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Changes in diversity and composition of fish species in the Southern Benguela Ecosystem of Namibian

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ABSTRACT:

Species diversity and composition of fish in bottom-trawling were investigated in the Namibian waters between Oranjemund and Henties Bay. Sampling followed a systematic transects design, along latitude gradients (28 - 22°S) at different seafloor depths (100 - 500 m). In total 21 transects were sampled containing 105 stations. At each trawled station the whole catch were sorted into species type and the total body mass (kg) of each fish species was recorded. Results indicated significant differences in means of fish species diversity at different seafloor depths. The Hierarchical Cluster Analysis indicated a complex interaction of gradients which have influenced the pattern in species composition. Differences in species diversity of fish at seafloor depths might be a result of absence of disturbances by bottom-trawling at shallower depths. It was concluded that environmental variability's of the Namibian coast influence fish species composition.

Keywords:
Seafloor depths, species diversity, species composition.

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INTRODUCTION

The ocean is characterized by dynamic processes which can cause remarkable changes in distribution of fish species throughout the ocean (Gordoa *et al.,* 2006). There are clear trends of decreasing species diversity from south to north in the marine system of Namibia, contrary to global biodiversity trends (Barnard, 1998; Sakko, 1998; Van zyl, 2000). This anomalous observation might be a result of natural fluctuations in conditions of the Benguela system (Shannon, 1985).

The changing character of the Benguela ecosystem determine and influence the distribution of fish species, resulting in significant catches of non-targeted species (Gordoa *et al.,* 2006). Most surveys favour certain fish species for studies, in particular valuable commercial fish species. This has resulted in poor understanding of less commercially valuable fish species and this may result in their eventual depletion either as by-catch or indirectly through impacts on other organisms they interact with. Thus, there is need for studies to incorporate the entire catch composition of fish species for sustainable management and conservation of all fish species, regardless of their commercial status. This study places greater emphasis on understanding changes in diversity and interaction of demersal species found off the Southern Namibian coast.

MATERIALS AND METHODS

Study area

The study area is located between Oranjemund (28°S) and Henties Bay (22°S) in an area along the coastline of Namibia on the southwest coast of Africa (Fig. 1).

The study area falls within Namibia's 200 (370.4 km) nautical miles (Nm) Exclusive Economic Zone (EEZ) over which Namibia has sovereign rights to control the utilization of marine resources in a sustainable way. The darkened points in Figure 1 represent 105 sampled stations in the Namibian water.

Sampling

Sampling followed a systematic transect design, with a semi-random distribution of stations along transects, selected in such a way that each 100m seafloor depth has at least one station. The study was designed in such a way that at least three replicate transect lines were sampled along each latitudinal line (i.e. 28°S, 27°S, 26°S, 25°S, 24°S, 23°S and 22°S) between Oranjemund and Henties Bay area. In total 21 transects were sampled. Transects were about 37-46 km apart, with transect lengths of about 148km.

Collection of biotic data

Data collection was carried out during the period of 10 January – 30 February 2008 using the FV-Blue Sea research vessel. Biological data were sampled at all 105 stopover stations within the study area. Gisund Super two-panel bottom trawl net, towed behind the vessel was used for trawling. The outer lining of the cod-end mesh size was 20mm while the inner-net was 10mm. An automated GPS (Global Positioning System) on the vessel was used to record the coordinates at each trawling station and were plotted using *ArcView* GIS 3.2 software programme to indicate the trawled stations.

At each trawled station, the whole catch was brought on deck and sorted manually into species. A scale instrument was used to determine measurements of the total body mass (kg) of each fish species.

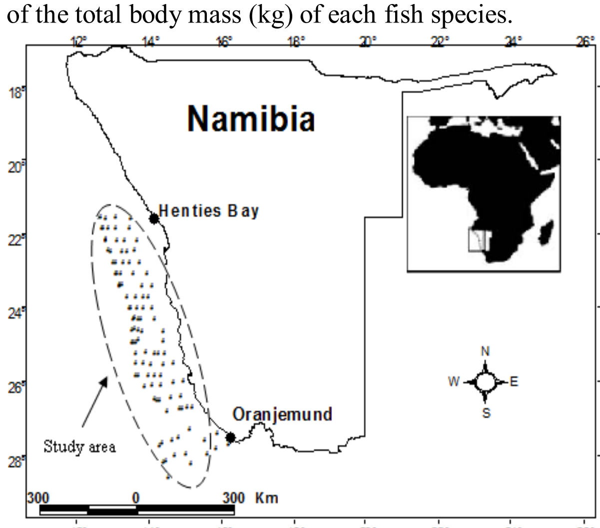

Figure 1: The study area off the Namibian coast.

Data manipulation and analysis

The statistical packages SPSS 14.0; Primer 5.0 and CANOCO 4.5 for Windows were used to analyze the data on species diversity and composition of fish. The Kolmogorov-Smirnov (K-S) test was used to test whether data for fish species diversity and composition followed a normal distribution.

The total body mass (kg) of fish species caught at each trawled station was used as surrogate for proportional abundance of fish species:

$$P_i = n_i/N$$

Where: p_i is the relative proportional abundance (kg) of fish belonging to the i^{th} species (n_i), N is the total body mass (kg) of all fish species in the trawled sample at i^{th} station (Brower and Zar, 1984).

The Shannon-Wiener diversity Index (H') was calculated for each trawled station using the proportional abundance (kg) of fish species caught by the net:

$$H' = \Sigma(pi)*(\ln\ pi)$$

Where H' is the information content of sample (value of Shannon-Wiener diversity Index); ln is the natural logarithm, while pi is the proportion of total sample belonging to ith species (Magurran, 1988).

Species diversity of fish was calculated for 100m, 200m, 300m, 400m and 500m seafloor depths along latitudinal transect lines of 28°S, 27°S, 26°S, 25°S, 24°S, 23°S and 22°S. The One-way Analysis of Variance (ANOVA) was used to test for significant differences in species diversity of fish at different seafloor depths and along different latitudinal lines. Seafloor depths and latitude lines were analysed separately. To determine which means differed, the Dunnet's post-hoc test was performed on SPSS 14.0 for Windows.

Determinants of fish species composition and interaction

The Hierarchical Cluster Analysis (HCA) using average linkage method was performed on species-transect matrix data from 105 stations and containing 91 fish species. Presence /absence data were used in the analysis. This test was carried out using Primer 5.0 for Windows to produce a classification identifying similarities and dissimilarity in species composition (Dytham, 2006).

RESULTS

Seafloor depths effects on fish species diversity

A total of 91 fish species were recorded during the study, and they comprised a range of different body sizes and lengths. There were significant differences in mean of species diversity of fish among the different seafloor depths ($F=14.02$, $df=4$, $p<0.001$). Inshore areas (100-200m seafloor depths) are less diverse than offshore areas (300m, 400m and 500m seafloor depths) (Fig. 2).

Fish species diversity at 100m and 200m was H'=0.87 whereas at 300m, 400m and 500m seafloor depths were H'=1.25, 1.36 and 1.46 respectively. Dunnett's post hoc test indicated that species diversity at 100m and 200m were significantly lower than at 300m, 400m and 500m ($p<0.05$).

Latitudinal effects on fish species diversity

Mean species diversity of fish fluctuated along a latitudinal gradient. A comparison of means in fish species diversity indicated that species diversity was relatively high at 28°S and low at 26°S latitude (Fig. 3).

Analysis of variance (ANOVA) indicated non-significant differences in means of species diversity along the latitudinal gradient ($F=1.281$, $df=6$, $p>0.05$). It is observant that the mean in species diversity around Lüderitz (26°S) was relatively lower and relatively higher around Oranjemund area (28°S).

Variations in fish species composition

The HCA dendrogram separated the fish species composition into five main distinct groups, formed at 30% similarity level (Fig. 4). The HCA revealed a classification of several fish species into similar groups with regard to seafloor depths and latitude lines.

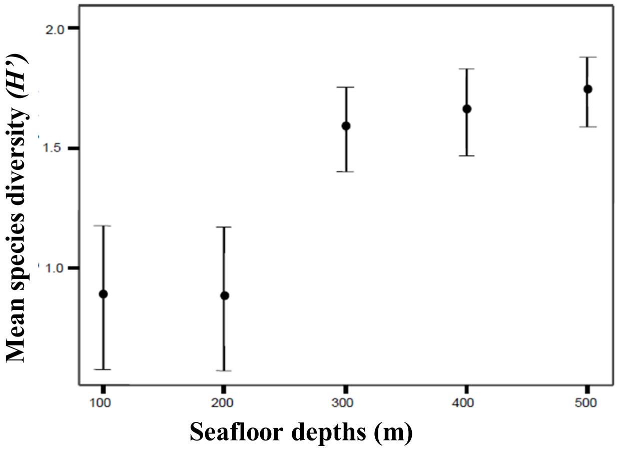

Figure 2: Comparison of mean species diversity at the seafloor depths (m). Error bars indicate 95% confidence intervals of the mean.

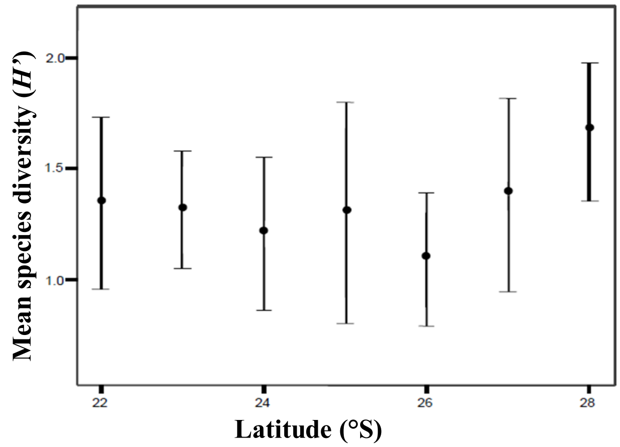

Figure 3: Comparison of mean in species diversity of fish along latitudinal gradient between Oranjemund (28°S) and Henties Bay (22°S). Error bars indicate 95% confidence intervals of the mean.

Cluster-1 was dominated by fish belonging to the family Melanostomitidae and was predominantly south at 28°S latitude, (i.e. in Oranjemund area) with an average seafloor depth of 100m. Cluster-2 was formed by species from stations found at 22°S latitude where the seafloor depth is 200m (except station 100 (S1)) and was dominated by Merluccius capensis. In Cluster-3, three sub-clusters (1, 2 and 3) can be identified. It is clear from sub-cluster-1 that stations 34, 35, 46, 47, 56 and 57 sampled at the 100m depth had a 100% similarity in fish species composition. Sub-cluster-2 was formed by species from stations at varying latitudes, at 100m and 200m seafloor depths. Sub-cluster-4 was formed by species found at 22°S latitude except for one station sampled at 28°S latitude. Cluster-3 was dominated by both Merluccius capensis and Merluccius paradoxus (Fig. 4).

Cluster-4 was formed by species from stations at 28°S latitude inshore dominated by Nezumia micronychodon. Cluster-5 was generally dominated by the Merluccius capensis in which three sub-clusters (1, 2 and 3) can be observed. The sub-cluster-1 was formed by species from stations at 23°S latitude and 300m seafloor depth. Sub-cluster-2 contains species assemblage sampled at 300m and 400m seafloor depths while sub-cluster-3 was sampled at 500m recording a 50% similarity level in species composition (Fig. 4). Sub-clusters-2 and 3 were formed by species from stations found at varying latitudes. Clusters formed by HCA dendrogram contained numerous fish species with Merluccius paradoxus commonly found in each cluster. Merluccius capensis and Merluccius paradoxus were the most frequently occurring species among clusters.

DISCUSSION

The present study investigated several patterns in fish species diversity and composition between the Oranjemund and Henties Bay area. Patterns observed might be related to environmental conditions of the Namibian coast. Significant differences in fish species diversity were observed between shallow (i.e. 100-200m) and deep seafloor depths (i.e. 300-500m). Rathod, (2011) pointed out that there is a rapid environmental change on earth and this can impact on the biodiversity. Significantly, this change can result in natural fluctuations in environmental conditions in the Benguela system. Similarly, a low diversity level at 100m and 200m depths might be accompanied by high abundance of fish species occurring (Sakko, 1998).

One important complexity in community ecology is to explain low and high diversity on the ocean seafloor, which might be associated with the level of

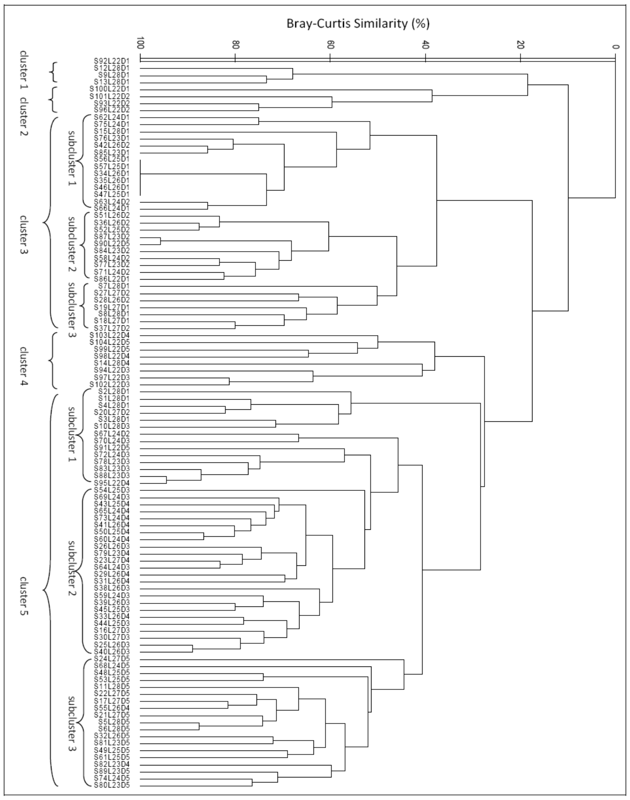

Figure 4: Hierarchical Cluster Analysis (HCA) dendrogram showing similarity of fish species composition at the seafloor depths along latitudinal gradient from Oranjemund (28ºS) to Henties Bay (22ºS) based on presence/absence of data. *Sample codes: S - station number, L – latitudinal position, D - seafloor depth.

disturbances. The Namibian marine environment is governed by several management regulations, aimed at fisheries resources sustainability (Government Gazette, 2000). Among these management options are restrictions on fishing at depths shallower than 200m which is imposed on all commercial fishing vessel operating within the Namibian water for conservation purposes and to safeguard illegal landing by mid-water trawlers (Oelofsen, 1999).

The level of disturbance would be minimal if the restrictions were to be enforced in the respective area. Ecologists point out that when disturbances are rare, the system hardly create new niches for new species colonization, whereas frequent disturbances may have detrimental impacts. Species with a low reproduction capacity may even go extinct. In-between there is an intermediate level of disturbance (an ideal called the 'intermediate disturbance hypothesis'), which maximizes biodiversity (Krebs, 1989). As a result absence of disturbances by bottom-trawling at shallower depths might be the reason for low species diversity at those localities.

It is also well-known that several fish species were restricted to several seafloor depths which might be associated with their biological adaptation. Although *Merluccius capensis* and *Merluccius paradoxus* were the most frequent fish species at all sampled stations, it is clear that greater numbers of fish species were absent at 100-200m depths contrasts to those that were entirely absent at 300-500m seafloor depths. The latter included *Chlorophthalmus atlanticus*, *Emmelichthys nitidus*, *Raja straeleni*, *Cruriraja parcomaculata*, *Callorhinchus capensis*, *Galeorhinus galeus*, *Allocyttus verrucosus* and *Zeus capensis*. This observation is related to environmental tolerance and adaptation to conditions at those depths.

In general, there is an increase in species diversity towards the equator (Sakko, 1998). In the case of Namibia, several authors have indicated that there is a clear decrease in species diversity from south to north, which seems to be influenced by instability of the Benguela system. This instability is regarded as more important than the latitudinal gradient when predicting species diversity in Namibia's marine environment (Sakko, 1998). In addition, this variation in species diversity can be linked to several ecological gradients (Binu, Chandrashekara and Rajendran, 2011).

A relative decline in mean species diversity observed around Lüderitz area might be associated with upwelling. Upwelling systems are in general more extreme in cases of unstable environments. Such systems, predictably, support a low diversity of species. At the same time they are among the most productive habitats of the world (McNaughton and Wolf, 1970). It is believed that the upwelling cells around Lüderitz are intense and perennial, which leads to anomalies in temperature, salinity and oxygen concentration. This upwelling cells provide nutrients to support high primary production, which contribute to extreme oxygen depletion in the water column (Bruchert *et al.,* 2006), and this can be the reason for a decline in diversity of fish species.

CONCLUSIONS

This study highlighted several trends in fish species diversity and composition of the Namibian coast between Oranjemund and Henties Bay area. Biodiversity (or fish diversity) within Namibian water varies with habitats (in particular with seafloor depths) and systematically increases from inshore to offshore. These trends might be associated with inherent fluctuating environmental conditions within the ocean.

In Namibian waters, commercial bottom-trawling is restricted to areas below 200m seafloor depth, thus displacement of local species are rare with no new niche being created for new fish species invasion that would increase biodiversity. This means disturbances are rare in areas below 200m and no new niches are being created to enable colonization of new species believed to increase species diversity.

The Namibian marine environment is associated with the Benguela system characterized by changes in environmental conditions. The fluctuations in environmental conditions created local trends in fish species diversity living in the Namibian waters. This trend is not in accordance with the global increase in species diversity toward the equator. Such observation indicates that global latitudinal trends in species diversity are less important in Namibian water and is rather characteristic of Benguela ecosystem having influenced this observed pattern.

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