

RESEARCH ARTICLE

The community structure of demersal fish species from bottom-trawls off Namibia and the West coast of South Africa

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Manuscript details:	ABSTRACT
<p>Received: 15.02.2017 Accepted: 24.06.2017 Published : 30.06.2017</p> <p>Editor: Dr. Arvind Chavhan</p> <p>Cite this article as: Mafwila SK (2017) The community structure of demersal fish species from bottom-trawls off Namibia and the West coast of South Africa <i>International J. of Life Sciences</i>, 5 (2): 180-188.</p> <p>Copyright: © 2017 Author (s), This is an open access article under the terms of the Creative Commons Attribution-Non-Commercial - No Derivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.</p>	<p>Changes in the structure and composition of the demersal fish assemblages are assessed using a variety of ecosystem indicators known to capture such changes, which may be induced by bottom-trawling. The aim of this study was to investigate whether there are any structural changes in demersal fish assemblages by way of latitudinal variation. The study was conducted from the Kunene River to Agulhas Bank during the 2007 demersal surveys. Abundance and biomass data was analysed using cluster analysis, non-metric multidimensional scaling, abundance biomass comparison curves, and similarity profiles in PRIMER v6 software. The dendrogram identified three main groups, two in northern Benguela, separated into shelf and slope assemblages and one in the southern Benguela, without any distinction between shelf and slope at 19% similarity. Identified assemblages are spatially distinct. The average similarities on the continental shelf in northern Benguela were driven by the following top three species: <i>M. capensis</i>, <i>Sufflogobius bibarbatus</i> and <i>Trachurus trachurus capensis</i>; on the continental slope they were driven by <i>M. paradoxus</i>, <i>Nezumia micronychodon</i> and <i>Helicolenus dactylopterus</i>; while the similarities in southern Benguela assemblages were driven by <i>M. paradoxus</i>, <i>H. dactylopterus</i> and <i>Lophius vomerinus</i>, in order of % contribution.</p> <p>Keywords: Demersal fish, bottom-trawling, community structure, assemblages</p>
	<p>INTRODUCTION</p> <p>The hake-directed bottom-trawl fishery in both Namibia and South Africa targets the shallow water Cape hake <i>Merluccius capensis</i> and the deep-water hake <i>M. paradoxus</i>. The South African hake fishery commenced in the early 1900s, after successful research catches attracted the first commercial trawler to the Cape in 1899, pioneering the South African fishing industry (Lees, 1969). The demersal fishery targeted Agulhas sole <i>Austroglossus pectoralis</i> and west coast sole <i>A. microlepis</i> (Payne and Badenhorst, 1989). However, this situation changed with the discovery of the hake resource off the west coast, which then became the targeted catch for the demersal trawl</p>

fishery (Payne and Punt, 1995), which became the most important fishery in the region. Commercially important bycatch in the bottom-trawl hake fisheries in both the Namibian and South African fisheries includes angelfish *Brama brama*, Cape dory *Zeus capensis*, gurnards *Chelidonichthys capensis* and *C. quekettii*, horse mackerel *Trachurus trachurus capensis*, jacobever *Helicolenus dactylopterus*, kingklip *Genypterus capensis* and monkfish *Lophius vomerinus* (MFMR, 2005; Walmsley *et al.*, 2007).

The two species of hake overlap in their distribution, with *M. capensis* occurring mainly on the shelf to approximately 400 m. This species is more abundant off the coast of Namibia and the south coast of South Africa. *M. paradoxus* overlaps with *M. capensis* between 150 and 400 m (Botha, 1980, Boyer and Hampton, 2001) although its range extends to 900 m (Payne and Punt, 1995). *M. paradoxus* occurs mainly south of 22°S making it more abundant along the west coast of South Africa than further north (Payne and Punt, 1995). The hake trawl fishery is the most economically valuable fishery in both Namibia and South Africa, and is managed separately in the two countries. However, Burmeister (2000) concludes that *M. paradoxus* in Namibian and South African waters is probably a single stock shared between two countries. Both fisheries in Namibia and South Africa were subjected to heavy exploitation in the mid- 1970s (Payne and Punt, 1995). Following restructuring of demersal fisheries after independence in Namibia (1990) and democracy in South Africa (1994), both fisheries are managed independently by means of TACs.

Studies off Namibia and South Africa's west coast have separated the two data sets according to the borders of the countries, due to different sampling methods and gear types. This is the first study which uses the pooled data for both Namibia and South Africa. The data were collected using the same gear and following the same sampling procedures. The aim of this study was to investigate whether there are any structural changes in demersal fish assemblages by way of latitudinal variation.

MATERIALS AND METHODS

The study was conducted in the Benguela Ecosystem from the Namibian northern border at the Kunene

River to the Agulhas Bank covering the west coast of South Africa (Fig. 1). The survey was conducted in Namibia by the MFMR scientists onboard a commercial vessel (*Blue Sea 1*), which was calibrated with the *R/V Dr Fridtjof Nansen* and on the South African side the *R/V Dr Fridtjof Nansen* was used. These surveys were conducted during January and early February by *Blue Sea 1*, and early April by *R/V Dr Fridtjof Nansen* in 2007; and followed a systematic transect design in both countries, (for full details of the sampling procedures and gears see Mafwila (2011) and Strømme (1992). A total of 289 tows were completed during the two surveys (Fig. 1).

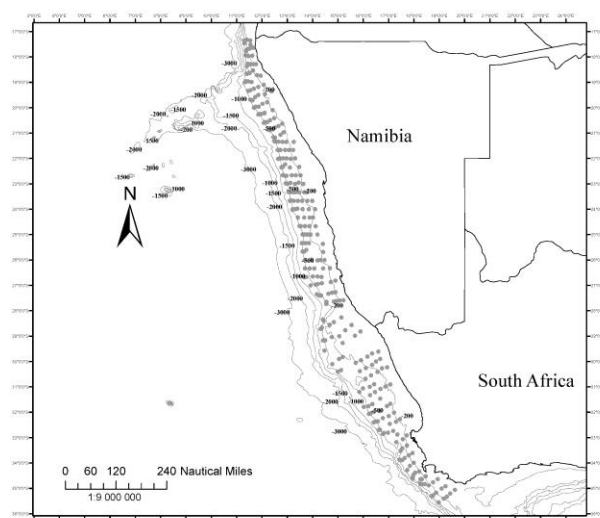


Fig. 1, Sampling stations covered during the hake biomass surveys in January/February 2007 off Namibia and early April 2007 along the west coast of South Africa.

The abundance and biomass data from all the stations were first normalised by dividing them by the number of stations covered in each survey. All fish species caught in the trawls were included in the analysis, although the emphasis is on demersal fish species.

Multivariate analysis

A cluster analysis (group average) employing the Bray-Curtis similarity index (Field *et al.*, 1982) was performed on the standardised abundance values of species using the multivariate techniques in PRIMER v6: MDS and cluster analysis (Clarke and Warwick, 1994). The data were transformed by applying a fourth-root transformation prior to the cluster analysis to avoid overemphasis of the most abundant species (Field *et al.*, 1982, Clarke and Warwick, 2001).

MDS ordination analysis was performed on the same data as the cluster analysis.

The ABC curves were constructed from the pooled abundance and biomass data averaged for both the shelf and slope. The *W*-statistic (Clarke and Warwick, 2001) was calculated for each of the treatment sites (shelf and slope). Species abundance and biomass data for all trawls (Fig. 1) were transformed by the fourth root, and then averaged across the two separate depth ranges: shelf (100 – 300 m) and slope (301 – 600 m), before being used to construct ABC curves using the PRIMER v6 software (Warwick and Clarke, 1994; Clarke and Warwick, 2001, Clarke and Gorley, 2006). The same data were pooled and weighted by the number of stations (in northern and southern Benguela separately, then combined), in order to construct ABC curves for the Benguela region.

Similarity percentage (SIMPER) was used to indicate the average contribution of each species density to the similarity (typifying species) and dissimilarity (discriminating species) between groups of samples (Clarke and Warwick, 1994, 2001). The SIMPER analysis was done on abundance data after a fourth-root transformation. The cluster group factors were chosen as A for the Namibian continental shelf, B for the Namibian continental slope, and C for South Africa

(both continental slope and shelf), as these groupings were identified by the cluster analysis and MDS. A Bray-Curtis similarity was chosen with a 90% cut for low contribution, to avoid some insignificant contributions. However, only the top ten species contributing most to the similarity and dissimilarity are shown in this study.

RESULTS AND DISCUSSION

Cluster and MDS

The group average dendrogram and MDS plots for the demersal fish assemblages of the Benguela System (off Namibia and the west coast of South Africa) are shown in Figs. 2 and 3. At about 19% of similarity, the dendrogram shows three main groups, two in northern Benguela (separated into shelf and slope assemblages) and one in the southern Benguela (Fig. 2). These identified cluster groups (assemblages) are also shown on the map and they are spatially distinct (Fig. 4). However, there is an overlap in assemblages whereby the southern Benguela assemblage extends slightly into Namibian waters. In northern Benguela, the southern Namibian shelf assemblage is different from the rest of Namibian trawl zones, but similar to the South African demersal fish assemblage in southern Benguela (Figs. 3 and 4).

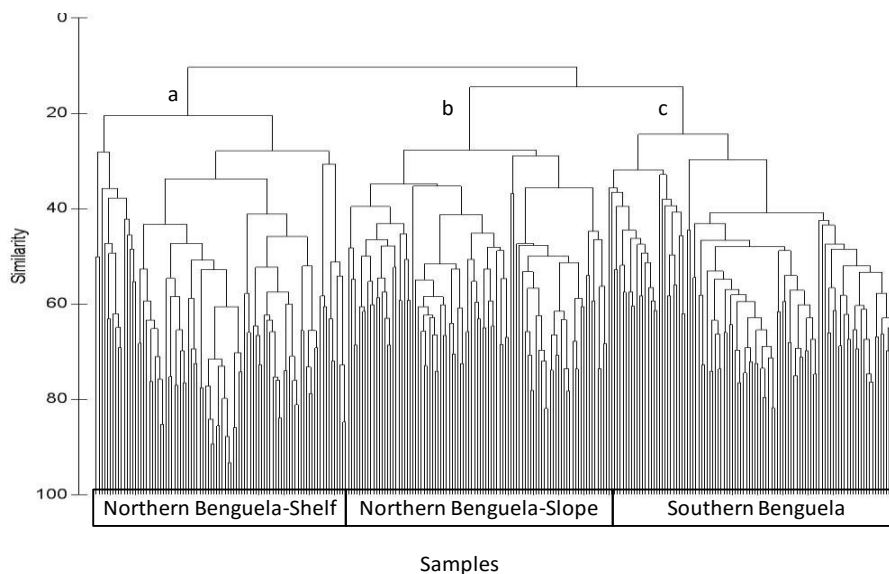


Fig. 2. Cluster dendrogram of demersal fish species per station, based on Bray-Curtis resemblance (at 19% similarity), after fourth root transformation and group-average sorting, in the Benguela System (off Namibia and the west coast of South Africa) in 2007. Station groupings are shown as a, b, and c, corresponding approximately to northern Benguela continental shelf and slope, and southern Benguela (pooled depth) respectively.

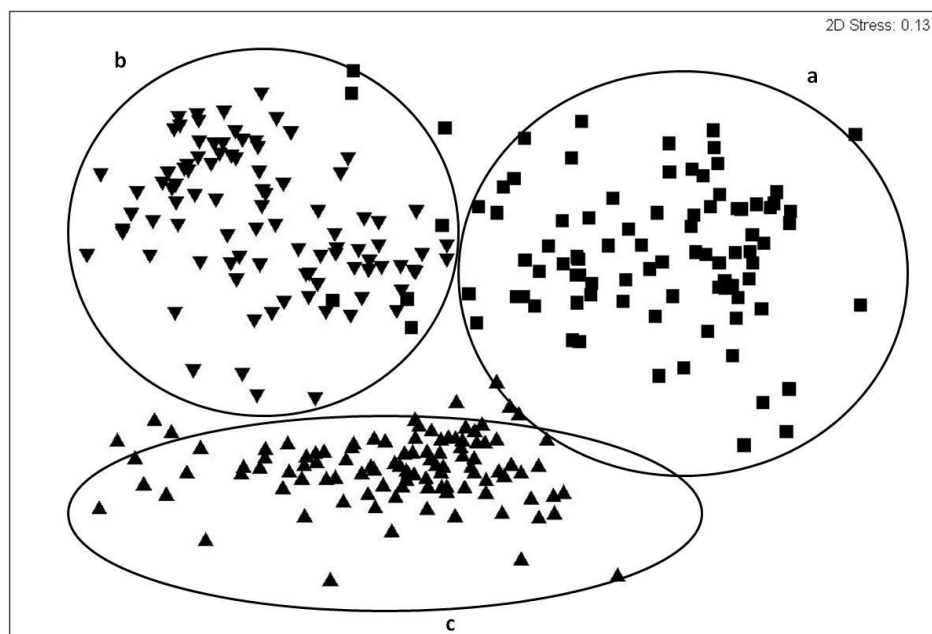


Fig. 3. The MDS plot of group averages for the demersal fish communities per station, based on Bray-Curtis resemblance after fourth root transformation, off Namibia and the west coast of South Africa, as identified by the cluster analysis. Groups are indicated at 19% similarity, shown here as (a) squares for northern Benguela slope, (b) inverted triangles for northern Benguela shelf and (c) triangles for southern Benguela.

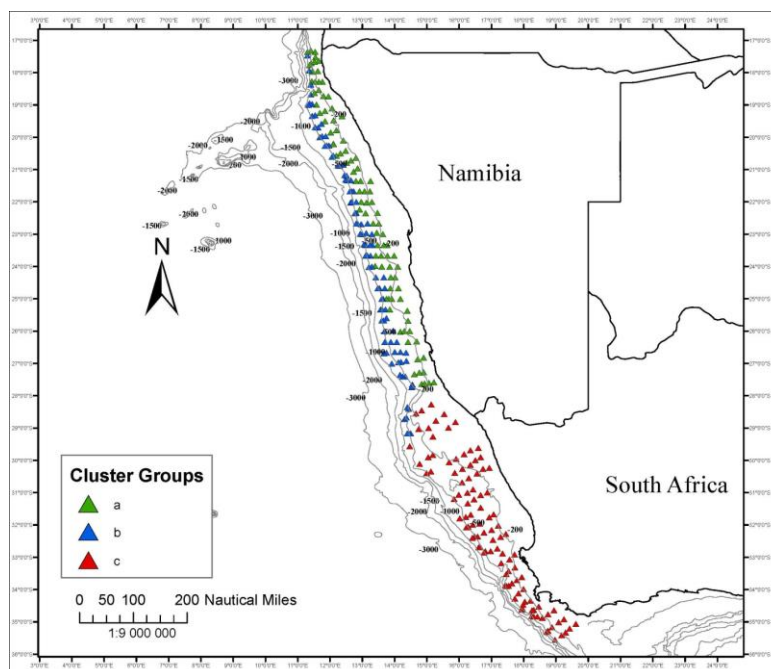


Fig. 4. Cluster groups for the demersal fish communities of the Benguela System (off Namibia and west coast of South Africa), as identified by the cluster analysis at 19% similarity, (a) northern Benguela shelf; (b) northern Benguela slope; (c) southern Benguela, based on 2007 hake biomass surveys.

Further cluster analysis of group C at 25% similarity separates the group into shelf and slope, thus making the demersal fish assemblages of southern Benguela different. Finally, ordination techniques on pre-selected groups by depth (shelf and slope) showed that the demersal fish assemblages of the continental shelf and slope in northern and southern Benguela are different from each other (Fig. 2). At 25% similarity the northern Benguela continental shelf separates into northern and southern shelf.

SIMPER Analysis

The SIMPER analysis results are shown in Tables 1 and 2. The average density similarities on the continental shelf in northern Benguela (group a) were driven by the following top three species: shallow water hake *M. capensis*, pelagic goby *Sufflogobius bibarbatus* and

horse mackerel *Trachurus trachurus capensis*; on the continental slope (group b) they were driven by deep water hake *M. paradoxus*, smalltooth grenadier *Nezumia micronechodon* and blackbelly rosefish (Jacopever) *Helicolenus dactylopterus*; while the similarities in southern Benguela assemblages (group c) were driven by *M. paradoxus*, *Helicolenus dactylopterus* and monk fish *Lophius vomerinus*, in order of % contribution (Table 1). The top three species distinguishing the cluster groups on the continental shelf and slope in northern Benguela were *M. paradoxus*, *M. capensis*, and *N. micronechodon*; the northern Benguela shelf and southern Benguela assemblages were distinguished by *M. paradoxus*, *M. capensis*, and *H. dactylopterus*; and the northern Benguela continental slope and southern Benguela assemblages by *N. micronechodon*, *M. paradoxus*, and *M. capensis* (Table 2).

Table 1: Average similarity within the cluster groups, (a) Namibian continental shelf assemblage, (b) Namibian continental slope assemblage, and (c) South African assemblage, broken into species contributions to the average Bray-Curtis similarity after 4th root transformation of abundance data. The similarity: standard deviation ratio, % contribution of each species to the group similarity, and cumulative % contribution are given. The abbreviations in the table are: Sim/SD = similarity/standard deviation; Contrib% = contribution percentage, and Cum.% = cumulative percentage. This table shows the species that hold each cluster together listed in order of their contributions to the similarity index.

Group a Average similarity: 33.74				Group b Average similarity: 37.72			
Species	Sim/SD	Contrib%	Cum.%	Species	Sim/SD	Contrib%	Cum.%
<i>Merluccius capensis</i>	1.63	45.38	45.38	<i>Merluccius paradoxus</i>	3.08	22.45	22.45
<i>Sufflogobius bibarbatus</i>	0.8	23.02	68.41	<i>Nezumia micronechodon</i>	2.3	16.47	38.92
<i>Trachurus capensis</i>	0.29	4.43	72.83	<i>Helicolenus dactylopterus</i>	0.94	7.91	46.83
<i>Astroglossus microlepis</i>	0.44	3.03	83.77	<i>Hoplostethus cadenati</i>	0.85	6.44	53.27
<i>Pterothrissus belloci</i>	0.3	2.99	86.76	<i>Selachophidium guentheri</i>	0.83	5.5	58.77
<i>Lophius vomerinus</i>	0.34	2.18	88.95	<i>Todarodes sagittatus</i>	0.72	5.19	63.96
<i>Caelorinchus simorhynchus</i>	0.32	2.01	90.96	<i>Lophius vomerinus</i>	0.64	4.57	68.53
				<i>Caelorinchus simorhynchus</i>	0.52	4.5	73.03
				<i>Trachyrincus scabrus</i>	0.4	3.08	76.11
				<i>Galeus polli</i>	0.51	2.35	78.46
Group c Average similarity: 37.76							
Species	Sim/SD	Contrib%	Cum.%				
<i>Merluccius paradoxus</i>	1.54	20.55	20.55				
<i>Helicolenus dactylopterus</i>	2.15	11.68	32.23				
<i>Lophius vomerinus</i>	1.24	7.89	40.12				
<i>Merluccius capensis</i>	0.83	7.67	47.79				
<i>Caelorinchus simorhynchus</i>	0.86	6.4	54.19				
<i>Paracallionymus costatus</i>	1.52	5.82	60.01				
<i>Todaropsis eblanae</i>	1.02	4.82	64.84				
<i>Genypterus capensis</i>	0.84	3.89	68.73				
<i>Centroscymnus crepidater</i>	0.71	3.01	71.74				
<i>Zeus capensis</i>	0.58	2.77	74.51				

Table 2: Table showing the species that best separate two clusters in order of their contribution. Average dissimilarity between cluster groups, (a) Namibian continental shelf assemblage, (b) Namibian continental slope assemblage, and (c) South African assemblage, divided into species contributions to the average dissimilarity between pairs of groups. Abbreviations: Av.Abund. = average abundance, Av.Diss. = average dissimilarity, Diss/SD = dissimilarity/standard deviation, Contrib% = contribution percentage, and Cum% = cumulative percentage. Bold numbers in the table indicate the cluster with the greater abundance of each species.

Groups a & b Average dissimilarity = 89.47							Groups a & c Average dissimilarity = 86.42						
Species	Group a Av.Abund	Group b Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%	Species	Group a Av.Abund	Group c Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Merluccius paradoxus</i>	0.21	1.99	6.43	2.29	7.18	7.18	<i>Merluccius paradoxus</i>	0.21	2.79	7.72	1.63	8.93	8.93
<i>Merluccius capensis</i>	2.22	0.35	6.41	1.68	7.17	14.35	<i>Merluccius capensis</i>	2.22	1.43	4.22	1.26	4.88	13.81
<i>Nezumia micronychodon</i>	0.09	1.56	4.99	2.19	5.58	19.93	<i>Helicolenus dactylopterus</i>	0.37	1.52	3.87	1.74	4.48	18.29
<i>Sufflogobius bibarbatatus</i>	1.1	0	3.87	1.19	4.33	24.26	<i>Sufflogobius bibarbatatus</i>	1.1	0	3.29	1.18	3.81	22.1
<i>Helicolenus dactylopterus</i>	0.37	1	3.4	1.23	3.8	28.06	<i>Caelorinchus simorhynchus</i>	0.43	1.14	2.98	1.18	3.44	25.54
<i>Hoplostethus cadonati</i>	0.06	0.95	3.04	1.17	3.4	31.46	<i>Lophius vomerinus</i>	0.43	1.17	2.83	1.4	3.28	28.82
<i>Caelorinchus simorhynchus</i>	0.43	0.82	2.98	0.94	3.33	34.79	<i>Trachurus capensis</i>	0.75	0.54	2.73	0.77	3.16	31.98
<i>Selachophidium guentheri</i>	0	0.87	2.72	1.17	3.04	37.83	<i>Paracallionymus costatus</i>	0	0.87	2.39	1.65	2.76	34.75
<i>Lophius vomerinus</i>	0.43	0.75	2.55	1.09	2.85	40.68	<i>Todaropsis eblanae</i>	0.13	0.77	2.04	1.29	2.36	37.11
<i>Todarodes sagittatus</i>	0.33	0.79	2.48	1.12	2.77	43.45	<i>Genypterus capensis</i>	0.17	0.73	2.02	1.13	2.34	39.45

Groups b & c Average dissimilarity = 81.13						
Species	Group b Av.Abund	Group c Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Nezumia micronychodon</i>	1.56	0	3.45	2.61	4.26	4.26
<i>Merluccius paradoxus</i>	1.99	2.79	3.19	1.35	3.93	8.18
<i>Merluccius capensis</i>	0.35	1.43	2.92	1.24	3.6	11.79
<i>Caelorinchus simorhynchus</i>	0.82	1.14	2.32	1.26	2.86	14.65
<i>Hoplostethus cadonati</i>	0.95	0	2.07	1.2	2.55	17.19
<i>Helicolenus dactylopterus</i>	1	1.52	1.96	1.36	2.42	19.61
<i>Lophius vomerinus</i>	0.75	1.17	1.91	1.33	2.35	21.96
<i>Paracallionymus costatus</i>	0.01	0.87	1.86	1.69	2.29	24.25
<i>Selachophidium guentheri</i>	0.87	0.07	1.81	1.18	2.23	26.49
<i>Todarodes sagittatus</i>	0.79	0.03	1.71	1.13	2.11	28.6

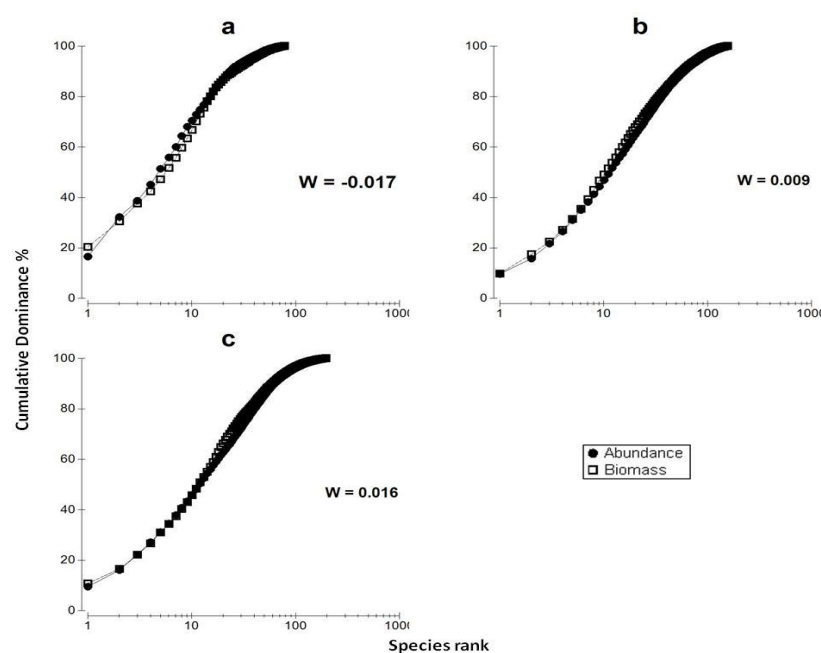


Fig. 5. ABC curves for demersal fish assemblages of northern Benguela (a) continental shelf, (b) continental slope, and (c) southern Benguela (pooled depth) based on the hake biomass survey 2007.

ABC curves and *W*-statistic

The ABC curves for the three demersal fish assemblages of the Benguela System, identified by the cluster analysis at 19% similarity are shown in Figure 5. The demersal fish assemblage on the continental shelf (a) in northern Benguela was moderately disturbed, while both the continental slope assemblages (b) in the northern and southern Benguela (c) were lightly to moderately disturbed, deduced from the fact that the abundance and biomass curves are close to each other with positive *W*-statistic value close to zero (Fig. 5) (see Mafwila, 2011; Warwick and Clarke, 1994).

Cluster and MDS analyses on demersal fish abundance data suggest that there are three major demersal fish assemblages, indicating that the southern Benguela (off the west coast of South Africa) assemblage was different from those of northern Benguela (off Namibia), where two separate assemblages emerged for the continental shelf (100 – 300 m) and slope (300 – 600 m) (Figs. 2 and 3). Thus, the demersal fish assemblages of the two sub-systems appear to differ. Clearly, the separation of the continental shelf and slope assemblages in the northern Benguela corresponds well to the distributional range of the two species of Cape hake. There was no separation between demersal fish species of the continental slope and shelf in southern Benguela, which therefore emerged as one assemblage in the cluster analysis and the MDS at 19% similarity (Fig. 4). The former coincides with the findings in Mafwila (2011), where the continental shelf and slope assemblages of the northern Benguela were clearly shown to be different. Bianchi *et al.* (2001) writing on the dynamics of the demersal fish assemblages off Namibia found a similar pattern.

The demersal fish assemblage of the continental shelf in northern Benguela showed some signs of moderate disturbance (Fig. 5), which could be attributed to fishing (Mafwila, 2011), and low dissolved oxygen distribution especially in the northern and central shelf (Mafwila, 2011). The oxygen-poor waters may have affected the distribution of other demersal fish based on their tolerance levels to low dissolved oxygen. Should this be the case for all other fish species in northern Benguela, then dissolved oxygen concentration could be playing a vital role apart from other environmental factors. Nonetheless, there was

no major adverse environmental variability (e.g. Benguela Niño) reported during 2006 or early 2007, which could have influenced the community structure. However, there was moderate disturbance reflected by the fish assemblages of the continental slope off Namibia and South Africa. Most of the commercial trawling was concentrated in the depth range 200 – 399 m, which could skew the effort distribution. This similar pattern of disturbance was found when considering 17 years of hake biomass survey data using the ABC method to detect change in the community structure of the demersal fish assemblages off Namibia. The results of the ABC method and the corresponding *W*-statistic should be carefully interpreted, since the method has only recently been applied to fisheries. Therefore, it may be tempting to over-interpret results. The upper continental slope is mostly trawled by commercial trawlers for hake, thus it was expected to reflect heavy disturbance, as shown in the bottom-trawl intensity (Mafwila, 2011).

The cluster analysis has shown three main groups, and within each group ABC analyses have suggested moderate disturbance ($W > 0$ but close to zero), according to the classification by Warwick and Clarke (1994). However, this is a broad scale assessment, and localised effects of fishing could be concealed at this large scale. Long term spatial and temporal observations of the *W*-statistic off the coast of Namibia have shown that within sub-regions in some years there are detectable signs of disturbance by fishing and other factors (e.g. environmental) (Mafwila, 2011). Interestingly, the cluster and MDS separation between the demersal fish assemblages in southern Benguela and those of northern Benguela extends slightly into southern Namibia (Fig. 4). This is thought unlikely to be an artefact of vessel effect. This could be due to the difference in hydrographic conditions leading to the separation between northern and southern Benguela. South of Lüderitz, a change in upwelling source water to a less saline and more oxygenated source from the Cape basin has been reported, though the major barrier layer is the surface on the narrow continental shelf region (Lett *et al.*, 2007). This supports the widely accepted idea that the Benguela system off Namibia and South Africa can be subdivided into the northern Benguela and southern Benguela (Shannon, 1985; Shannon and Field, 1985; and re-emphasised in Hutchings *et al.*, 2010 and the references therein), with the boundary near Lüderitz in Namibia.

Another feature of this area is the Orange River cone; the continental shelf in this area extends offshore then it narrows on both the northern and southern parts. These two zones are distinct from one another due to differences in oceanographic conditions marking the pelagic boundary, especially for small pelagic fish such as anchovy and sardine (Andrews and Hutchings, 1980; Nelson and Hutchings, 1983; Shannon, 1985; Chapman and Shannon, 1985; Shannon and Pillar, 1986; Crawford *et al.*, 1987; Shannon and Nelson, 1996; Hill *et al.*, 1998; Field and Shillington, 2004; Mackas *et al.*, 2006; Shannon *et al.*, 2006; Shillington *et al.*, 2006; and van der Lingen *et al.*, 2006). However, this is unlikely to apply to demersal fish that are found much deeper than the marine pelagic boundary, which only affects the epipelagic zones (Hutchings *et al.*, 2009). Nevertheless, findings of this study point to the fact there are signs of latitudinal differences in terms of the demersal fish community structure along the coast of Namibia and the west coast of South Africa, which cannot be linked to the different types of vessels used. However, there was some overlap between the demersal fish assemblages in northern and southern Benguela as identified by the cluster analysis and MDS. This shows that despite the data being collected by different vessels, they were comparable, and further carefully co-ordinated and inter-calibrated surveys would be helpful in terms of management of the hake fisheries of the Benguela System. Ecosystem conservation and management starts and stops at an international border, which does not correlate with ecosystem boundaries.

CONCLUSION

Although, this study was based on only on a once-off survey data, (2007), it sheds some light in terms of the community structure of demersal fish assemblages of the Benguela System with its sub-systems, northern and southern Benguela (off Namibia and South Africa respectively). The dominance of two demersal assemblages off Namibia by *M. capensis* on the shelf and *M. paradoxus* on the slope is consistent with their main distribution patterns in shallow and deep waters. The paper revealed the boundaries of the northern and southern Benguela, which depicted by the fish assemblages suggesting that the demersal fish assemblages are spatially distinct. This is also a contribution towards management of the trans-boundary resources, and, through the focus on

communities rather than target and bycatch species only, a step towards the realization of an ecosystem approach to fisheries.

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