Delivrable N° 4.1 : Habitat descriptors – Environmental factors and plankton descriptors

Projet: FED/2018/402-604 - DEMERSTEM, DEMERsal ecosySTEMs
Décision: FED/2017/038-922 - Improved regional fisheries governance in Western Africa (PESCAO)

Version du 28/08/2023

Habitat descriptors – Environmental factors and plankton descriptors

An evaluation of demersal fish' habitats in North-West Africa was done based on two Oceanographic Cruises conducted in different seasons within the framework of DEMERSTEM.
In both Cruises, samples of phyto- and mesozooplankton (including fish and invertebrate larvae) were collected using the same sampling protocol in a selected numbers of stations. In particular, vertical tows between the surface and 200 m depth or between the surface and the bottom in shallower stations, were used to collect phytoplankton (20 µm mesh size) and zooplankton (200 µm mesh size) samples.
The samples were preserved in buffered formalin and subsequently analysed by the experts of the SZN in order to identify and counts phyto- and zooplankton species that characterise the basis of the trophic web, on which demersal fish feed upon.
Here below a short synthesis of the main results is presented. The key findings of this study, together with the associated data sets, will be made publicly available following publication in peer reviewed journals, through the SZN website (https://marine-observatory.szn.it/north-atlantic-cclme/).

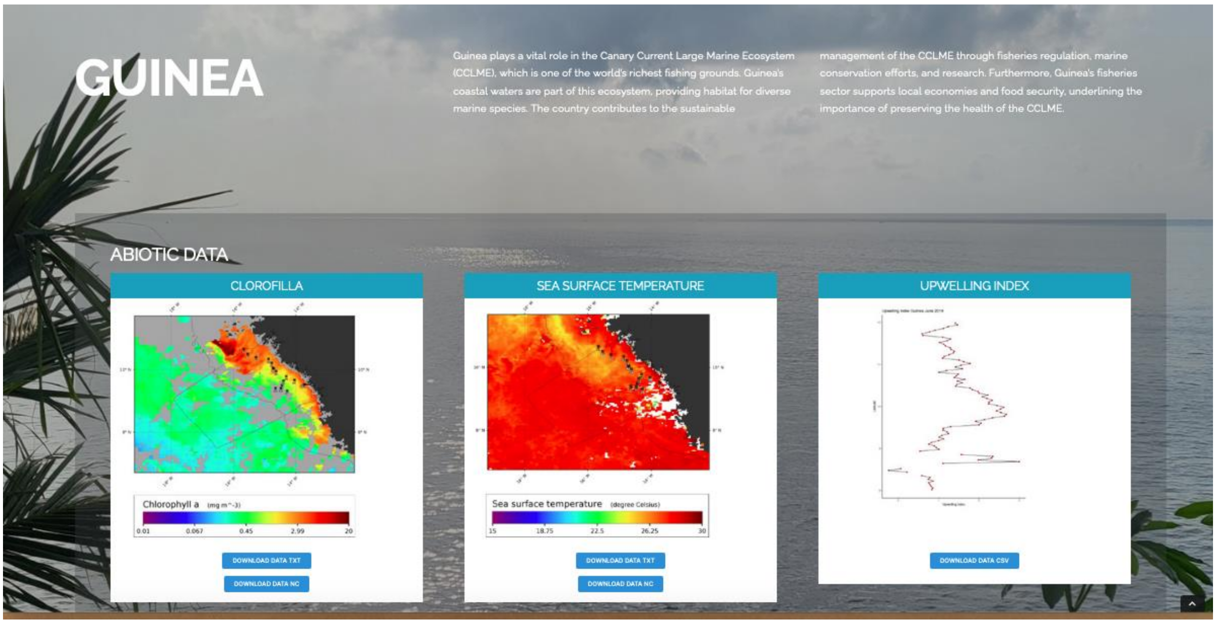

Figure 1. Environmental data products analysed within DEMERSTEM to define the environmental habitat of the Guinean region during the 2019 DEMERSTEM Cruise. SZN webpage https://marine-observatory.szn.it/north-atlantic-cclme/.

Mauritania Case Study

A series of abiotic (i.e. temperature, salinity, Mixed Layer Depth, in situ oxygen concentrations measured during the cruise; weekly records of sea surface temperature and chlorophyll *a*/fluorescence from satellite, Nasa MODIS-Aqua Ocean Color Data level 3) and biotic variables (i.e. abundance and species composition of phytoplankton and mesozooplankton communities) were measured in 23 stations located between 21°LatN and 16°LatN during an oceanographic cruise conducted between 26 October and 5 November 2019 (Fig.2).

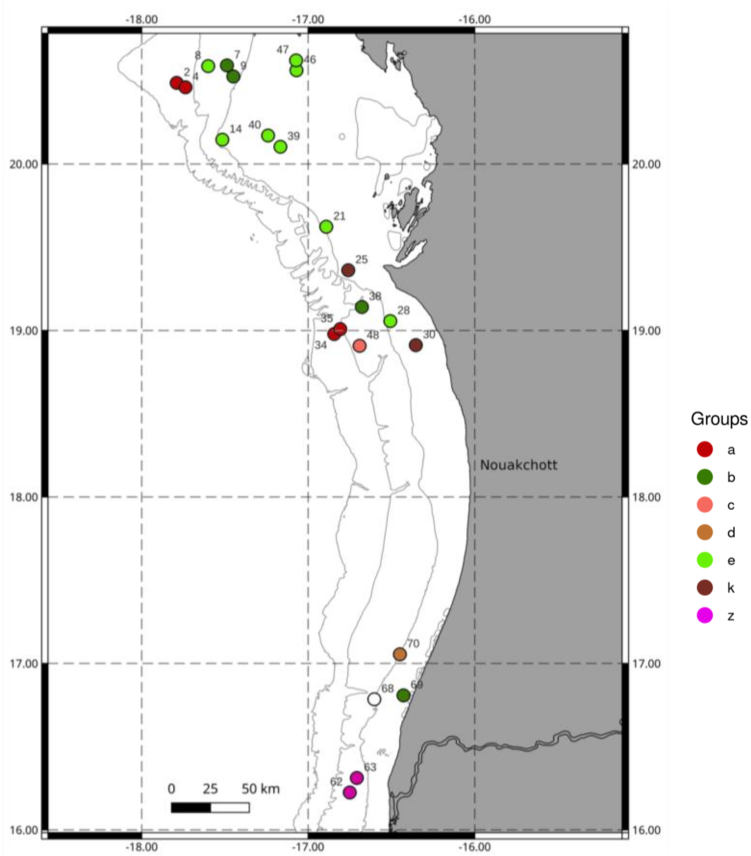

Figure 2. DEMERSTEM Mauritanian Cruise. Circles indicate stations in which data of temperature, salinity, oxygen concentration, phyto-, and zooplankton were collected between 26 October and 5 November 2019. In the same sites, weekly chlorophyll *a* concentrations were also obtained from satellite (NASA/JPL.,2020a; NASA Ocean Biology Processing Group., 2022). Colours indicate groups of stations with similar environmental features, as identified by cluster analysis on environmental data (Q-mode analysis based on Euclidean distance, not shown). White colour indicates no abiotic data available. Isobaths at 5, 200, 500 and 1000m depths are also shown (bathymetry dataset from https://www.gebco.net/).

The analysis of abiotic factors pointed out significant differences in the northern and central Mauritanian region, which encompassed a coastal habitat (<200 m depth) characterised by very productive and oxygen rich water-masses (see stations of groups “b” and also “e” in Fig. 2 and Fig.3), as opposed to an offshore, relatively more oligotrophic habitat (see stations of group “a” in Fig. 2 and Fig.3). The significant influence of the Canary Current up-welling on the northernmost stations progressively decreased moving southwards, with the region around Cap Timiris likely characterised by complex hydrological features, such as eddies originated by the encounter of different water-masses (see stations of group “k” in Figs. 2 and 3). The southern

Mauritanian region showed very different environmental features, also due to the influence of the river Senegal (see stations of group "z" and also groups "c" and "d" in Figs. 2 and 3).

<u>Bathymetry, chlorophyll *a*, depth-averaged salinity and oxygen concentration</u> appeared to drive the main abiotic differences between stations (Fig.3).

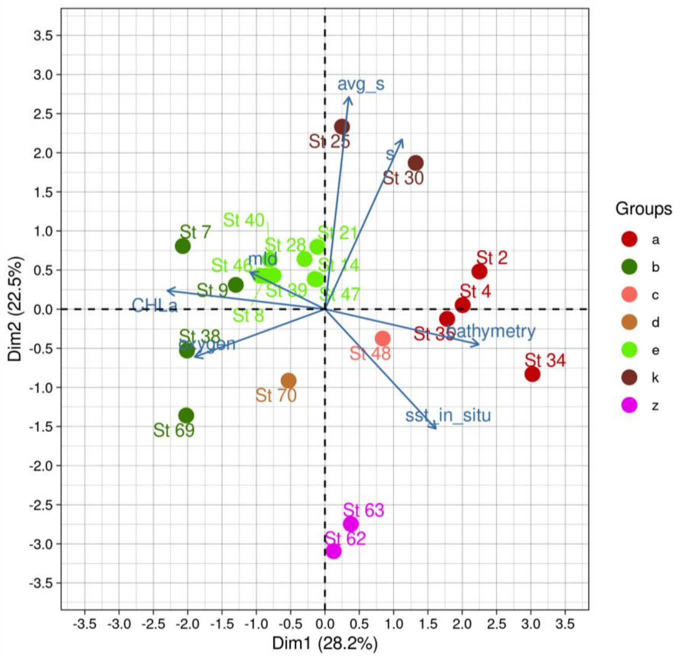

Figure 3. DEMERSTEM Mauritanian Cruise. Ordination of stations obtained by Principal Component Analysis (PCA) based on environmental factors such as sea surface temperature (sst_in_situ), bathymetry, chlorophyll (CHLa), surface oxygen concentration (oxygen), mixed layer depth (MLD), surface salinity (s) and depth-averaged salinity (avg_s). For explanation on groups of stations, see legend of Fig.2.

Overall, 166 phytoplankton species/taxa were identified in Mauritanian waters in autumn. In the highly productive northern/central Mauritanian region (Fig. 4), the phytoplankton community was mainly characterised by diatoms, with relatively high abundance of large-size species, such as *Coscinodiscus* in the northernmost stations (see "blue" stations in Fig. 5 and Tab.1) and *Chaetoceros* on the continental shelf (see "green" stations in Fig. 5 and Tab.1).

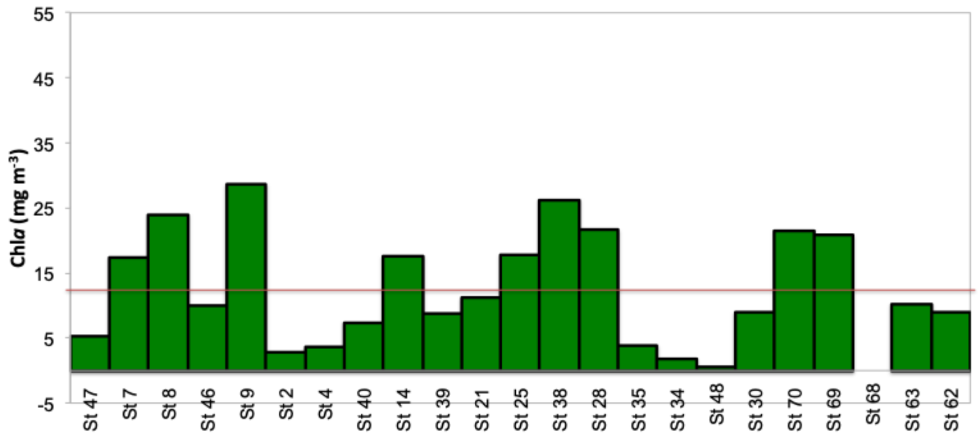

Figure 4. DEMERSTEM Mauritanian Cruise. Surface Chlorophyll a concentration (weekly average, mg m^{-3}) in each sampling station from satellite (NASA Ocean Biology Processing Group., 2022). Red line indicates overall average.

In the southern region, the peaks of Chl*a* were instead associated with the presence of different species of dinoflagellates (see "red" stations in Fig. 5 and Tab.1) and potentially harmful diatom species of the genus *Pseudo-nitzschia* (see "yellow" stations in Fig. 5 and Tab.1)

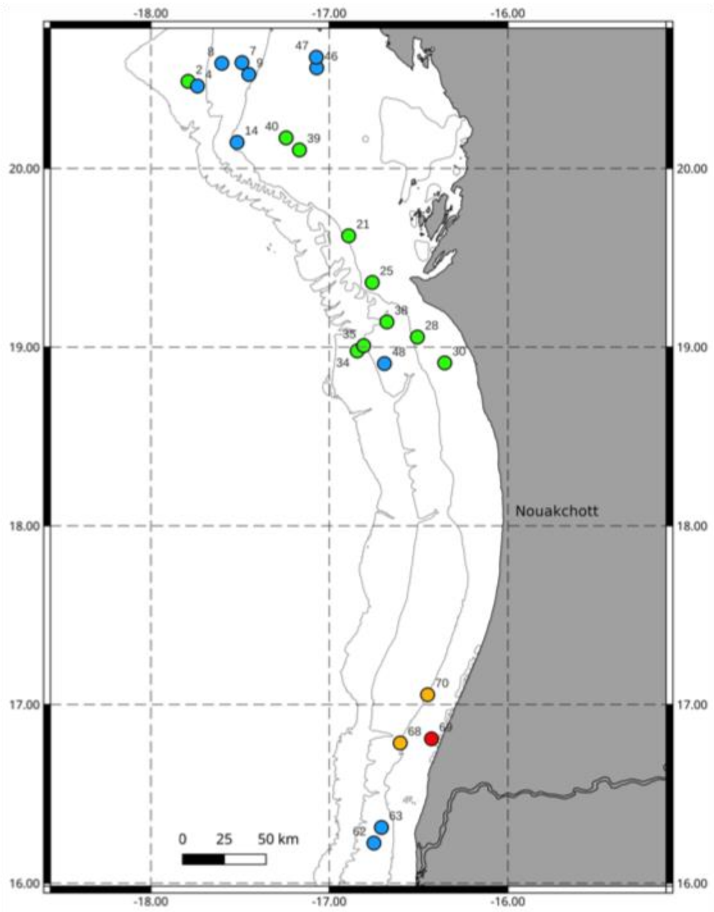

Figure 5. DEMERSTEM, Mauritanian Cruise. Colours indicate stations with similar phytoplankton community, as identified by cluster analysis on phytoplankton data (Q-mode analysis based on Hellingher distance, Fig.Suppl.1). Isobaths at 5, 200, 500 and 1000m depths are also shown (bathymetry dataset from https://www.gebco.net/).

Table 1. DEMERSTEM, Mauritanian Cruise. Main phytoplankton associations identified by cluster analysis (R-mode clustering based on Hellingher distance between 73 phytoplankton taxa/groups, not shown). In bold are indicated taxa associations identified by clustering, which were confirmed by the Indval Index approach as characteristic of the group (i.e. Indval >25%, Legendre & Dufrene, 1997)

GROUP *Blue*	GROUP *Yellow*
Centric Diatoms <10 µm; C.D.>10 µm; C.D.30-50 µm	***Pseudo-nitzchia seriata* group; *P. pseudodelicatissima***
Coscinodiscus asteromphalus/radiatus; *C. wailesii*	*Gonyaulax spinifera*
Octactis octonaria var. pulchra	*Protoperidinium paraoblongum*
Thalassionema nitzschioides	*Dictyocha fibula*
Actinoptychus senarius	*Rhizosolenia bergoni*
Cerataulina pelagica	*Prorocentrum micans;* ***Prorocentrum* spp.**
Leptocylindrus danicus	
Thalassiosira rotula	GROUP *Red*
Rhizosolenia cf. imbricata; ***Rhizosolenia spp.***	*Dinophysis sacculus*
Ditylum brightwellii	*Heterocapsa niei*
Guinardia flaccida	*Haslea* sp.
Planktoniella sol	***Thalassionema bacillare/frauenfeldii***
***Pleurosigma* spp.**	**Naked Dinoflagellates <15 µm; N.D.>15 µm**
Undetermined Cryptophyceae < 10 µm	***Paralia sulcata***
Asteromphalus heptatis	*Tripos minutum;* ***T. furca***
Protoperidinium cf grani; *P. crassipes*	***Protoperidinium* spp.**
	Thecate Dinoflagellates <15 µm; T.D.>15 µm
GROUP *Green*	*Cylindrotheca closterium*
Chaetoceros didymus/protuberans	*Eucampia zodiacus*
***Thalassiosira rotula*; *Thalassiosira* spp.**	***Proboscia alata/indica***
Chaetoceros* socialis; *C. pseudocurvisetus* (vegetative cells & spores)**; ***C. decipiens;	Pennate Diatoms > 10 µm
***Chaetoceros didymus* (spores)**; *Chaetoceros* spp. (vegetative cells & spores)	***Dictyocha fibula***
Dactyliosolen phuketensis; D. fragilissimus	
Stephanopyxis turris	
***Bacteriastrum* spp.**	
Pseudosolenia calcar-avis	
Guinardia striata	
Biddulphia alternans	
Bacillaria paradoxa	
Asterionellopsis glacialis	
Pennate Diatoms > 10 µm	

Overall, 66 mesozooplankton species/taxa were identified in Mauritanian waters, with highest abundance recorded at offshore stations (>100 m depth) in north and central Mauritania (Fig.6).

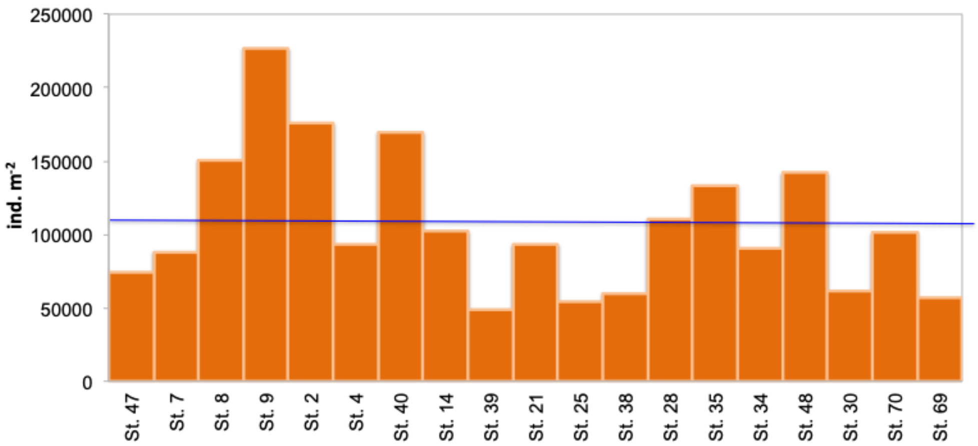

Figure 6. DEMERSTEM Mauritanian Cruise. Integrated (0-200m depth or 0m-bottom depth in shallow stations) abundance of zooplankton in each sampled station (ind. m^{-2}). Blue line indicates overall average.

In autumn the mesozooplankton community in Mauritania was generally dominated by crustacean copepods, but in offshore stations, strongly influenced by the up-welling, and off Cap-Timeris (see "red" stations in Fig. 7), the relative abundance of gelatinous filter-feeders, such as appendicularians and thaliaceans increased (Fig. Suppl.2). In these stations the copepod community was mainly characterised by a number of deep-living species (e.g. *Rhincalanus, Heterorhabdus, Rhincalanus* spp., see Group "red" in Tab.2), while in more coastal stations, neritic species (e.g. *Centropages, Temora, Clausocalanus* and *Paracalanus* spp.) and small-size copepods (e.g. *Oithona* and *Oncaea* spp.) tended to dominate (Fig. 7 and Tab.2)

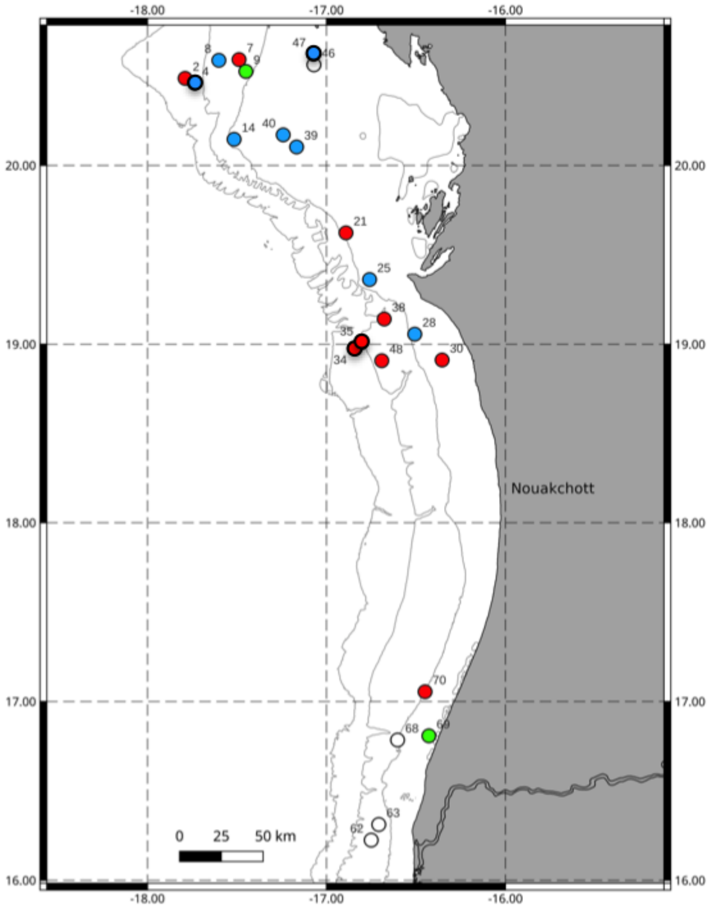

Figure 7. DEMERSTEM, Mauritanian Cruise. Colours indicate stations with similar zooplankton (copepods) communities, as identified by cluster analysis on zooplankton data (Q-mode analysis based on Hellingher distance, Fig.Suppl.2). Stations indicated by white circles were not included in the analysis, due to poor preservations of the samples that might have biased the counts. Isobaths at 5, 200, 500 and 1000m depths are also shown (bathymetry dataset from https://www.gebco.net/).

Table 2. DEMERSTEM, Mauritanian Cruise. Main zooplankton (copepods) associations identified by cluster analysis (R-mode clustering based on Helligher distance between 57 copepod taxa, not shown) In bold are indicated taxa associations identified by clustering, which were confirmed by the Indval Index approach as characteristic of the group (i.e. Indval >25%, Legendre & Dufrene, 1997).

GROUP Red	GROUP Blue
Neocalanus gracilis	***Centropages chierchiae***
Acartia danae; *A. plumosa*	***Oithona plumifera; O. nana***
Rhincalanus cornutus	***Subeucalanus monachus***
Calocalanus styliremis	***Oncaea frosti***
Clausocalanus jobei	***Onychocorycaeus giesbrechti***
Centropages typicus; C. furcatus	
***Pleuromamma abdominalis; Pleuromamma* spp**.; *P. borealis*	GROUP Green
Paracalanus denudatus	***Oithona similis***
Heterorabdus papilliger	***Calanoides carinatus***
Lucicutia flavicornis	***Clausocalanus furcatus***
Oithona plumifera	***Temora turbinata, T. stylifera***
Temora stylifera	***Paracalanus indicus***
Subeucalanus pileatus; S. monachus	***Oncaea frosti***
Nannocalanus minor	***Centropages chierchiae***
Calanoides natalis	*Microsetella rosea*
Ditrichocorycaeus africanus	***Subeucalanus pileatus***
Onychocorycaeus giesbrechti	
Parvocalanus scotti	
Pseudodiaptomus serricaudatus	
Sapphirina nigromaculata	
Euterpina acutifrons	

Hydrozoan jellyfish (i.e. small-medium size gelatinous carnivorous) were mainly found offshore, in the north Mauritania (stns. 8, 9, 14), off Cap Timiris (stns. 28, 38) and on the continental shelf (st. 70) in south Mauritania. In these areas high quantities of big schyphozoan medusae were also caught by fish trawls, with remarkable swarms recorded in the south, off the river Senegal (Fig.8).

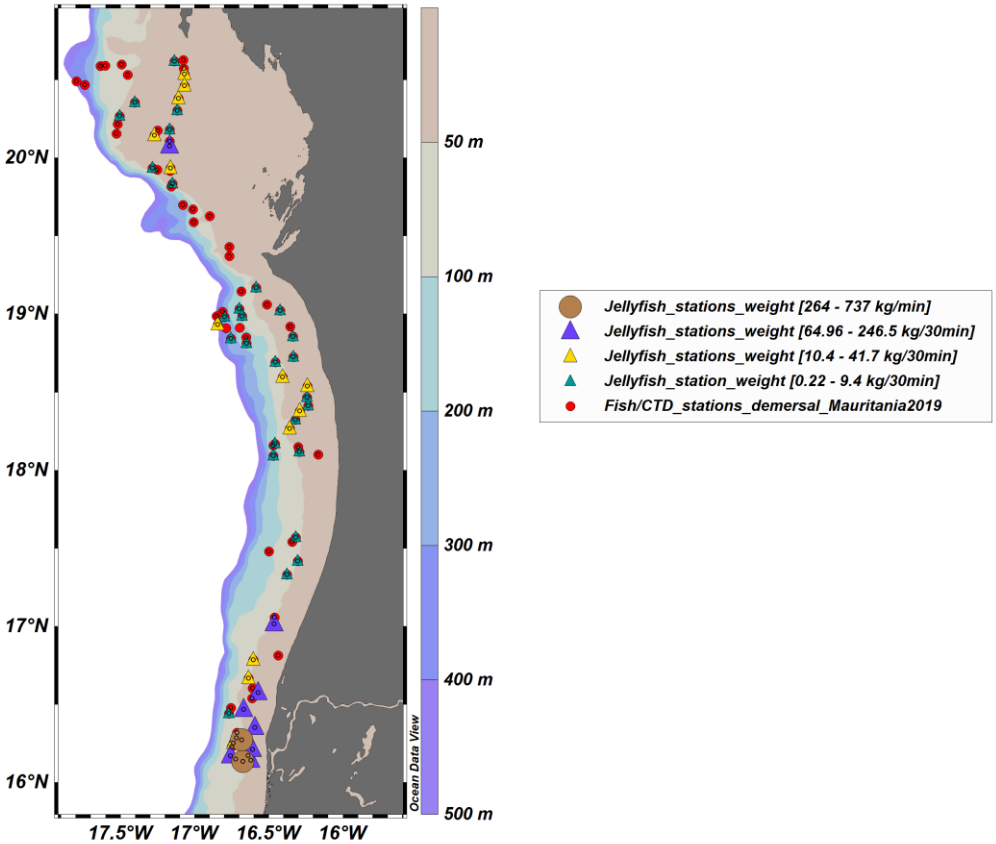

Figure 8. DEMERSTEM, Mauritanian Cruise. Records of schyphozoan jellyfish collected by fish trawl between 26 October and 5 November 2019 at demersal sampling stations. Please note, red dots indicate stations in which no jellyfish were found.

<u>Guinea Case Study</u>

In Guinea phytoplankton and mesozooplankton data were collected between18 and 28 June 2019 at 16 stations located between 09°LatN and 11°LatN (Fig.9). In each station, surface and bottom temperatures were measured, while monthly records of sea surface temperature and chlorophyll *a*/fluorescence from satellite were also considered, as weekly records were not available due to cloud covering.

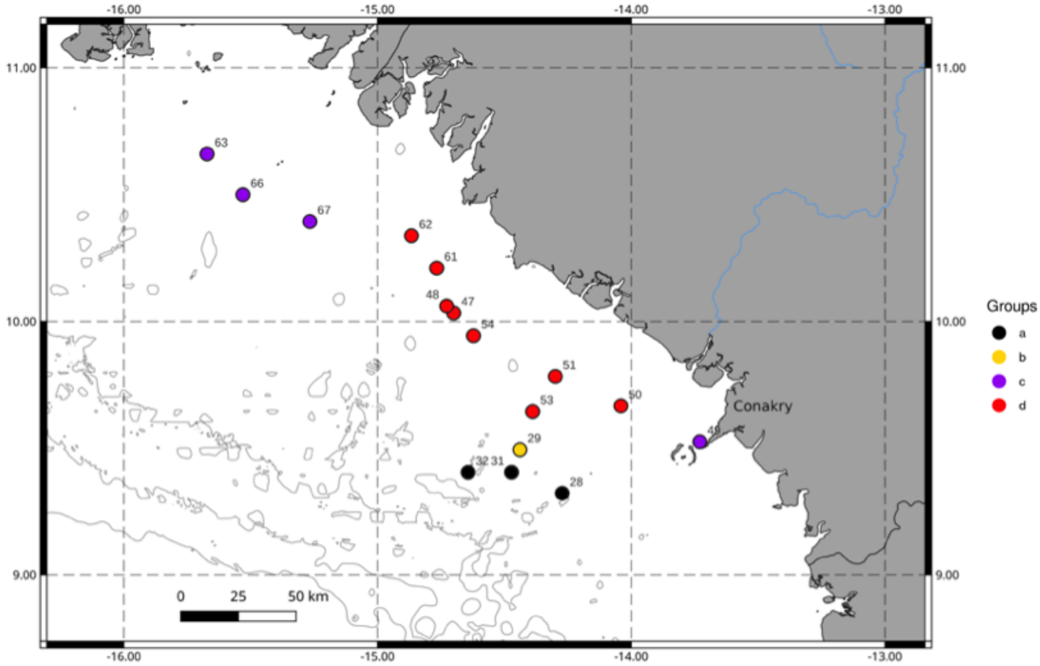

Figure 9. DEMERSTEM Guinean Cruise. Circles indicate stations in which data of temperature, phyto-, and zooplankton were collected between 18 and 28 June 2019. In the same sites monthly chlorophyll *a* concentrations were also obtained from satellite (NASA/JPL.,2020b; NASA Ocean Biology Processing Group., 2022). Colours indicate stations with similar environmental features, as identified by cluster analysis on environmental data (Q-mode analysis based on Euclidean distance, not shown). Isobaths at 25 and 200m depths are also shown (bathymetry dataset from https://www.gebco.net/).

During the cruise, stations located in the northernmost region and offshore Conakry were characterised by warmer temperatures and high chlorophyll *a* concentration (see stations of group “c” in Figs. 9-11).

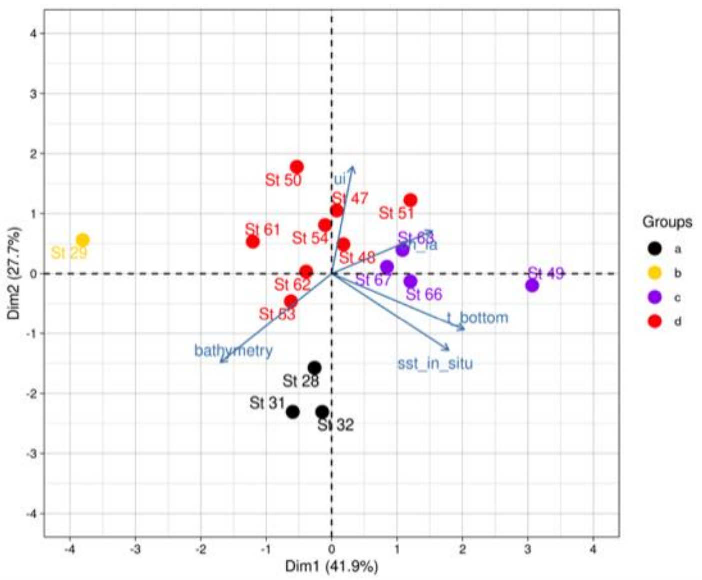

Figure 10. DEMERSTEM Guinean Cruise. Ordination of stations obtained by Principal Component Analysis (PCA) based on environmental factors such as sea surface temperature (sst_in_situ), bottom temperature (t_bottom), chlorophyll *a* (CHLa) and bathymetry. For explanation on groups of stations, see legend of Fig.9.

In spring the phytoplankton community was dominated by different species of diatoms. In the most productive areas (Fig.11) the community was highly diversified, encompassing a number of centric diatom species and numerous not abundant species of dinoflagellates (see group "green" in Fig. 12 and Tab.3). Benthic diatom species were also frequently observed in very shallow waters. On the continental shelf, cyanobacteria (e.g. *Merismopedia* sp.) were also found (see group "blue" in Fig. 12 and Tab.3), while offshore stations were characterized by different species of *Proboscia* and *Rhizosolenia*, together with potentially harmful species of the diatom genus *Pseudo-nitzchia* (see group "red" in Fig. 12 and Tab.3).

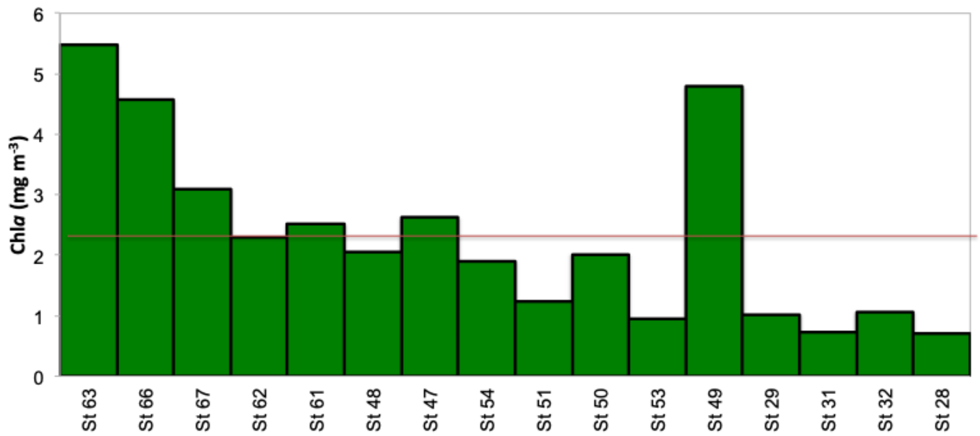

Figure 11. DEMERSTEM Guinean Cruise. Surface Chlorophyll *a* concentration (monthly average, mg m^{-3}) in each station from satellite (NASA Ocean Biology Processing Group., 2022). Red line indicates overall average.

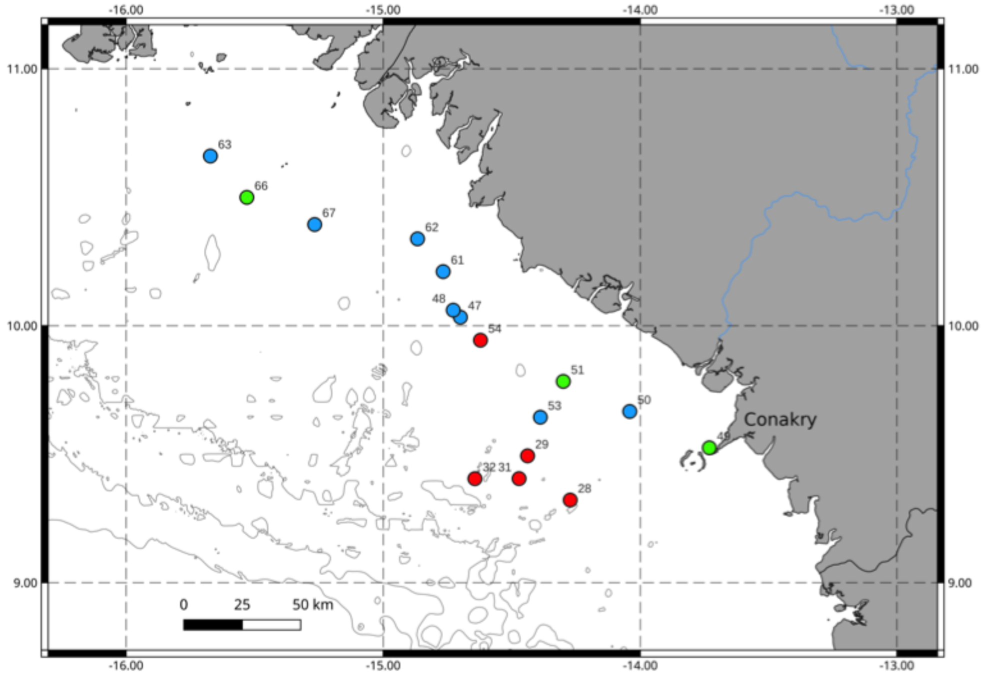

Figure 12. DEMERSTEM, Guinean Cruise. Colours indicate stations with similar phytoplankton community, as identified by cluster analysis on phytoplankton data (Q-mode analysis based on Hellingher distance, Fig.Suppl.3). Isobaths at 25 and 200m depths are also shown (bathymetry dataset from https://www.gebco.net/).

Table 3. DEMERSTEM, Guinean Cruise. Main phytoplankton associations identified by cluster analysis (R-mode clustering based on Hellingher distance between 77 phytoplankton taxa/groups, not shown). In bold are indicated taxa associations identified by clustering, which were confirmed by the Indval Index approach as characteristic of the group (i.e. Indval >25%, Legendre & Dufrene, 1997).

GROUP *Red*	GROUP *Green*	GROUP *Blue*
Leptocylindrus danicus; *L. convexus*	***Podolampas palmipes***	***Meuniera membranacea***
Ornithocercus thumii	***Tripos furca;*** *Tripos axialis; T. declinatus f. normalis; T. euarcuatum; T. falcatiforme*	***Pseudosolenia calcar-avis***
Climacodinium **sp.**	**Centric Diatoms>10 µm; C.D.30-50 µm; C.D.>50 µm**	***Hemiaulus membranaceus***
Cylindrotheca closterium	***Azpetia/Actinocyclus*** **(25-40 um)**	*Dactyliosolen fragilissimus; D. phuketensis*
Pseudo-nitzchia seriata **group;** ***P. pseudodelicatissima***	***Trieres chinensis;*** *T. mobiliensis*	***Thalassiosira*** **spp.**
Octactis octonaria **var.** ***pulchra***	***Paralia sulcata***	***Merismopedia*** **sp.**
Chaetoceros compressus/contortus; C. peruvianus; C. curvisetus; ***Chaetoceros*** **spp.**	*Pleurosigma spp.*	***Chaetoceros brevis***
Proboscia alata/indica	*Pyrophacus horologium*	***Thalassiosira eccentrica***
Thecate Dinoflagellates > 15 µm	***Cyclotella*** **spp.**	***Rhizosolenia cf. imbricata; R. setigera***
Rhizosolenia bergoni; R. cf. imbricata	*Gonyaulax* spp.	*Thalassionema nitzschioides*
Pronoctiluca pelagica	Pennate Diatoms >100um; **P.D. > 10 µm**	Pennate Diatoms>10 µm
Goniodoma polyedricum	***Biddulphia*** **sp.**	***Bellerochea*** **sp.**
Planktoniella sol	***Thalassionema bacillare/frauenfeldii***	***Haslea*** **sp.**
Prorocentrum compressum	***Asteromphalus*** **spp.**	*Coscinodiscus asteromphalus/radiatus*
Undetermined Calciodinelloideae	***Coscinodiscus asteromphalus/radiatus***	***Protoperidinium*** **spp.;** *P. conicum*
Oscillatoria sp.	***Rhizosolenia*** **spp.;** ***R. debyana***	***Pennate Diatoms inflessione***
Bacteriastrum spp.	***Eucampia zodiacus***	***Umbilicosphaera sibogae***
Guinardia striata	*Protoperidinium* spp.; *P. oblongum*	***Cerataulina pelagica***
Dinophysis ovum	***Dinophysis caudata***	*Proboscia alata/indica*
	Guinardia flaccida	*Haslea wawrickae*
	Haslea wawrickae	*Scrippsiella* spp.
	Oscillatoria **sp.**	*Ebria tripartita*
	Hemidiscus sp.	
	Melosira sp.	
	Palmerina hardmaniana	
	Goniodoma spp.	
	Prorocentrum cordatum; ***P. gracile;*** *P. micans*	
	Dinophysis spp.	
	Thecate Dinoflagellates <15 µm; T. D.>15 µm	
	Neocalyptrella robusta	

Zooplankton was more abundant in the central Guinean region (stations 61 and 54, Fig.13 and Fig.14), even though relatively high zooplankton densities were also recorded at some offshore stations in north and south Guinea (stations 66 and 28, Fig.13 and Fig.14).

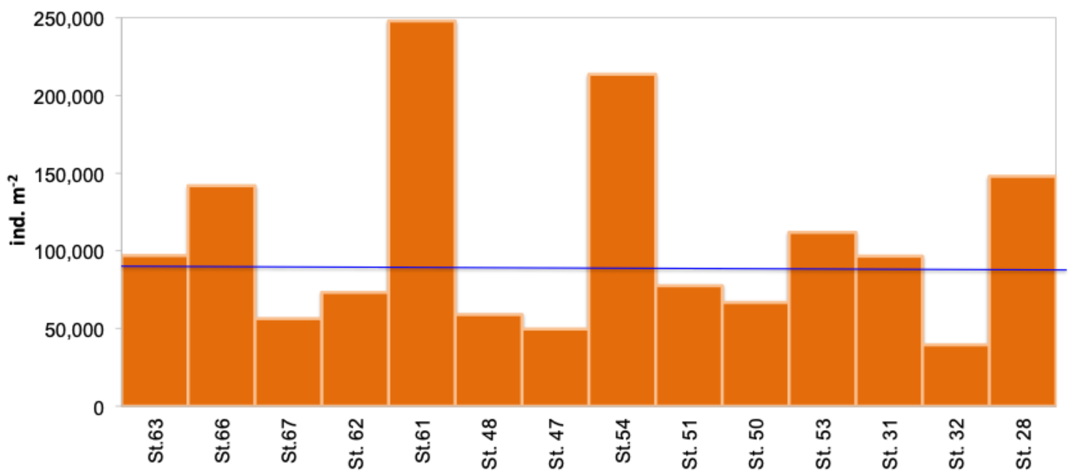

Figure 13. DEMERSTEM Guinean Cruise. Integrated (0-200m depth or 0m-bottom depth in shallow stations) abundance of zooplankton in each sampled station (ind. m^{-2}). Blue line indicates overall average.

The mesozooplankton community was dominated by crustaceans, mainly copepods but also cladocerans, which were particularly abundant in central Guinea (see “blue” stations in Fig. 13 and Fig. Suppl.4). Gelatinous filter-feeders (appendicularians and thaliaceans) were present across the whole region and were particularly abundant offshore (Fig. Suppl.4).

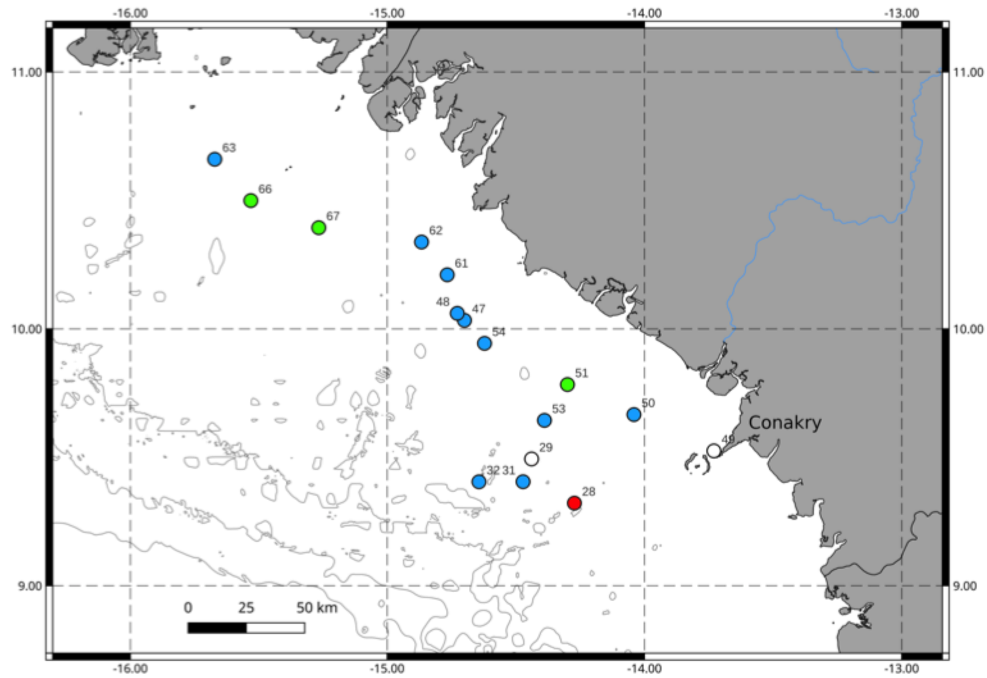

Figure 14. DEMERSTEM, Guinean Cruise. Colours indicate stations with similar zooplankton (copepods) communities, as identified by cluster analysis on zooplankton data (Q-mode analysis based on Hellingher distance, Fig.Suppl.4). Stations indicated by white circles were not included in the analysis, due to poor preservations of the samples that might have biased the counts. Isobaths at 25 and 200m depths are also shown (bathymetry dataset from https://www.gebco.net/).

In spring the copepod community in Guinea was generally dominated by small-size species characterised by different feeding strategies, including herbivorous such as *Paracalanus* spp., carnivorous such as *Onychocorycaeus giesbrechti* and *Ditrichocorycaeus africanus* and detritivorous such as *Oncaea* spp. (Tab.4).

Table 4. DEMERSTEM, Guinean Cruise. Main zooplankton (copepods) associations identified by cluster analysis (R-mode cluster based on Hellingher distance between 57copepod taxa, not shown) In bold are indicated taxa associations identified by clustering, which were confirmed by the Indval Index approach as characteristic of the group (i.e. Indval >25%, Legendre & Dufrene, 1997).

GROUP Red	GROUP Green
Paracalanus indicus; P. quasimodo	***Acartia plumosa; A. longiremis***
Clausocalanus furcatus	***Oithona nana***
Temora turbinata	***Parvocalanus scotti***
Oithona plumifera	***Euterpina acutifrons***
Pseudodiaptomus serricaudatus	*Centropages chierchiae;* ***C. furcatus***
Onychocorycaeus giesbrechti	***Ditrichocorycaeus africanus***
Oncaea frosti	***Temora stylifera***
Centropages furcatus	*Eucalanus spp.*
	Microsetella rosea
GROUP Blue	*Candacia* spp.
Subeucalanus pileatus; *S. monachus*	***Paracalanus indicus***
Paracalanus parvus	
Ditrichocorycaeus africanus	
Temora stylifera	
Sapphirina nigromaculata	
Corycaeus speciosus	
Centropages furcatus	

Hydrozoan jellyfish were found across the whole Guinean region, with peaks in stations 63, 66, 62, 61, 54, 53, 32 and 28. High quantities of big schyphozoan medusae were caught by fish trawls in coastal waters off Conakry, around stations 50 and 51.

Methods-Numerical analyses

Stations with similar environmental features were identified by hierarchical clustering (Q-mode analysis based on Euclidean distance and complete linkage) and Principal Components Analysis (PCA) on abiotic environmental data (e.g. bathymetry, temperature, salinity etc).
Stations characterised by similar phytoplankton and zooplankton associations were instead obtained by hierarchical clustering (Q-mode analysis based on Hellingher distance and complete linkage) applied to phytoplankton and zooplankton abundance.
Plankton associations were further confirmed by a complementary numerical approach, based on the Indval index method (Dufrene and Legendre, 1997). An Indval index was calculated for each phytoplankton and zooplankton taxon in each group of stations previously obtained by clustering on plankton data. The index is calculated multiplying two independent indices that measure the abundance (specificity, Aij) and recurrence (fidelity, Bij) of a species within a specific group of stations, as compared to the other groups. Values of Indval ≥25% were considered to select most characteristic species of a cluster of stations.

List of References and datasets

Dufrêne, M., & Legendre, P. (1997). Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological monographs*, *67*(3), 345-366.

NASA/JPL. (2020)a. MODIS Aqua Level 3 SST Thermal IR 8 Day 4km Nighttime V2019.0 [dataset]. NASA Physical Oceanography Distributed Active Archive Center. https://doi.org/10.5067/MODSA-8D4N9

NASA/JPL. (2020)b. MODIS Aqua Level 3 SST Thermal IR Monthly 4km Nighttime V2019.0 [dataset]. NASA Physical Oceanography Distributed Active Archive Center. https://doi.org/10.5067/MODSA-MO4N9

NASA Ocean Biology Processing Group. (2022). Aqua MODIS Level 3 Mapped Chlorophyll Data, Version R2022.0 [dataset]. NASA Ocean Biology Distributed Active Archive Center. https://doi.org/10.5067/AQUA/MODIS/L3M/CHL/2022

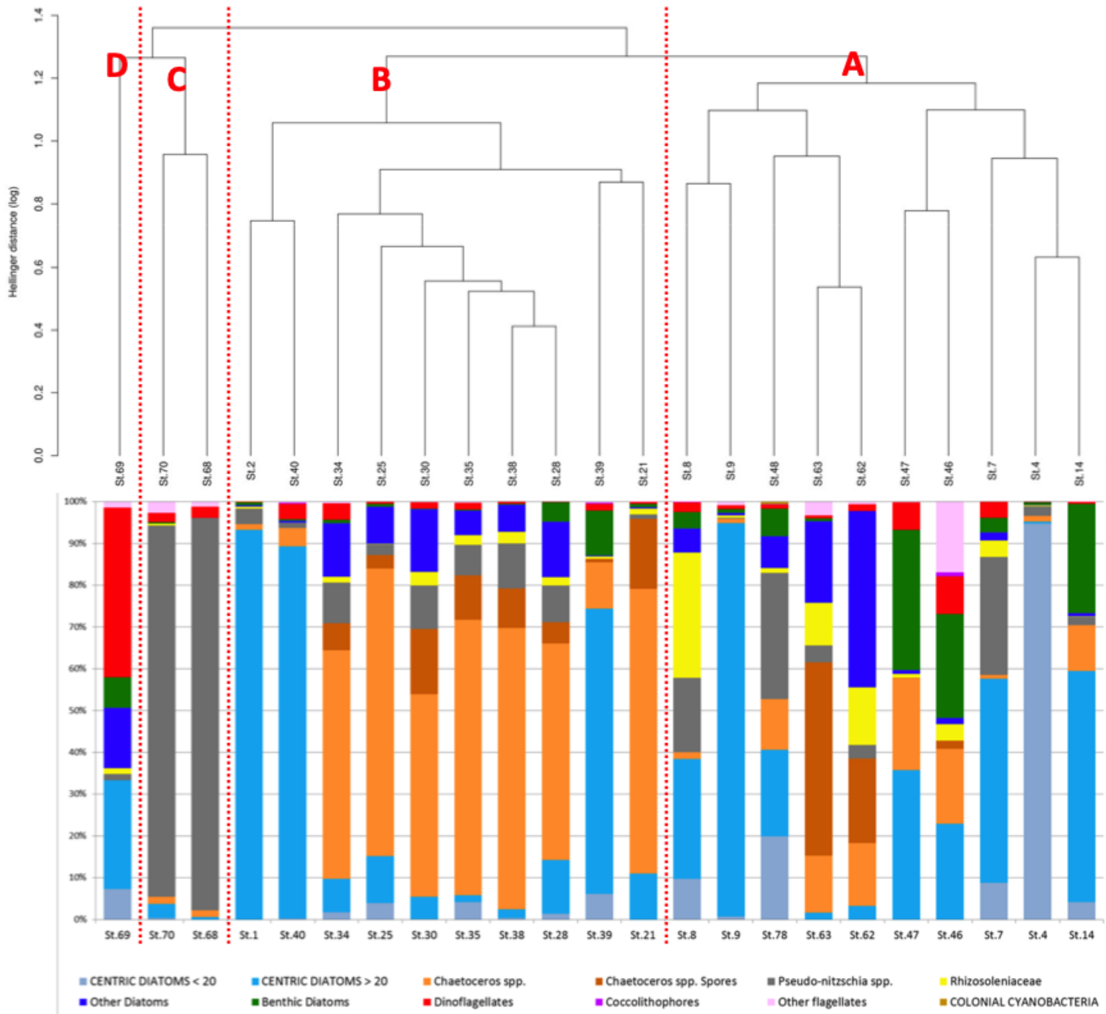

Figure Supplementary 1. DEMERSTEM Mauritanian Cruise. Upper panel shows ordination of stations obtained by Q-mode clustering (complete linkage on Hellingher distance between stations, based on records of 73 main phytoplankton species/taxa). Lower panel shows relative abundance (%) of main phytoplankton taxa/groups in each station.

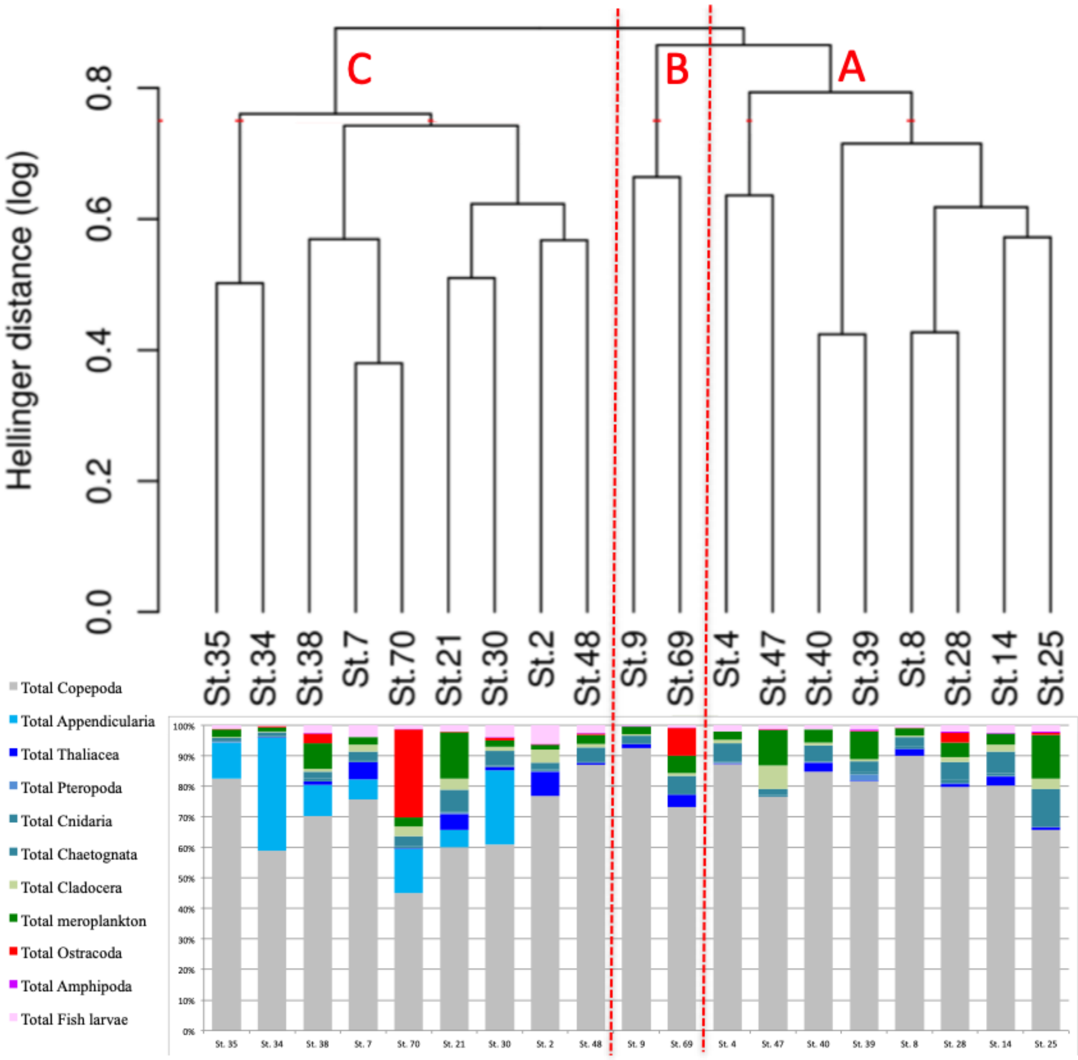

Figure Supplementary 2. DEMERSTEM Mauritanian Cruise. Upper panel shows ordination of stations obtained by Q-mode clustering (complete linkage on Hellingher distance between stations, based on records of 57 copepod species/taxa). Lower panel shows relative abundance (%) of main zooplankton groups in each station.

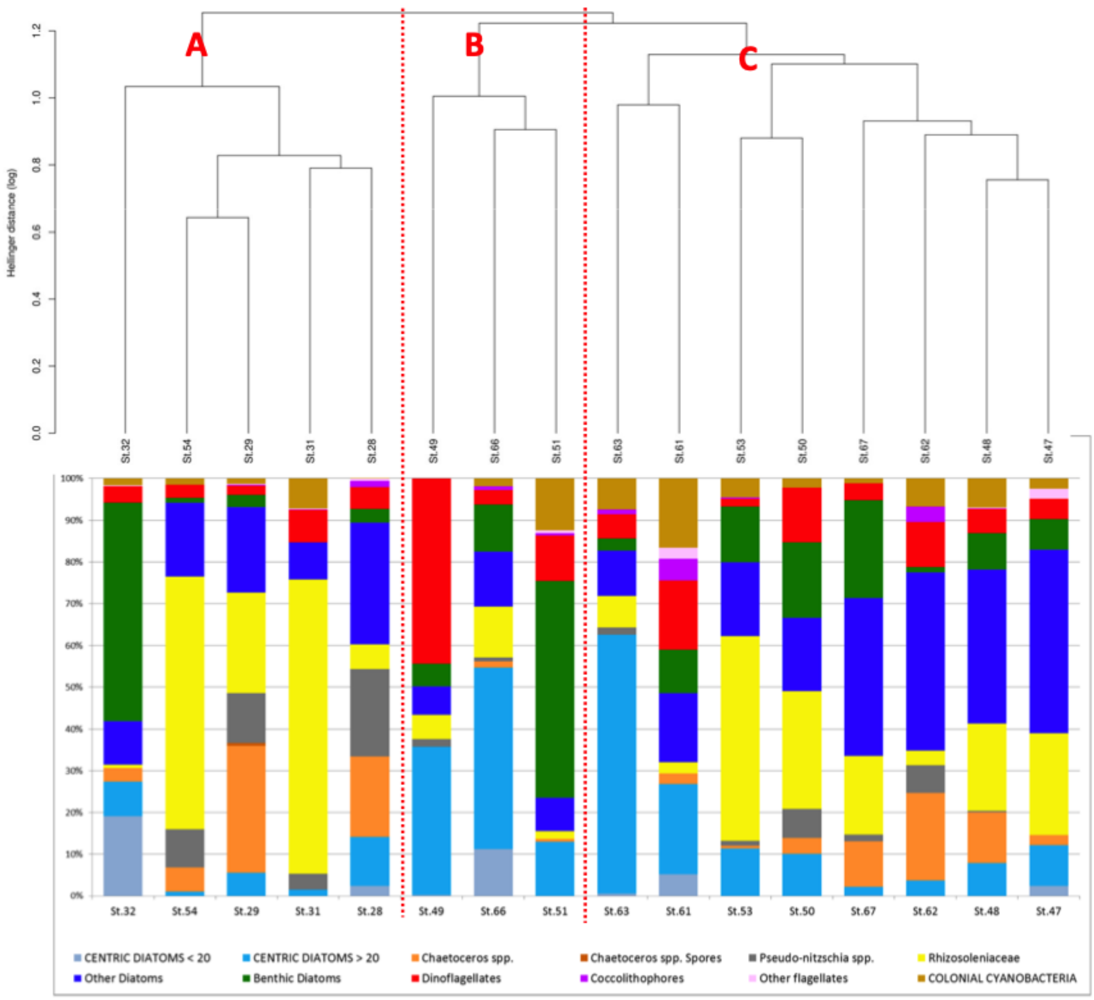

Figure Supplementary 3. DEMERSTEM Guinean Cruise. Upper panel shows ordination of stations obtained by Q-mode clustering (complete linkage on Hellingher distance between stations, based on records of 171 phytoplankton species/taxa). Lower panel shows relative abundance (%) of main phytoplankton taxa/groups in each station.

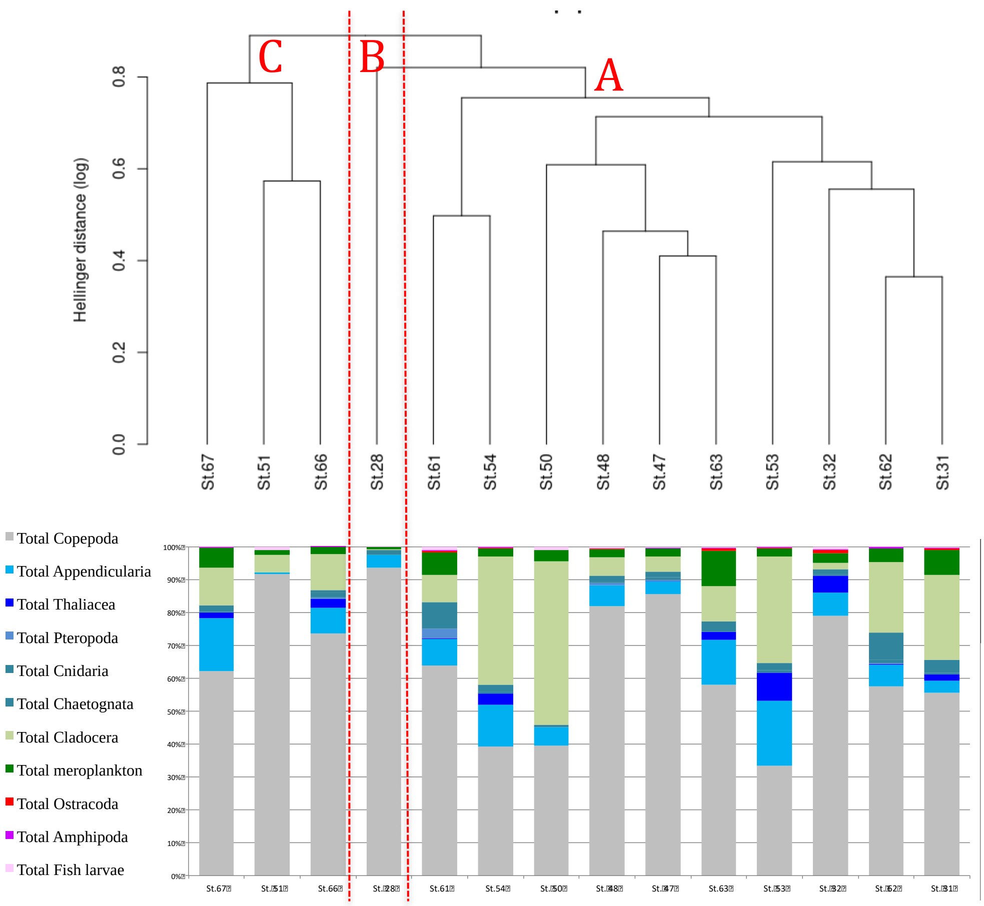

Figure Supplementary 4. DEMERSTEM Guinean Cruise. Upper panel shows ordination of stations obtained by Q-mode clustering (complete linkage on Hellingher distance between stations, based on records of 36 copepod species/taxa). Lower panel shows relative abundance (%) of main zooplankton groups in each station.