliclona cinerea

Scypha sp1

Cnidaria – Hydrozoa



Amphisbetia cf distans

Cnidaria – Hydrozoa

Diphasia sp1

Macrorhynchia phoenicea

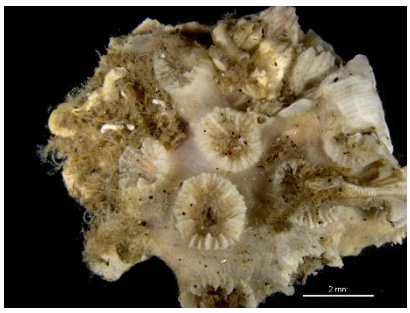
Cnidaria – Anthozoa

Carijoa riisei

Cnidaria – Anthozoa

Caryophyllia smithii

Edwardsia kameruniensis



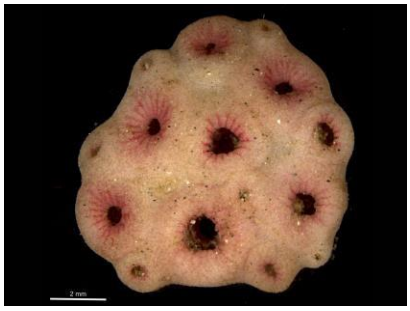
Hexacorallia sp1

Leptogorgia gaini

Leptogorgia varians

Palythoa cf caribaeorum

Cnidaria – Anthozoa



Siderastrea siderea

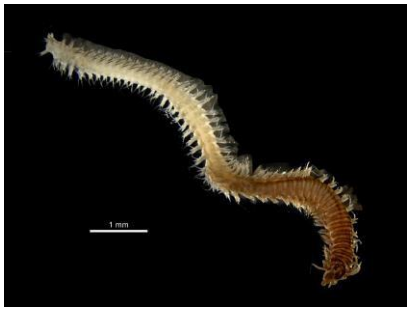
Tubastraea coccinea

Annelida – Polychaeta

Ampharetidae sp1

Annelida – Polychaeta

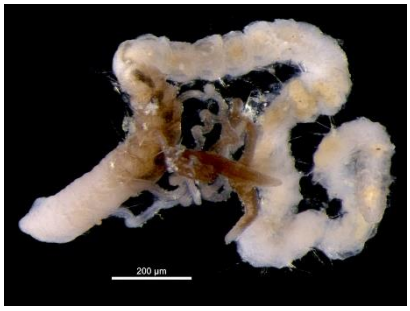
Amphictene souriei



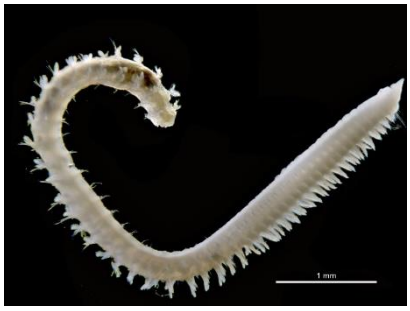
Aponuphis brementi

Chrysopetalum debile

Cirratulidae sp1



Cirratulidae sp2



Dispio sp1

Eteone sp1

Eunice filamentosa

Glycera sp1

Galathowenia sp1

Isolda whydahensis

Leiochone johnstoni

Leodamas dubius

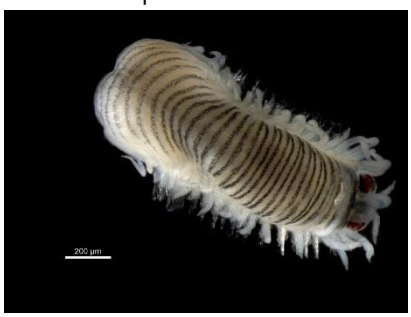
Lumbrineridae sp1

Lysidice unicornis cf

Nereididae sp1

Nereiphylla castanea

Nothria africana

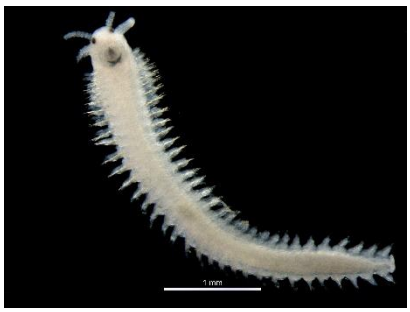


Odontosyllis guillermoi

Opheliidae sp1

Orbiniidae sp1

Paratherochaeta africana



Parougia sp1

Poecilochaetus modestus

Polyophthalmus pictus

Phyllodoce sp1

Polychaeta sp1

Polynoidae sp1

Sigalion vazensis

Spionidae sp1

Spirobranchus tetraceros

Syllidae sp1

Syllidae sp2

Syllidae sp3

Syllidae sp4

Syllidae sp5

Annelida — Sipuncula

Phascolonidae sp1

Sipuncula sp1

Nemertea

Nemertea sp2

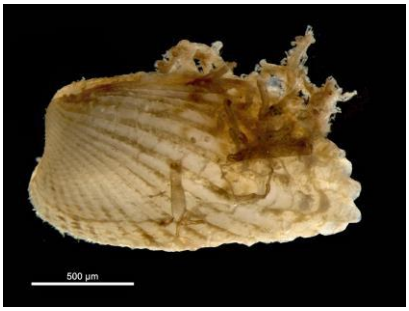
Mollusca — Bivalvia

Anadara globosa

Arca bouvieri

Arcuatula senhousia

Cardiocardita lacunosa



Carditamera contigua

Corbula chudeaui

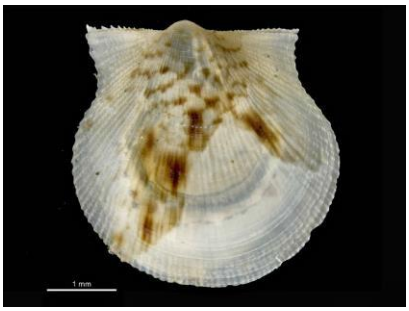
Costellipitar longior

Donax pseudacutangulus

Huberimactra grayi

Isognomon dunkeri

Kellia suborbicularis



Lissochlamys exotica

Lucinella legouxi

Oudardia coseli

Pholadidea eborensis

Pholas campechiensis

Pteria atlantica

Semele modesta

Strigilla splendida

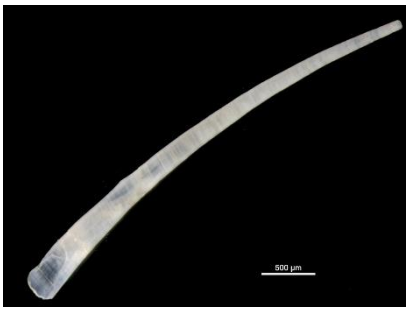
Striostrea denticulata

Tivela bicolor

Mollusca – Scaphopoda

Dentalium congoensis

Dischides politus



Episiphon sowerbyi

Mollusca – Gastropoda

Calyptraea africana

Clavatula caerulea

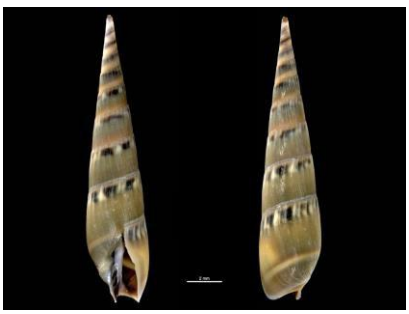
Eulima grimaldii

Eulimella kobelti

Fissurella nubecula

Glabella tyermani

Haminoea elegans



Hastula exacuminata

Leucorhynchia lirata

Lirularia canaliculate

Naytia glabrata

Retusa truncatula

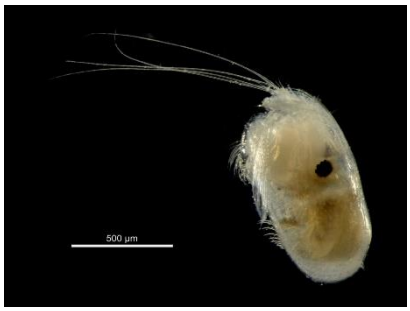
Turritella ligar

Volvarina exilis

Volvulella acuminata

Arthropoda – Ostracoda

Hemicytheridae sp1



Ostracoda sp1

Ostracoda sp2

Arthropoda – Amphipoda

Ampelisca brevicornis

Ampelisca heterodactyla

Ampelisdca rubella

Ampelisca tenuicornis

Amphipoda sp1

Amphipoda sp2

Amphipoda sp4

Amphipoda sp5

Amphipoda sp6

Apolochus neapolitanus

Elasmopus sp1

Ericthonius punctatus

Latigammaropsis togoensis

Leucothoe occidentalis

Neoischyrocerus gorgoniae

Podocerus africanus

Podocerus variegatus

Stenothoe adhaerens

Arthropoda — Cumacea

Bodotria africana

Iphinoe brevipes

Arthropoda — Mysida

Mysida sp1

Arthropoda — Isopoda

Arcturina rhomboidalis

Astacilla sp1

Cyathura carinata

Joeropsis paulensis

Sphaeromatidae sp1

Uromunna powelli

Arthropoda — Tanaidacea

Apseudidae sp1

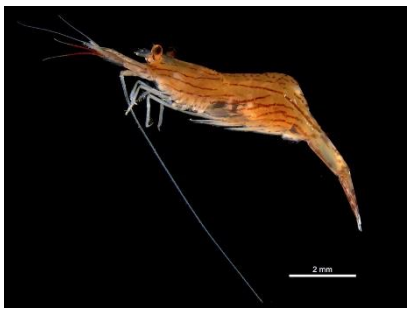
Tanaidacea sp1

Alpheidae sp1

Arthropoda — Caridea

Alpheidae sp2

Caridea sp1



Hippolyte sp1

Ogyrides rarispina

Palaemonella atlantica

Processa sp1

Arthropoda – Anomura

Albunea sp1

Anapagurus wolffi

Clibanarius sp1

Arthropoda – Anomura

Dardanus sp1

Diogenidae sp1

Arthropoda – Brachyura

Cronius ruber

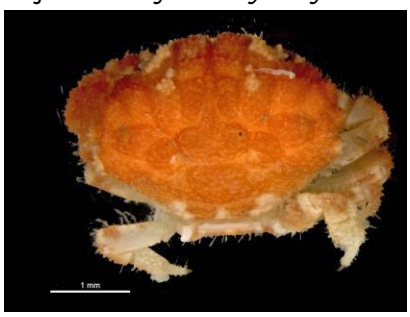
Arthropoda – Brachyura

Macropodia straeleni

Majidae cf *Maja brachydactyla*

Mebeli michaelseni

Menippe nodifrons



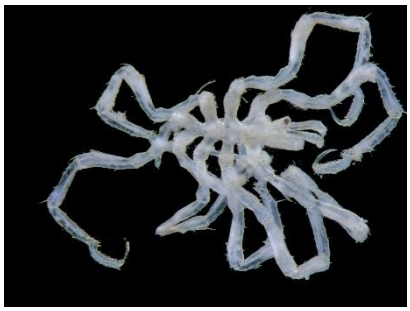
Paractaea margaritaria

Serenepilumnus pisifer

Pycnogonida

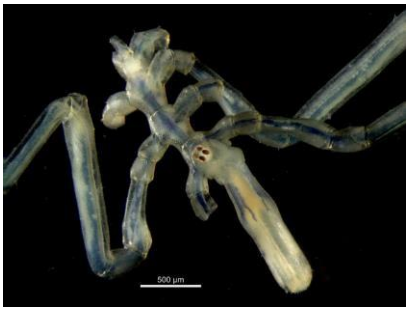
Achelia sp1

Ammotheidae sp1



Anoplodactylus sp1

Callipallenidae sp1

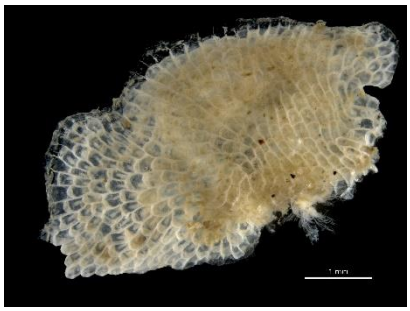


Endeis straughani

Pycnogonida sp2

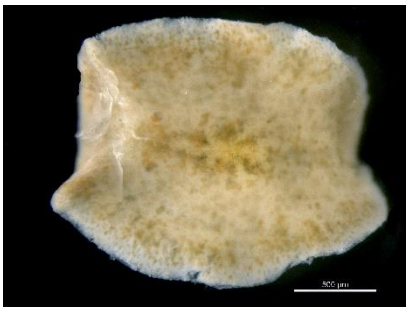
Brachiopoda

Discinisca tenuis



Biflustra sp1

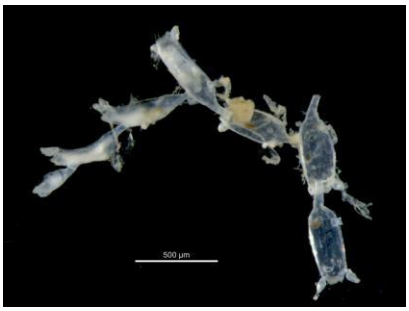
Platyhelminthes



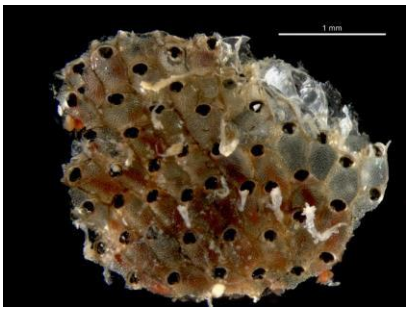
Polycladida sp1

Menipea triseriata

Bryozoa

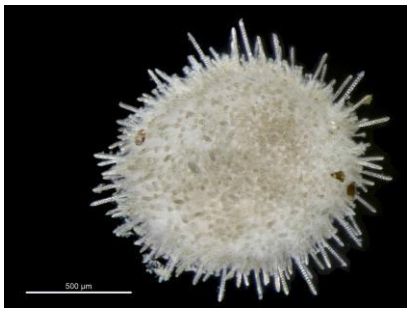


Beania klugei

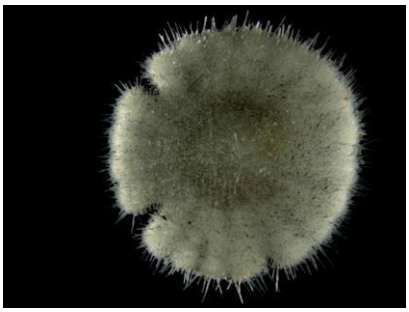


Watersipora subtorquata

Echinodermata

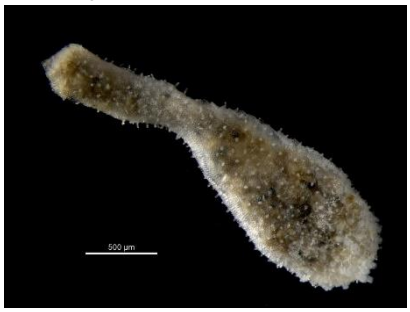


Echinocyamus pusillus

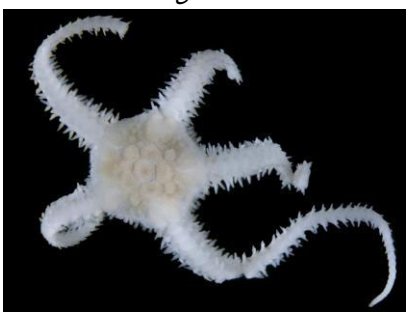


Rotula deciesdigitatus

Cherbocnus cabindaensis

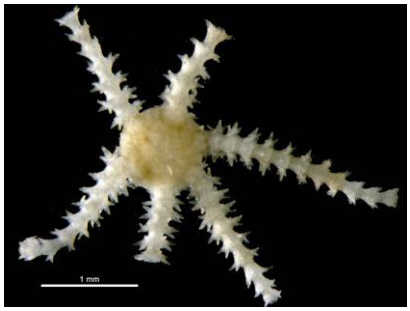


Thyone sp1



Acrocnida semisquamata

Amphipholis squamata



Ophiactis lymani

Ophiactis luetkeni

Ophiothrix cotteaui

Annex 8 Benin invertebrates bibliography 2024

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