ORIGINAL RESEARCH

Impact of ports construction activities on structure, composition and diversity of fish population: case study of Tema, Ghana

Samuel K. K. Amponsah[1, *], Francis K. E. Nunoo[2], Angela M. Lamptey[2], Patrick K. Ofori-Danson[2] and Ayaa Armah[3]

[1]Department of Fisheries and Water Resources, University of Energy and Natural Resources, Sunyani, Ghana. [2]Department of Marine and Fisheries Sciences, University of Ghana, Legon, Ghana. [3]Enviromental Service Limited, Ghana.
ORCID *Samuel K. K. Amponsah* https://orcid.org/0000-0001-5559-3139

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ABSTRACT. Ports offer economic progress to many coastal developing countries. In view of the economic importance, the rising demand for maritime benefits requires the expansion of existing ports. However, marine ecosystems may become vulnerable to negative impact from the construction of these maritime structures. Therefore, the aim of the study was to establish the impact of Tema port expansion on the diversity and population structure of fish species. Data were collected quarterly from June 2018 to November 2021 through trawling fishing activities off the coast of Greater Accra, Ghana, and subsequently analysed using Primer 6 software. Sampling locations along the coast of Greater Accra included Vernon Bank (VNB), Disposal area (DSA) and Offshore Sakumono (OSK). The increased and reduced number of species at VNB and DSA, respectively, could be alluded to dredging and disposal of dredged spoils. Diversity indices at OSK site was higher than those observed in disturbed areas due to the absence of impact in this control area. Thus, it is recommended to conduct further studies on the assemblage of invasive species that migrated to the VNB during dredging activities, since these species can have severe economic impact on fishing activities of artisanal fishermen, especially at the local level.

Key words: Marine fisheries, management, ecology.

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*Correspondence:
samuel.amponsah@uenr.edu.gh

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Impacto de las actividades de construcción de puertos en la estructura, composición y diversidad de la población de peces: estudio de caso de Tema, Ghana

RESUMEN. Los puertos ofrecen progreso económico a muchos países costeros en desarrollo. En vista de la importancia económica, la creciente demanda de beneficios marítimos requiere la ampliación de los puertos existentes. Sin embargo, los ecosistemas marinos pueden volverse vulnerables al impacto negativo de la construcción de estas estructuras marítimas. Por lo tanto, el objetivo del estudio fue establecer el impacto de la expansión del puerto de Tema sobre la diversidad y estructura de la población de peces. Los datos se recopilaron trimestralmente desde junio de 2018 hasta noviembre de 2021 mediante actividades de pesca de arrastre frente a la costa del Gran Accra, Ghana. Los mismos se analizaron utilizando el software Primer 6. Los lugares de muestreo a lo largo de la costa del Gran Accra incluyeron Vernon Bank (VNB), Disposal area (DSA) y Offshore Sakumono (OSK). El mayor y menor número de especies en VNB y DSA, respectivamente, podría deberse al dragado y disposición de los escombros removidos. Los índices de diversidad en el sitio OSK fueron más altos que los observados en áreas perturbadas debido a la ausencia de impacto en esta área de control. Por lo tanto, se recomienda realizar más estudios sobre las asociaciones de especies invasoras que migraron al VNB durante las actividades de dragado, ya que estas especies pueden tener severos impactos económicos en la actividad pesquera de los pescadores artesanales, especialmente a nivel local.

Palabras clave: Pesquerías marinas, manejo, ecología.

INTRODUCTION

Ports play important role in the development of low-income countries, particularly in times when the focus of economic growth and development is on trade. In landlocked countries, the efficiency or otherwise of transit ports has direct effects on international trade and competitiveness (Asuliwonno 2011). However, port operations are known to have major impacts (such as marine pollution, runoffs of heavy metals, hydrocarbons and others) on the water quality and biodiversity of the marine environment. However, many west African coastal countries have overlooked the negative impacts of ports on marine resources with much focus on anthropogenic benefits, resulting in either the construction of new ports or the expansion of existing ones along the coastline. In Ghana, the efficiency of port operations has increased over the years and has contributed valuably to the development of the nation. This efficiency and the need to meet the growing economic demand have led to the expansion of the existing Tema port (Asuliwonno 2011).

Construction activities, including disposal and dredging activities for port development, interfere with coastal processes in the region, resulting in major impacts on the coastline (Kudale 2010). In addition, the construction or expansion may affect the population structure of fish species within marine ecosystems, leading to relatively higher rate of emigration of species with tolerant levels from disturbed areas to perceived suitable niches (Breitwieser and Ford 2023). Fish diversity, community structure, and species assemblages are interdependent on many factors (biotic and abiotic) determining the success or failure of fish species assemblages. Understanding factors involved in structuring fish assemblages and the response of fishery resources to environmental changes is therefore valuable to formulation of fishery management plan and species conservation strategies (Amponsah et al. 2022). Information on fish biodiversity is important in identifying the structure, functional role as well as the state of ecosystems and fish communities, and is thus a useful tool in designing ecosystem management and conservation strategies (Okyere 2015).

However, studies on the effect of port construction on the structure of fish population appear to be non-existent in Ghana. Such scarcity of scientific information could affect management of fish species, especially in the wake of intense maritime construction activities. Furthermore, it will be difficult to identify impacts of such valuable economic assets on marine ecosystems. Given this, the aim of the study was to assess the impact of dredging and dumping activities during the expansion of Tema port on the fish population structure, which will serve as a baseline information for future management of marine resources in Ghana.

MATERIALS AND METHODS

Study area

Tema Harbour is one of the largest harbors in West Africa and has a long history of urbanization and industrialization within its catchments (Botwe et al. 2018). The port of Tema was built in 1952 and has an entrance of 243.8 m wide with a depth of at least 10.7 m. The area of enclosed water in the main port is 1,660 km^2 with a fishing harbor adjacent to the port at the eastern end. The main breakwater is 2,514.6 m long and the lee breakwater is 1,082.0 m long (Galley 1985). Tema port is located about 25 km east of Accra, Ghana's capital city. At present, the port handles about 80% of Ghana's maritime international trade, contributing to almost 90% to Ghana's total trade throughout (de Boer et al. 2019).

The construction phase of the port expansion was done between 2018 and 2020. The study focused on three offshore stations, namely Vernon Bank (VNB, 05° 40′ 32.91″ N-000° 09′ 57.94″ E), Disposal Site (DSA, 05° 35′ 32.78″ N-000° 04′ 12.38″ E), and Offshore Sakumono (OSK, 05° 34’ 54.59″ N-000° 02′ 31.64″ W) (Figure 1). The VNB covers an area of about 18.7 km^2. It has an average depth of about 24 m and serves as the site for dredging of material for some construction activities from Tema Port Expansion Project (TPEP). The area within the VNB is predominantly composed of coarse sand (92%) with minute fractions of silt (4%), gravels/cobbles (3%) and clay (1%). The DSA covers about 3 km^2 and is influenced by fast-moving currents. The disposal of sediment from the TPEP is conducted at an average rate of 6 times per day and the volume of material per each disposal is approximately 1,000 m^3. The OSK area was selected as the control site due to eastward movement of sediment and currents, ensuring that sediment from port expansion activities would not be deposited at this control location. On the contrary, DSA and VNB were within the area of influence under the TPEP. The OSK area was mostly composed of a fine mixture of sand and silt fractions with some amounts of clay (Bernacsek 1986).

Data collection

Sampling was conducted quarterly at the VNB, DSA, and OSK areas from June 2018 to November 2021. A bottom trawl made of a multifilament cod-end net of 0.25 cm mesh size (diagonal stretch) was deployed at each sampling location using a Ghanaian inshore fishing boat (trawler). The trawling was executed with assistance from local fishermen. Nets were deployed to about 18 m depth at

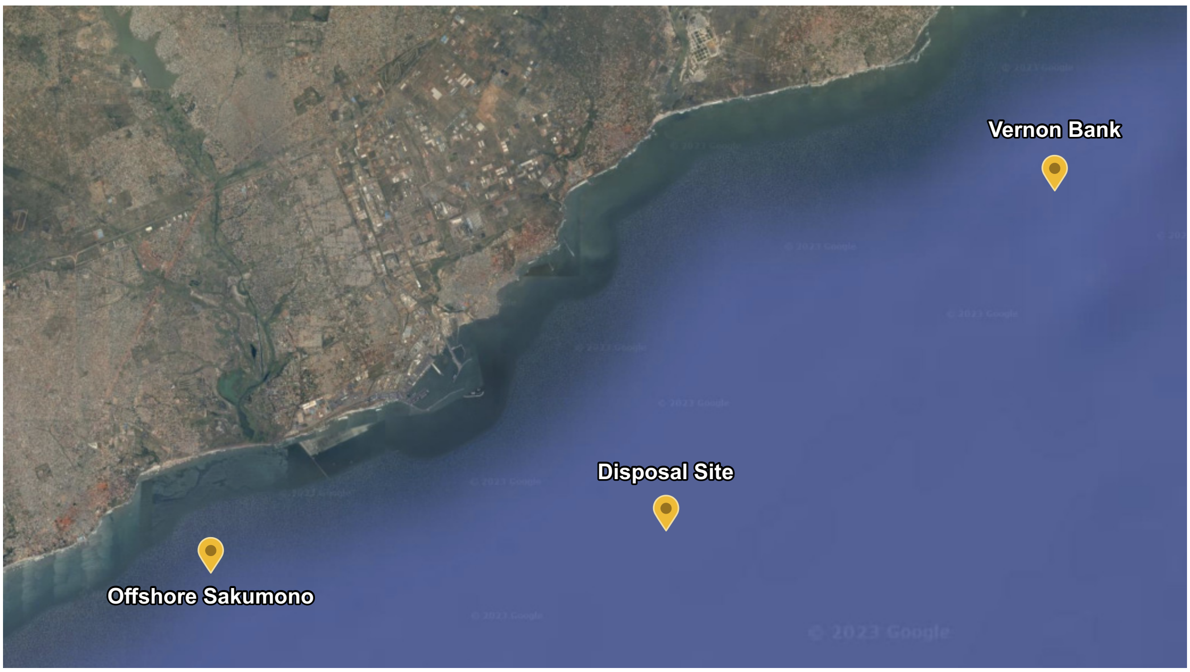

Figure 1. Sampling areas around Tema harbor. OSK: Offshore Sakumono. DSA: Disposal Site. VNB: Vernon Bank.

OSK, and about 32 m and 44 m depths at VNB and DSA, respectively. The average trawling duration was 1 h at 3.2 kn average speed. At each sampling location, trawling was done three times depending on the gear condition. In situations where fishing gears got torn, sampling was repeated. To ensure the uniformity of conditions, samplings at the three sampling locations were done on the same day. On rare occasions where sampling was not completed, it was continued the next day. A standard container was used to subsample the catch. Samples were sorted out according to species using identification keys from Schneider et al. (1990) and Kwei and Ofori-Adu (2005), and subsequently transported on ice to the laboratory of the Department of Marine and Fisheries Science of the University of Ghana for further analysis.

Indices

The frequency of occurrence indicates how rare or common a species is relative to other species in a defined location. It was calculated in percentage using the expression of Negi and Mamgain (2013): (number of species/total number of species) * 100. Species richness index (SRI) is the number of different species represented in an ecological community. Margalef (1985) index was used to determine the species richness with the following expression:

$$D = (S-1) \ln N$$

where S is the number of different species represented in the sample, and N is the total number of individual organisms in your sample. Species evenness index (SEI) refers to how close in numbers of each species in an environment. Pielou's evenness index (Pielou 1966) was used to calculate the evenness of the fish species in the sample using the following expression:

$$J' = H'/H'max$$

where H' is the number derived from Shannon diversity index and H'max is the maximum possible value of H' (if every species was equally likely). Shannon-Wiener index (SWI) is a way to measure the diversity of species in a community. It was calculated in the following way:

$$H' = -\sum p_i \ln p_i \text{ (Shannon and Wiener 1963)}$$

where p_i is the proportion of individuals found in species i. For a homogeneously sampled community, this proportion can be estimated as $p_i = n_i/N$, where n_i is the number of individuals in species i and N is the total number of individuals in the community.

Data analysis

For univariate analyses, test of normality of the sample was performed by using Anderson Darling test ($p > 0.05$). Parametric tests including ANOVA or ANCOVA were used to determine differences in species composition among sampling sites in each location (i.e. OSK, DSA and VNB) after log transformation of species abundance data.

For multivariate analyses, analysis of similarity (ANOSIM) was used to test for differences among OSK, VNB and DSA sampling areas. A non-metric multidimensional scaling (nMDS) (Bray-Curtis similarity matrix) was used to determine trends in structure and composition of fish samples. The similarity percentage (SIMPER) procedure was performed to determine which species contributed most for both the similarity in sampling areas and for the dissimilarity between catch from sampling areas.

Cluster analysis was done to identify sampling locations with similar community structure. Prior to these analyses, abundance data were standardized using a square root transformation to down weight the effect of common species. Results were compared to determine if there were differences in the standardized proportions of fish species in the assemblages. Analyses were performed using PRIMER software (Clarke and Warwick 2001).

RESULTS

The MDS ordination of surveys produced a complementary visualization of survey similarity to the cluster analysis. The best three-dimensional configuration of 1,000 iterations achieved a stress level of 0.11, while the best two-dimensional configuration had a stress level of 0.15. Identifying factors such as study sites and treatment superimposed on the survey ordination and the grouping pattern aligned with the study site, as suggested by the cluster analysis (Figure 2). When a similarity isocline at a Bray-Curtis value of 34 was drawn, two groups were created, namely: i) trawl surveys within the disturbed areas and, ii) trawl surveys within the control area. The MDS ordination agreed with significant SIMPROF clusters, showing internal consistency of significant clusters. However, station D7, D9, D10 and D6 within the DSA sampling area were biologically similar to stations within the OSK than to other stations of DSA. Cluster analysis revealed two significant clusters (black dotted lines) based on similarity profile at similarity level of 34% (see Appendix). Cluster one was mainly stations within control sites, whereas cluster two was mainly locations within disturbed areas. SIMPROF analysis revealed no significant difference among locations within disturbed areas (red dotted lines). However, significant differences were observed among stations within control areas as portrayed by black lines.

SIMPER analysis broke down similarities within the three significantly different sampling stations, and dissimilarity between stations, into contributions from individual species to characterize those species most typical of discriminating between different locations (i.e. OSK, DSA and VNB groups). Typifying or discriminating species showed a high ratio of similarity or dissimilarity to standard deviation, meaning they were consistently important in defining or differentiating groups. The similarity between surveys within the OSK was dominated by *Brachydeuterus auritus*, which accounted for nearly 18.93% of the average Bray-Curtis similar-

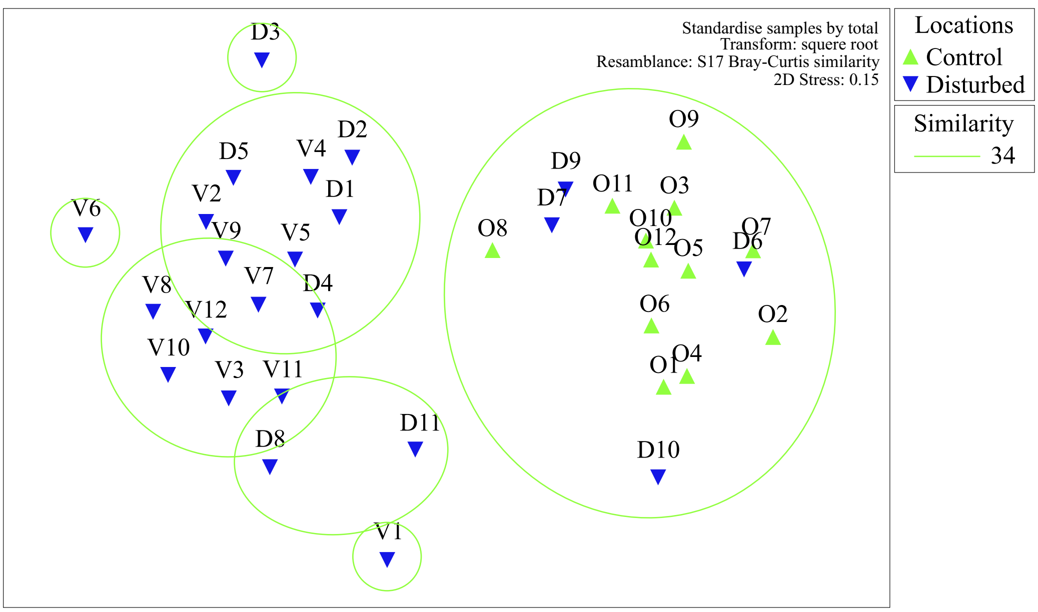

Figure 2. Two-dimensional MDS ordination of individual fish trawl surveys based on species level data. Green line indicates clusters at a similarity index of 34%. O: Offshore Sakumono (OSK). V: Venon Bank (VNB). D: Disposal Area (DSA).

ity and achieved the highest Sim/SD of the group at 1.58. Other notable species typical (high Sim/SD) of OSK were *Selene dorsalis* (Sim/SD = 1.05, Contrib = 17.0%), *Cynoglossus senegalensis* (Sim/SD = 1.39, Contrib = 13.59%), and *Galeoides decadactylus* (Sim/SD = 1.01, Contrib = 11.87%) (Table 1).

Similarity between surveys within the VNB was dominated by *Pseudupeneus prayensis*, which accounted for nearly 28.6% of the average Bray-Curtis similarity and also achieved the highest Sim/SD of the group (1.66). Other notable species typical (high Sim/SD) of disturbed areas were *Pagrus caeruleostictus* (Sim/SD = 0.95, Contrib = 16.2%), *Balistes punctatus* (Sim/SD = 0.88, Contrib = 13.3%), and *Acanthostracion notacanthus* (Sim/SD = 0.79, Contrib = 11.65%) (Table 2). Similarity between surveys within the DSA was dominated by *P. prayensis*, which accounted for nearly 23.4% of the average Bray-Curtis similarity and also achieved the highest Sim/SD of the group (0.81). Other notable species typical (high Sim/SD) of disturbed areas were *A. notacanthus* (Sim/SD = 0.64, Contrib = 14.0%), *C. senegalensis* (Sim/SD = 0.46, Contrib = 10.0%), and *Syacium micrurum* (Sim/SD = 0.46, Contrib = 9.24%) (Table 3).

The average dissimilarity between OSK and VNB areas was 93.4%. The most discriminating species (largest Diss/(SD) ratio) was *P. prayensis*, with a ratio of 1.77 and contributing percentage of 6.37%. Other high contributing dissimilarity species were *B. auritus* with a Diss/SD ratio of 1.76 and a contributing percentage of 6.98%, *C.*

Table 1. Species contributing the most to survey similarity within significant clusters, ranked by percent contribution (Contrib%). Also included are the average abundance (Av. abund) of species within the group, average similarity (Av. sim) contribution relative to its standard deviation (Sim/SD), and the cumulative percent contribution of species to the average group similarity (Cum.%, species up to 90% included). OSK: Offshore Sakumono.

Group OSK	Species	Av. abund	Av. sim	Sim/SD	Contrib%	Cum.%
Average similarity:	*Brachydeuterus auritus*	3.52	8.32	1.38	18.93	18.93
43.95	*Selene dorsalis*	3.72	7.46	1.05	16.97	35.90
	Cynoglossus senegalensis	2.59	5.97	1.39	13.59	49.50
	Galeoides decadactylus	2.72	5.22	1.01	11.87	61.37
	Pteroscion peli	2.28	3.66	0.77	8.33	69.70

Table 2. Species contributing the most to survey similarity within significant clusters, ranked by percent contribution (Contrib%). Also included are the average abundance (Av. abund) of species within the group, average similarity (Av. sim) contribution relative to its standard deviation (Sim/SD), and the cumulative percent contribution of species to the average group similarity (Cum.%, species up to 90% included). VNB: Venon Bank.

Group VNB	Species	Av. abund	Av. sim	Sim/SD	Contrib%	Cum.%
Average similarity:	*Pseudupeneus prayensis*	3.36	9.49	1.66	28.56	28.56
33.22	*Pagrus caeruleostictus*	2.41	5.37	0.95	16.15	44.71
	Balistes punctatus	2.34	4.09	0.88	12.32	57.02
	Acanthostracion notacanthus	2.41	3.87	0.79	11.65	68.67
	Stephanolepis hispida	1.57	2.06	0.59	6.21	74.88

Table 3. Species contributing the most to survey similarity within significant clusters, ranked by percent contribution (Contrib%). Also included are the average abundance (Av. abund) of species within the group, average similarity (Av. sim) contribution relative to its standard deviation (Sim/SD), and the cumulative percent contribution of species to the average group similarity (Cum.%, species up to 90% included). DSA: Disposal area.

Group DSA	Species	Av. abund	Av. sim	Sim/SD	Contrib%	Cum.%
Average similarity:	*Pseudupeneus prayensis*	2.59	4.78	0.81	23.39	23.39
20.43	*Acanthostracion notacanthus*	1.86	2.86	0.64	14.00	37.40
	Cynoglossus senegalensis	1.71	2.05	0.46	10.03	47.42
	Syacium micrurum	1.73	1.89	0.46	9.24	56.66
	Selene dorsalis	1.63	1.24	0.33	6.09	62.75

senegalensis with a ratio of 1.55 and a contributing percentage of 4.68%, *S. dorsalis* with a ratio of 1.27 and a contributing percentage of 7.40%, and *P. caeruleostictus* with a ratio of 1.36 with a contributing percentage of 4.62% (Table 4). The average dissimilarity between OSK and DSA was 78.8%. The most discriminating species (largest Diss/(SD) ratio) was *C. senegalensis* with a ratio of 1.43 and contributing percentage of 5.45%. Other high contributing dissimilarity species were *B. auritus* with a Diss/SD ratio of 1.55 and a contributing percentage of 7.40%; *G. decadactylus* with a ratio of 1.26 and a contributing percentage of 6.08%; *S. dorsalis* with a ratio of 1.25 and contributing percentage of 8.07%; and *Drepane africana* with a ratio of 1.24 and contributing percentage of 4.28% (Table 5). The average dissimilarity between DSA and VNB was 78.6%. The most discriminating species (largest Diss/SD ratio) was *P. caeruleostictus* with a ratio of 1.34 and contributing percentage of 5.80%. Other high contributing dissimilarity species were *P. prayensis* with a ratio of 1.32 and contributing percentage of 5.84%, *B. punctatus* with a Diss/SD ratio of 1.06 and a contributing percentage of 5.25%, *Stephanolepis hispida* with a ratio of 0.99 and a contributing percentage of 4.29%, and *A. notacanthus* with a ratio of 1.19 and a contributing percentage of 5.69% (Table 6).

Significant spatial differences were observed between fish communities in the control area and under the influence of construction (ANOSIM: R = 0.56, p-value = 0.01) (Table 7). Multidimensional scaling ordination analyses, corroborated by the ANOSIM test, clearly demonstrated the dissimilarity between the control and disturbed areas.

Species abundance and composition

For OSK, the number of species declined from fifteen during the survey Q1 to nine in Q5 sampling period (Figure 3). From Q5, species abundance rose to sixteen in Q12. For DSA, the number of species declined from eighteen during the Q1 to nine species and four species in Q5 and Q11 respectively (Figure 3). For VNB, the number of species increased from three during the Q1 to thirteen in Q3 and finally declined to eleven species in Q12 (Figure 3). One-way ANOVA revealed significant difference in the species abundance across the three sampling locations (df = 35, F-value = 5.44, p-value = 0.009). *Post hoc* Tukey test analysis showed significant difference between OSK and DSA, as well as between OSK and VNB.

The trend analysis showed general increase in species abundance at VNB and OSK, with a decline at DSA (Figure 4).

From OSK, 5,273 fishes representing 32 taxonomic species were recorded, with *S. dorsalis* forming the majority of the catch (33.3%), followed by *B. auritus* (15.2%) and *G. decadactylus*

Table 4. Species contributing most to survey dissimilarity within significant clusters, ranked by percent contribution (Contrib%). Also included are the average abundance (Av. abund) of species within the group, average dissimilarity (Av. diss) contribution relative to its standard deviation (Diss/SD), and the cumulative percent contribution of species to the average group similarity (Cum.%, species up to 90% included). 1: Offshore Sakumono (OSK). 2: Venon Bank (VNB). Average dissimilarity: 93.37.

Species	Av. abund (1)	Av. abund (2)	Av. diss	Diss/SD	Contrib%	Cum.%
Selene dorsalis	3.72	0.09	6.91	1.27	7.40	7.40
Brachydeuterus auritus	3.52	0.00	6.52	1.76	6.98	14.38
Pseudupeneus prayensis	0.27	3.36	5.95	1.77	6.37	20.75
Galeoides decadactylus	2.72	0.00	5.10	1.24	5.47	26.22
Cynoglossus senegalensis	2.59	0.40	4.37	1.55	4.68	30.90
Pagrus caeruleostictus	0.19	2.41	4.31	1.36	4.62	35.52
Balistes punctatus	0.07	2.34	4.22	1.07	4.52	40.04
Pteroscion peli	2.28	0.00	4.19	1.10	4.49	44.53
Acanthostracion notacanthus	0.24	2.41	4.18	1.03	4.47	49.01
Pseudotolithus senegalensis	1.78	0.48	3.67	1.24	3.93	52.94
Drepane africana	1.58	0.00	2.91	1.21	3.11	56.05
Stephanolepis hispida	0.00	1.57	2.84	0.88	3.04	59.09
Scorpaena histrio	0.15	1.52	2.80	0.80	3.00	62.09
Scarus hoefleri	0.00	1.29	2.32	0.59	2.48	64.58
Chloroscombrus chrysurus	1.25	0.12	2.29	0.86	2.45	67.03
Lethrinus atlanticus	0.24	1.18	2.17	0.79	2.32	69.35
Dentex gibbosus	0.00	1.06	2.01	0.57	2.15	71.50
Ilisha africana	1.12	0.00	2.00	0.75	2.15	73.65
Lagocephalus laevigatus	0.76	0.45	1.98	0.82	2.12	75.77
Trichiurus lepturus	1.07	0.00	1.91	0.59	2.04	77.81
Pseudotolithus typus	0.93	0.00	1.69	0.79	1.81	79.62
Syacium micrurum	0.37	0.82	1.69	0.87	1.81	81.43
Dasyatis margarita	0.45	0.86	1.68	0.98	1.80	83.22
Rypticus saponaceus	0.05	0.98	1.67	0.67	1.79	85.02
Acanthurus monroviae	0.00	0.85	1.49	0.70	1.59	86.61
Zanobatus maculatus	0.39	0.59	1.39	0.83	1.49	88.09
Sphyraena sphyraena	0.79	0.00	1.37	0.63	1.46	89.56
Decapterus punctatus	0.00	0.67	1.23	0.30	1.31	90.87

(11.8%) (Table 8). The two least common species were *Dactylopterus volitans* and *Rypticus saponaceus* (0.02% of total catch) (Table 2). Overall, 36 trawls were made during the 12-month sampling period.

Individuals of only 7 species were recorded in more than 7 sampling periods, indicating that these species occur mainly in coastal waters of OSK (Figure 5). These species included *Pseudotolithus senegalensis*, *Pteroscion peli*, *B. auritus*, *D. africana*, *C. senegalensis*, *G. decadactylus* and *S. dorsalis* (Figure 5). One-way ANCOVA indicated a significant difference among sampling periods (df = 190, F-value = 4.106, p-value = 0.0015).

Table 5. Species contributing most to survey dissimilarity within significant clusters, ranked by percent contribution (Contrib%). Also included are the average abundance (Av. abund) of species within the group, average dissimilarity (Av. diss) contribution relative to its standard deviation (Diss/SD), and the cumulative percent contribution of species to the average group similarity (Cum.%, species up to 90% included). 1: Offshore Sakumono (OSK). 2: Disposal area (DSA). Average dissimilarity: 78.73.

Species	Av. abund (1)	Av. abund (2)	Av. diss	Diss/SD	Contrib%	Cum.%
Selene dorsalis	3.72	1.63	6.35	1.25	8.07	8.07
Brachydeuterus auritus	3.52	1.36	5.83	1.55	7.40	15.47
Pseudupeneus prayensis	0.27	2.59	4.84	1.07	6.14	21.61
Galeoides decadactylus	2.72	1.00	4.78	1.26	6.08	27.69
Cynoglossus senegalensis	2.59	1.71	4.29	1.43	5.45	33.14
Pteroscion peli	2.28	0.37	4.22	1.12	5.36	38.50
Drepane africana	1.58	0.98	3.37	1.24	4.28	42.78
Acanthostracion notacanthus	0.24	1.86	3.33	1.01	4.23	47.01
Pseudotolithus senegalensis	1.78	0.31	3.29	1.34	4.17	51.19
Syacium micrurum	0.37	1.73	3.20	0.86	4.06	55.25
Chloroscombrus chrysurus	1.25	0.99	2.92	1.00	3.71	58.95
Rhinobatus albomaculatus	0.32	1.10	2.22	0.76	2.82	61.77
Ilisha africana	1.12	0.26	2.12	0.85	2.69	64.46
Trichiurus lepturus	1.07	0.05	1.94	0.61	2.47	66.93
Dasyatis margarita	0.45	0.88	1.93	0.80	2.46	69.38
Pseudotolithus typus	0.93	0.19	1.79	0.85	2.27	71.65
Pagellus bellottii	0.20	0.94	1.77	0.62	2.24	73.90
Sphyraena sphyraena	0.79	0.30	1.66	0.70	2.11	76.00
Balistes punctatus	0.07	0.92	1.64	0.74	2.08	78.08
Lagocephalus laevigatus	0.76	0.10	1.42	0.97	1.80	79.88
Stephanolepis hispida	0.00	0.68	1.41	0.46	1.80	81.68
Lutjanus fulgens	0.00	0.74	1.37	0.41	1.73	83.41
Pagrus caeruleostictus	0.19	0.69	1.31	0.54	1.66	85.08
Sphoeroides marmoratus	0.25	0.48	1.25	0.51	1.59	86.67
Scorpaena histrio	0.15	0.55	1.25	0.43	1.58	88.25
Dentex canariensis	0.00	0.70	1.19	0.66	1.51	89.76
Chromis limbata	0.00	0.63	1.16	0.40	1.47	91.23

From VNB, 530 individual fishes representing 30 species were recorded with *P. prayensis* as the dominant species (11.9%), followed by *Decapterus punctatus* (11.7%) and *A. notacanthus* (8.9%) (Table 9). However, five species (*P. senegalensis*, *D. hystrix*, *S. dorsalis*, *Umbrina canariensis*, and *Synodus synodus*) of the total catch were the least represented (i.e. 0.19%) (Table 3). Overall, 36 trawls were carried out during the 12 sampling periods. The low number of species was due to tear of trawling gear during the sampling period.

Individuals of only four species recorded from more than 7 sampling periods indicated that these species contributed mainly to the total abundance of individuals recoded in the study (Figure 6). These species included *P. prayensis*, *A. notacan-*

Table 6. Species contributing most to survey dissimilarity within significant clusters, ranked by percent contribution (Contrib%). Also included are the average abundance (Av. abund) of species within the group, average dissimilarity (Av. diss) contribution relative to its standard deviation (Diss/SD), and the cumulative percent contribution of species to the average group similarity (Cum.%, species up to 90% included). 1: Venon Bank (VNB). 2: Disposal area (DSA). Average dissimilarity: 78.62.

Species	Av. abund (1)	Av. abund (2)	Av. diss	Diss/SD	Contrib%	Cum.%
Pagrus caeruleostictus	2.41	0.69	4.63	1.34	5.88	5.88
Pseudupeneus prayensis	3.36	2.59	4.59	1.32	5.84	11.73
Acanthostracion notacanthus	2.41	1.86	4.45	1.19	5.67	17.39
Balistes punctatus	2.34	0.92	4.11	1.06	5.23	22.63
Cynoglossus senegalensis	0.40	1.71	3.53	0.80	4.49	27.12
Syacium micrurum	0.82	1.73	3.44	0.97	4.37	31.49
Stephanolepis hispida	1.57	0.68	3.37	0.99	4.29	35.78
Scorpaena histrio	1.52	0.55	3.33	0.86	4.23	40.01
Selene dorsalis	0.09	1.63	3.04	0.69	3.87	43.88
Brachydeuterus auritus	0.00	1.36	2.50	0.60	3.17	47.06
Scarus hoefleri	1.29	0.00	2.42	0.59	3.07	50.13
Dasyatis margarita	0.86	0.88	2.33	0.94	2.97	53.10
Rhinobatus albomaculatus	0.00	1.10	2.23	0.66	2.83	55.93
Lethrinus atlanticus	1.18	0.09	2.18	0.75	2.78	58.71
Rypticus saponaceus	0.98	0.64	2.11	0.86	2.68	61.40
Dentex canariensis	0.48	0.70	2.11	0.59	2.68	64.08
Dentex gibbosus	1.06	0.00	2.10	0.57	2.67	66.74
Chloroscombrus chrysurus	0.12	0.99	2.02	0.64	2.57	69.32
Galeoides decadactylus	0.00	1.00	2.01	0.56	2.56	71.88
Drepane africana	0.00	0.98	1.96	0.53	2.50	74.38
Pagellus bellottii	0.31	0.94	1.93	0.60	2.46	76.83
Acanthurus monroviae	0.85	0.22	1.70	0.75	2.17	79.00
Sphoeroides marmoratus	0.53	0.48	1.69	0.56	2.15	81.15
Chromis limbata	0.35	0.63	1.61	0.54	2.05	83.20
Pseudotolithus senegalensis	0.48	0.31	1.58	0.41	2.01	85.21
Lutjanus fulgens	0.15	0.74	1.57	0.46	2.00	87.21
Decapterus punctatus	0.67	0.11	1.43	0.34	1.82	89.03
Chaetodon robustus	0.55	0.38	1.40	0.75	1.78	90.81

thus, *B. punctatus* and *P. caeruleostictus*. One-way ANCOVA indicated significant difference among sampling periods (df = 11, F-value = 2.42, p-value = 0.037).

At DSA, 1,061 fishes representing 37 taxonomic species were recorded, with *S. dorsalis* as the dominant species (20.0%), followed by *Pagellus bellottii* (8.64%) and *P. caeruleostictus* (8.45%) (Table 10). However, nine species of the total catch were the least represented (i.e. 0.09%). Some of these less represented species were *U. canariensis*, *Trichiurus lepturus* and *Alectis alexandrina*. Overall, 26 trawls were made at DSA during the 12-month sampling period.

Table 7. Analysis of similarity among the three sampling locations. OSK: Offshore Sakumono. VNB: Venon Bank. DSA: Disposal area.

Pairwise tests groups	R statistic	Significance level%	Actual permutations
OSK, VNB	0.946	0.1	999
OSK, DSA	0.381	0.1	
VNB, DSA	0.235	0.3	

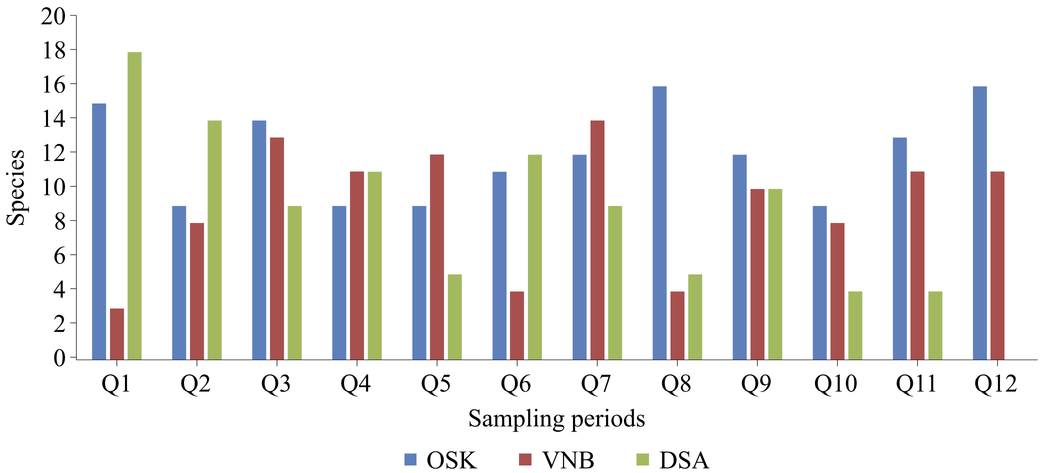

Figure 3. Species abundance for the three sampling locations during the study period. OSK: Offshore Sakumono. VNB: Venon Bank. DSA: Disposal area.

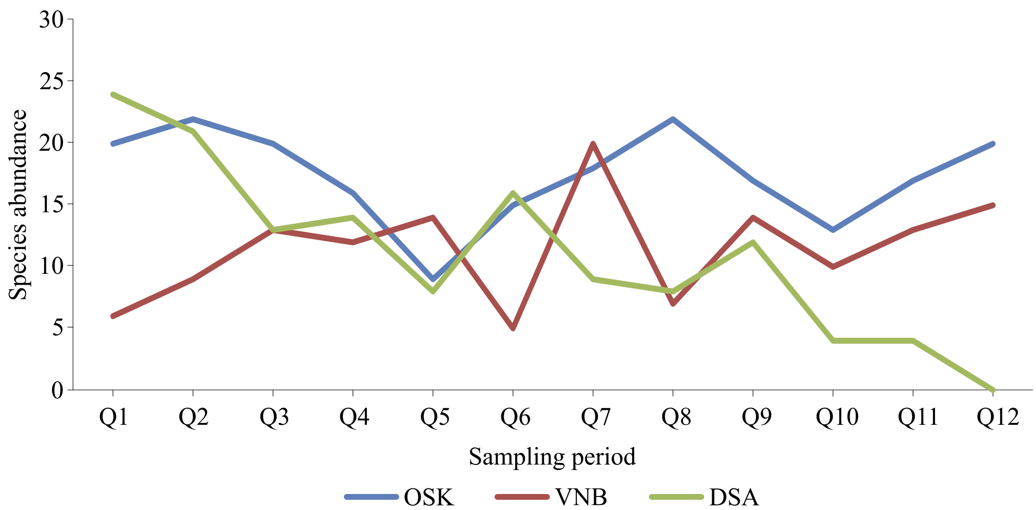

Figure 4. Trend analysis of species abundance at OSK (Offshore Sakumono), VNB (Venon Bank), and DSA (Disposal Area), during the sampling period.

Table 8. Total abundance and frequency of occurrence (FO) of species recorded from the Offshore Sakumono (OSK) sampling area from June 2018 to November 2021.

Species	Total	%FO
Selene dorsalis	2,086	39.56
Brachydeuterus auritus	954	18.09
Galeoides decadactylus	436	8.27
Pteroscion peli	315	5.97
Chloroscombrus chrysurus	269	5.10
Pseudotolithus senegalensis	242	4.59
Cynoglossus senegalensis	168	3.19
Sphyraena sphyraena	145	2.75
Drepane africana	118	2.24
Ilisha africana	99	1.88
Trichiurus lepturus	86	1.63
Pseudotolithus typus	77	1.46
Pagellus bellottii	54	1.02
Lagocephalus laevigatus	33	0.63
Pseudupeneus prayensis	25	0.47
Syacium micrurum	25	0.47
Umbrina canariensis	23	0.44
Dasyatis margarita	22	0.42
Caranx crysos	20	0.38
Alectis alexandrina	16	0.30
Sphoeroides marmoratus	11	0.21
Rhinobatus albomaculatus	10	0.19
Synodus synodus	9	0.17
Zanobatus maculatus	8	0.15
Pagrus caeruleostictus	6	0.11
Acanthostracion notacanthus	5	0.09
Lethrinus atlanticus	3	0.06
Balistes punctatus	2	0.04
Scorpaena histrio	2	0.04
Pegusa cadenati	2	0.04
Rypticus saponaceus	1	0.02
Dactylopterus volitans	1	0.02
Total	5,273	100.00

Individuals of only 1 species were recorded in more than 7 sampling periods, indicating that this species (*P. prayensis*) contributed most to the total abundance of individuals recoded in the study (Figure 7). One-way ANOVA indicated significant difference among sampling periods (df = 10, F-value

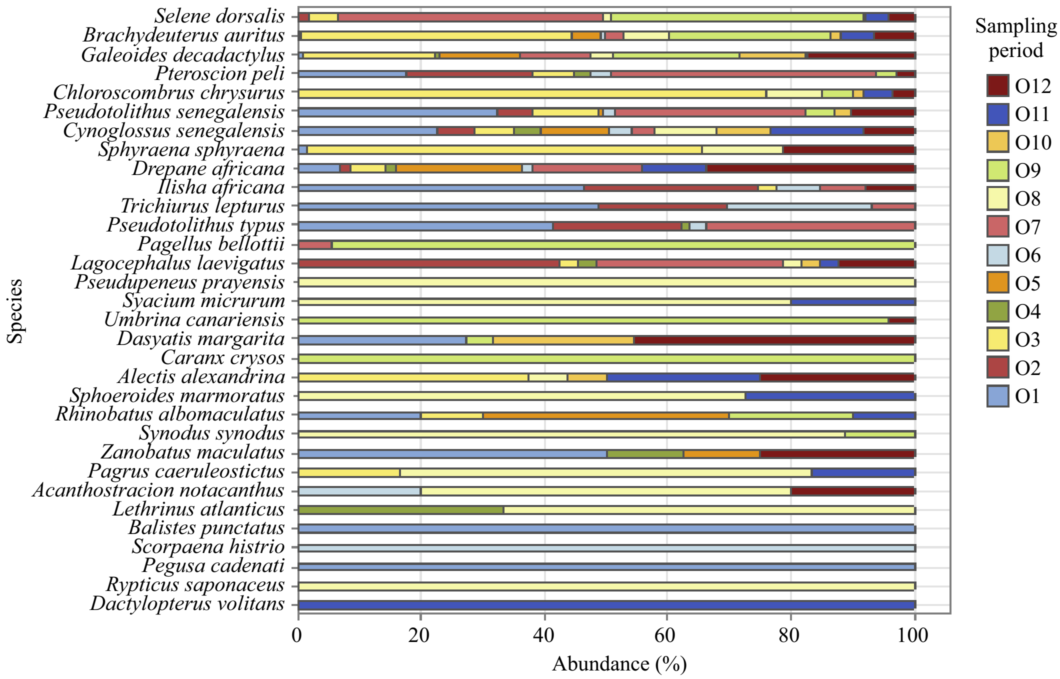

Figure 5. Stacked graph of species abundance at Offshore Sakumono (OSK) during the sampling period. O = OSK.

= 5.992, p-value < 0.0001). No catch was recoded for November 2021 at DSA sampling area.

The SRI, SEI and SWI at Offshore Sakumono were 3.31 ± 0.21, 0.96 ± 0.01 and 2.24 ± 0.07, respectively. Estimated SRI, SEI and SWI at the Disposal Area were 2.24 ± 0.39, 0.95 ± 0.01 and 1.99 ± 0.14, respectively (Table 11). Estimated SRI, SEI and SWI at Venon Bank were 2.42 ± 0.30, 0.91 ± 0.01 and 2.01 ± 0.14, respectively. With the exception of Shannon-Wiener index, SRI and SEI were significantly different among the three sampling locations (SEI One-way ANOVA, F-statistic = 7.091, p-value = 0.003, df = 34; SRI One-way ANOVA, F-statistic = 3.429, p-value = 0.04, df = 34).

DISCUSSION

In general, the MDS ordination analyses corroborated by the ANOSIM test, clearly demonstrated the dissimilarity between control and disturbed areas. Furthermore, SIMPROF analysis indicated significant differences between control and disturbed stations probably due to the alteration in habitat substrate following dredging and dumping activities. Thus, species such as *P. prayensis*, *B. punctatus*, *S. histrio*, *S. micrurum* and *A. notacanthus* differentiated disturbed areas from control sites with an average dissimilarity of 78%. Other species that contributed significantly to the dissimilarity between control and disturbed areas included *B. punctatus* and *Dentex gibbosus*.

According to Gutperlet et al. (2015), dredging causes a coarsening of the substrate, increasing the sand fraction at the dredging site. In the wake of dredging activities, these substrates contain rich and diverse feed items such as crustaceans, worms, mollusks and small fishes, as well as carcasses of dead organisms (Kabasakal 2001; Prabha and Manjulatha 2008; Ballard and Rakocinski 2012; Narvaez et al. 2015; Barletta et al. 2016; Ferri and Matic-Skoko 2021).

The rising trend of species abundance at VNB

Table 9. Total abundance and frequency of occurrence (FO) of species recoded from the Venon Bank (VNB) sampling area from June 2018 to November 2021.

Species	Total	%FO
Pseudupeneus prayensis	63	11.89
Decapterus punctatus	62	11.70
Acanthostracion notacanthus	47	8.87
Lethrinus atlanticus	45	8.49
Balistes punctatus	44	8.30
Stephanolepis hispida	38	7.17
Lagocephalus laevigatus	30	5.66
Pagrus caeruleostictus	28	5.28
Scorpaena histrio	25	4.72
Scarus hoefleri	22	4.15
Acanthurus monroviae	20	3.77
Rypticus saponaceus	16	3.02
Dentex gibbosus	15	2.83
Zanobatus maculatus	13	2.45
Dasyatis margarita	10	1.89
Chaetodon robustus	8	1.51
Syacium micrurum	7	1.32
Chromis limbata	7	1.32
Sphoeroides marmoratus	7	1.32
Pagellus bellottii	5	0.94
Cynoglossus senegalensis	4	0.75
Lutjanus fulgens	3	0.57
Chloroscombrus chrysurus	2	0.38
Pegusa cadenati	2	0.38
Dactylopterus volitans	2	0.38
Selene dorsalis	1	0.19
Pseudotolithus senegalensis	1	0.19
Umbrina canariensis	1	0.19
Dentex canariensis	1	0.19
Synodus synodus	1	0.19
Total	530	100.00

may be attributed to the immigration of species from adjacent areas because of prey items made available in the wake of dredging activities. This observation lends credence to the finding of Barletta et al. (2008), who attributed the increase in the number of species in the main channel, where dredging was ongoing, to the migration of fish species. Certain species, including *Scorpaena histrio*, *Scarus hoefleri*, *Acanthurus monroviae*, *R. saponaceus*, *S. hispida*, and *Lethrinus atlanticus*, were

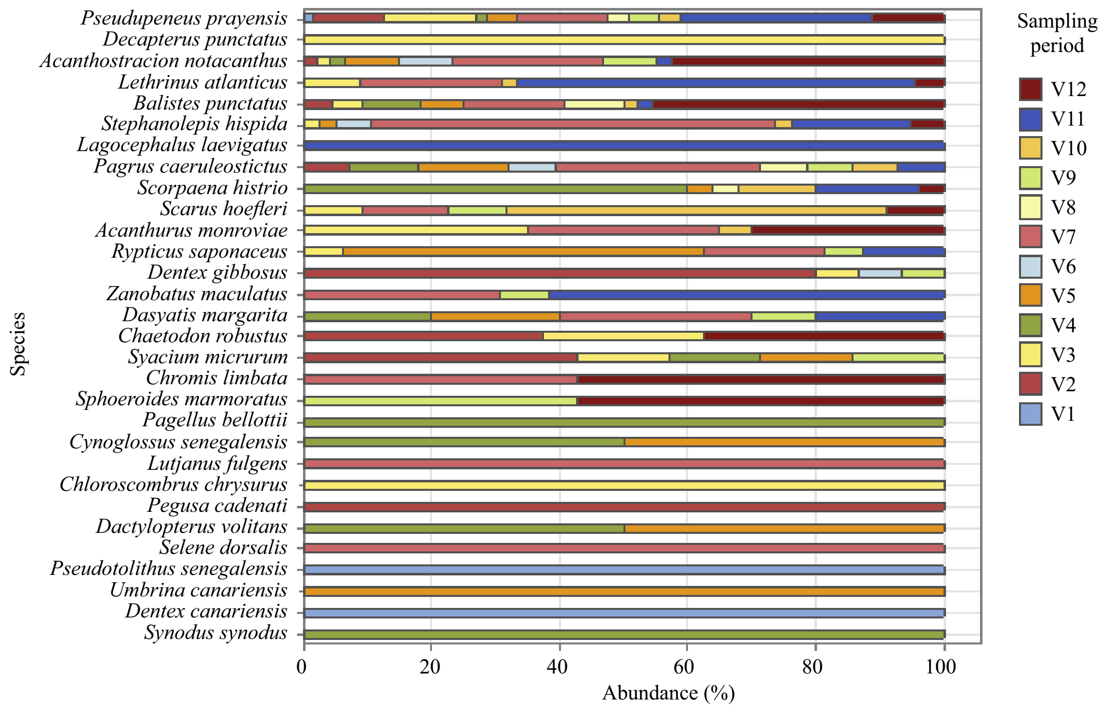

Figure 6. Stacked graph of species abundance at Venon Bank (VNB) during the sampling period. V = VNB.

absent from the dredging site prior to the start of the dredging activities in 2019. However, during the period of dredging activities from 2019 to 2020, the abundance of these species increased. They include herbivores (*S. hoefleri*, *A. monroviae*, and *L. atlanticus*), carnivores (*Lagocephalus laevigatus*, *R. saponaceus*), and omnivores (*S. hispida*) species, and they all benefited from feeding activities of *P. prayensis*. Species like *A. monroviae*, *S. hoefleri*, *L. laevigatus*, and *L. atlanticus* are also non-migratory, so once a favorable niche is found, leaving does not become an option. In addition, herbivorous (*P. prayensis*), carnivorous (*B. punctatus* and *P. caeruleostictus*), and omnivorous species (*A. notacanthus*) increased in abundance during the dredging process. The increase in abundance of carnivorous species, such as *B. punctatus*, *P. caeruleostictus*, and *A. notacanthus*, may be due to the action of habitat modifiers such as *P. prayensis*. This species disturbs sediments during feeding, exposing crustaceans and mollusks as prey items to omnivorous and carnivorous species. However, some species that were present prior to the dredging activity at VNB, such as *P. senegalensis*, *Pegusa cadenati*, *D. gibbosus*, and *Dentex canariensis*, became absent during the dredging period, possibly due to out-migration from VNB. The emigration of these species from VNB may be due to their preference for live prey that may not be present during dredging activities, as dredging mostly results in the crashing of prey items. According to Chao (2002), sciaenids such as *P. senegalensis* feed mainly on live prey on the bottom. Furthermore, because these species are highly valuable to artisanal fishermen, their absence from VNB is a critical information for conservation efforts.

Disposing dredged spoils at DSA in the form of loose to medium sand and moderate to highly weathered gravels may have increased the seabed by certain meters leading to smothering of species and high rate of mortality. The reduction in species abundance at DSA may be the direct impact

Table 10. Total abundance and frequency of occurrence (FO) of species recorded from the Disposal Area (DSA) sampling from June 2018 to November 2021.

Species	Total	%FO
Selene dorsalis	213	20.00
Pagellus bellottii	92	8.64
Pagrus caeruleostictus	90	8.45
Syacium micrurum	69	6.48
Pteroscion peli	64	6.01
Brachydeuterus auritus	58	5.45
Pseudupeneus prayensis	46	4.32
Pseudotolithus senegalensis	44	4.13
Galeoides decadactylus	39	3.66
Acanthostracion notacanthus	36	3.38
Dasyatis margarita	36	3.38
Balistes punctatus	30	2.82
Lutjanus fulgens	28	2.63
Rypticus saponaceus	26	2.44
Drepane africana	22	2.07
Chromis limbata	22	2.07
Cynoglossus senegalensis	18	1.69
Dentex canariensis	18	1.69
Pseudotolithus typus	17	1.60
Chloroscombrus chrysurus	13	1.22
Pegusa cadenati	11	1.03
Rhinobatus albomaculatus	10	0.94
Dactylopterus volitans	10	0.94
Sphyraena sphyraena	7	0.66
Ilisha africana	7	0.66
Chaetodon robustus	6	0.56
Lagocephalus laevigatus	5	0.47
Scorpaena histrio	5	0.47
Sphoeroides marmoratus	5	0.47
Synodus synodus	5	0.47
Lethrinus atlanticus	3	0.28
Acanthurus monroviae	3	0.28
Decapterus punctatus	2	0.19
Stephanolepis hispida	2	0.19
Trichiurus lepturus	1	0.09
Umbrina canariensis	1	0.09
Alectis alexandrina	1	0.09
Total	1,061	100.00

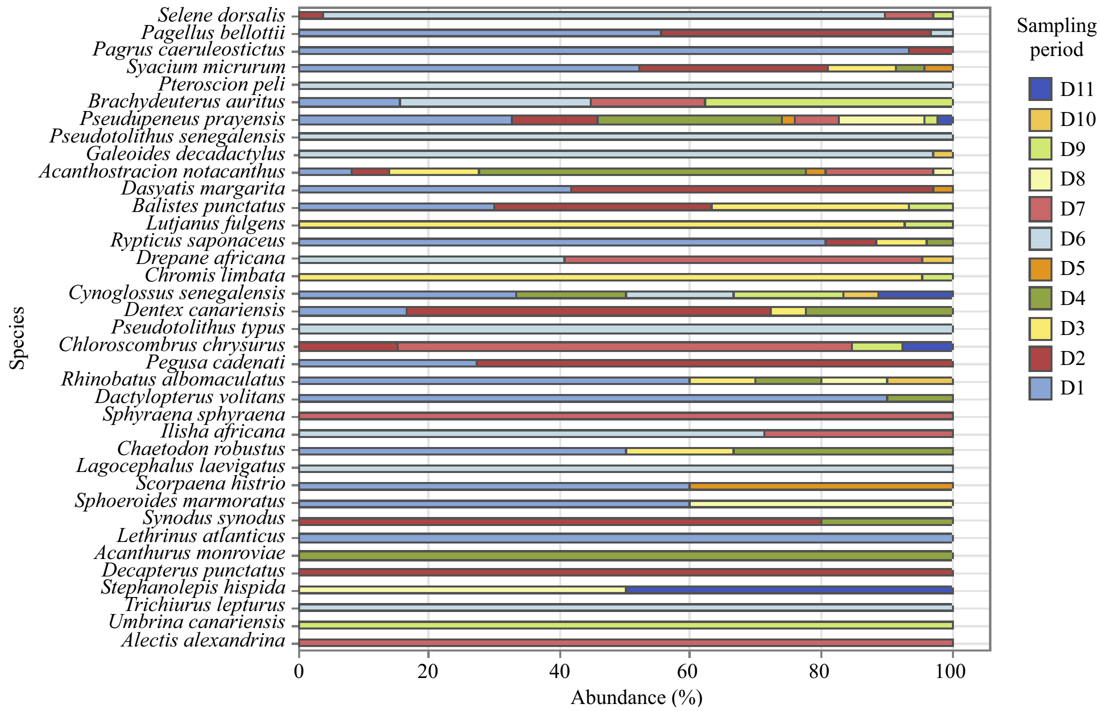

Figure 7. Stacked graph of species abundance at Disposal Area (DSA) during the sampling period. D = DSA.

Table 11. Diversity indices of control and disturbed sampling sites during the study period (2018-2021). OSK: Offshore Sakumono. VNB: Venon Bank. DSA: Disposal area.

Diversity indices	OSK	VNB	DSA
SWI	2.235 ± 0.065	2.009 ± 0.138	1.99 ± 0.139
SRI	3.31 ± 0.212	2.42 ± 0.296	2.24 ± 0.391
SEI	0.96 ± 0.014	0.91 ± 0.008	0.95 ± 0.009

of dumping of dredged spoils leading to habitat loss. Freitas et al. (2009) made similar observation where covering of beach rock tidal pools by the dredge spoil led to decline in total fish habitat loss during the harbor construction at Pecém Beach, Brazil. To support this claim, species that were present before the start of dumping activities but declined in abundance during dumping activities included *S. histrio*, *D. canariensis*, *P. bellottii*, *P. caeruleostictus*, *L. atlanticus*, *P. cadenati*, *S. micrurum*, *B. punctatus* and *R. saponaceus*. The decline in abundance of species from various feeding guilds, including carnivores such as *D. canariensis*, omnivores such as *P. bellottii* and invertivores such as *P. cadenati*, may be due to the unavailability of prey items. However, species such as *B. auritus*, *S. dorsalis*, *P. prayensis*, *A. notacanthus* and *C. senegalensis* increased in abundance during the dumping period. Flatfishes such as *C. senegalensis* consume crustaceans exposed by ecosystem engineers such as *P. prayensis* (Prabha and Manjulatha 2008; Rafrafi-Nouira et al. 2016; van der Veer et al. 2018). Some of these species resort to feeding on detritus when the bottom is disturbed during dumping of dredged spoils (Jayaprakash 2000). As a result, species such as *Fistularia petimba* and *B. punctatus* exhibit high migratory behavior in search of prey items such as *Coris julis*, crabs and bivalves (Corsini et al. 2002; Golani et al. 2007; Dance 2017; Bryan et al. 2019). *Pteroscion peli*, *P. senegalensis*, *G. decadactylus*, *Lutjanus fulgens*, *Pseudotolithus typus*, *Chloroscombrus chrysurus* and *Ilisha africana* that were absent before the start of dumping activity, were present during the dumping period, indicating the possibility of migration of these migratory species from adjacent niches to habitats within DSA sampling area. Additionally, non-migratory species such as *D. africana* and *Chromis limbata* may have become available due to the availability of resources in DSA. The absence of these important fish species during the dredging period is relevant for their sustainable management. The large number of species in undisturbed areas within OSK may have accounted for the significantly high SRI and SEI at OSK sampling location. The undisturbed area was highly characterized by *B. auritus*, *C. senegalensis*, *G. decadactylus*, *S. dorsalis* and *P. senegalensis*. These species have high affinity for either sandy, hard or muddy substrate, which is characteristic of OSK sampling area. The persistent presence of these typical species implies that the structure of species at the control site was not severely impacted on by construction activities.

Increased dredging activities are inversely proportional to the habit size and quality leading to reduced species diversity and composition (Barletta et al. 2016). Increase in turbidity, leading to re-suspension of sediments within the water column caused by the action of dredging and dumping, can foster changes in the life history of fish species, having a negative impact on fishing activities within study areas (Griffin et al. 2009). Dredging activities throughout the sampling period could have detrimental impact on the reproductive and recruitment potential of fishes (Barletta et al. 2016). Such impact will have tremendous negative effects on economic wellbeing on fishing households that depend on these species for survival.

CONCLUSIONS

The present study included quantitative data on species abundance assessing the impact of port construction on fish diversity, assemblages and structure. It showed that declined species diversity and abundance at the disposal area was triggered by dumping activities during the construction of port Tema. However, increase in species diversity was observed at the Venon Bank triggered by dredging of building materials. From the study, a significant difference was observed between the control and disturbed areas.

Suggestions for the planning of port constructions should include undertaking local ecological knowledge on other fish species that serve as essential natural resources for resident populations. Additionally, studies using regression models should be carried out to highpoint biological and environmental variables determining the fish assemblage affected by dredging and disposal activities in the marine environment of Ghana. Fishery resources off the coast of Greater Accra, Ghana, are an important source of financial and food support for local households, so it is essential to study ontogenetic phases as habitat indicators for conservation purposes. It is recommended that findings from the study be used as a reference for future projects concerning port construction in the maritime space of Ghana.

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Author contributions

Samuel K. K. Amponsah performed writing-original draft, methodology, formal analysis, data curation and conceptualization. Francis K. E. Nunoo, Angela M. Lamptey and Patrick K. Ofori-Danson performed writing-review and editing, supervision and conceptualization. Ayaah Armah performed resources, project administration, supervision, conceptualization and funding acquisition.

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APPENDIX

Cluster analyses of fish species data from control and disturbed sites based on Bray-Curtis similarity using square-root transformed species abundance data. Black lines indicate significantly different clusters according to the SIMPROF test ($p < 0.05$). O: Offshore Sakumono (OSK). V: Venon Bank (VNB). D: Disposal Area (DSA).