Size Spectra Analysis of Demersal Fish Communities in Northwest Africa

— Article —

Analyse des spectres de taille des communautés de poissons démersaux en Afrique du Nord-Ouest

— Article —

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ABSTRACT

THE present study is a contribution to ongoing research on size spectra analysis in a tropical setting, taking advantage of numerous surveys that have been undertaken in the Northwest African region. Data on numbers and weights of fish caught during trawl surveys, available for Cape Verde, Gambia, Guinea, Guinea-Bissau and Senegal, were compiled and standardised in order to construct size spectra slopes and intercepts. The isometric growth model ($W=0.01xL^3$) was used to construct the size spectra and these were tested for significant effects of factors such as area, depth, and time. Focus was placed on change over time and a trend of increasing intercept and steeper decreasing slope of the size spectra regression was observed for Cape Verde and, less clearly, for Guinea-Bissau. Longer time series were available for Guinea and SeneGambia where fishing intensity appears to have increased. Surprisingly, in these cases, there was no trend over the study period. Instead, intercepts and slopes of the size spectra regression appear to show natural variability in the size structure of demersal fish communities over time.

Key words

Size spectra — Northwest Africa — Spatial and temporal structure

RÉSUMÉ

LA PRÉSENTE étude est une contribution aux recherches en cours sur les analyses de spectres de taille dans un contexte tropical en utilisant les nombreuses campagnes d'évaluation menées dans la région nord-ouest Africaine. Les données numériques et pondérales des poissons capturés lors de campagnes d'évaluation par chalutage au Cap-Vert, en Gambie, en Guinée, en Guinée Bissau et au Sénégal ont été compilées et standardisées dans le but d'estimer les pentes et ordonnées à l'origine des spectres de taille. Le modèle de croissance isométrique ($Z=0,01xL^3$) a été utilisé pour construire les spectres de taille qui ont été testés pour des effets significatifs de facteurs tels que la zone, la profondeur et le temps. Un accent particulier a été porté sur les changements en fonction du temps et une tendance croissante des ordonnées à l'origine et décroissante des pentes a été observée sur les spectres de taille du Cap-Vert et moins clairement pour la Guinée Bissau. Des séries temporelles plus longues étaient disponibles pour la Guinée et la Sénégambie où l'intensité de pêche semble avoir augmenté mais, étonnamment, dans ces cas aucune tendance ne s'est dégagée sur la période d'étude. En revanche, la régression des ordonnées à l'origine et des pentes des spectres de taille semble montrer une variabilité naturelle dans la structure des tailles des communautés de poissons démersaux au cours du temps.

Mots clés

Spectres de taille — Afrique du Nord-Ouest
Structure spatiale et temporelle

INTRODUCTION

IN RECENT years, an intensive field of research has been to determine the effects of fishing on marine ecosystems from a global or broad perspective. Quantitative ecosystem indicators can be considered appropriate and feasible for this type of approach. Also, many of these indicators provide a comprehensive bridge between different scientific disciplines, including the ecological, environmental and fisheries perspectives, and constitute a more efficient way to communicate results for management purposes (CURY & CHRISTENSEN, 2001 [1]).

Efforts have gone into the development of these new complementary management tools, which may prove useful for improving the current state of fisheries resources. Numerous aggregate indices or ecosystem indicators have been proposed, for example those based on size structure, biomass, diversity, richness, and trophic structure (*e.g.* ICES 2002, 2001; BLANCHARD & BOUCHER, 2001; JENNINGS *et al.*, 2001; BIANCHI *et al.*, 2000; RICE, 2000; JENNINGS & KAISER, 1998; PAULY *et al.*, 1998). Current efforts are under way to develop the theory behind these indicators, considering changes in marine ecosystems (both states and processes), including the robustness and usefulness of these proposed indicators (CURY & CHRISTENSEN, 2001).

Applications of size structure analysis showed that exploitation has brought about change in size structure by decreasing numbers and biomass as well as mean size (HAEDRICH & BARNES, 1997). Other studies have added evidence in that changes in size structure may be related to fishing, observed as a steeper decreasing slope and increasing intercept of the size spectrum (BIANCHI *et al.*, 2000; GISLASON & RICE, 1998; RICE & GISLASON, 1996). Results from tropical regions are less conclusive due to the difficulty in obtaining consistent time series, but similar trends have been observed (*e.g.* BIANCHI *et al.*, 2000; GOBERT, 1994).

The present study is a collaborative effort within the context of the "Fisheries Information and Analysis System project (Siap)" covering the Northwest African region, including Cape Verde, Gambia, Guinea, Guinea-Bissau and Senegal. Numerous trawl research surveys have undertaken in the region, which makes it possible to study the size structure of demersal fish communities and the possible effects of fishing over a period from 1970 to 1998. Thus, we hope to contribute to ongoing research in this field, contributing to existing knowledge for tropical areas in particular.

1. — Information available at: www.ecosystemindicators.org

MATERIAL & METHODS

ALL data used for the analysis of size spectra were obtained from demersal surveys carried out with the objective of assessing demersal resources. Senegal and Gambia are considered one region as the surveys were carried out by the same vessels. Survey methodology varied over time, both in terms of sampling strategy and area coverage, even when considering the same vessel. This is the case for surveys undertaken in Guinea and Guinea-Bissau, in particular. For example, the R/V *Nizery* surveys in Guinea covered depths ranging from 5 to 30 m, assessing resources available to the artisanal fisheries, but in 1992 to 1994 the area was expanded to depths of 225 m, considering the industrial fisheries. Also, the objective of the Guinea-Bissau survey in 1995 was to assess shrimp resources primarily, restricting the survey area to the northern shrimp fishing grounds. Various reports are available for in-depth information on survey design, sampling methodology, and vessel/gear characteristics (*e.g.* DOMAIN & SIDIBÉ, 1998; MORIZE & DIALLO, 1997; MORIZE & DOUMBOUYA, 1997; IPIMAR & CIPA, 1996; THORSTEINSSON *et al.*, 1995; INIP & CIPA, 1993; INIP & LBM, 1992, 1990, 1989; DOMAIN, 1989; PALSSON, 1989), but an overview of the data is useful as this will explain the strategy adapted in terms of analysis (table I). The data available for the present study covers a period from 1970 to 1998, but the surveys were not carried out every year, for Cape Verde and Guinea-Bissau in particular. Also, vessel characteristics varied (table II).

TABLE I

Years for which survey data were available for the present study, considering region and the vessel used in that year

Années pour lesquelles des données de campagnes étaient disponibles pour la présente étude, en fonction de la zone et du navire utilisé l'année donnée

REGION	VESSEL	70	71	72	74	85	86	87	88	89	90	91	92	93	94	95	97	98
Cape Verde	*Fengur*																	
	Islandia																	
Guinea Bissau	*Capricórnio*																	
	Noruega																	
Guinea	*Antea*																	
	Nizery																	
SeneGambia	*L.-Sauger*																	
	L.-Amaro																	

TABLE II

Some characteristics concerning the different survey vessels

Quelques caractéristiques relatives aux différents navires de recherche

REGION	VESSEL	OVERALL LENGTH	ENGINE POWER	TRAWLER TYPE	HAUL DURATION
Cape Verde	*Fengur*	27m	565 Hp	Stern trawler	2 nm
	Islandia	22m	520 Hp	Stern trawler	2 nm
Guinea Bissau	*Capricórnio*	47m	1200 Hp	Stern trawler	30 min
	Noruega	48m	1500 Hp	Stern trawler	30 min
Guinea	*Antea*	35m	1284 Hp	Catamaran trawler	30 min
	Nizery	24m	800 Hp	Stern trawler	30 min
SenGambia	*L.-Amaro*	24m	350 Hp	Trawler/Seiner	30 min
	L.-Sauger	37m	800 Hp	Stern trawler	30 min

All surveys registered the total number and total weight caught by species and haul. Size measurements were undertaken, but often only for important commercial species. However, the two surveys undertaken in Cape Verde provided detailed information on the total number, total weight, and size measurements by haul for each species caught. Considering that size measurements were partial at best or completely lacking, the isometric growth model ($W = 0.01xL^3$) was used to construct size spectra. Average weights by species and haul were calculated, based data on total numbers and weights.

Size categories were determined to correspond to 10 cm intervals and the corresponding theoretical weight intervals were calculated from the isometric growth model (*e.g.* BIANCHI *et al.*, 2000).

Size spectra were constructed for each pre-defined factor, including Country/Region, Year, Season, Depth, and Area, in order to study the possible differences in size structure of demersal fish communities between the different levels or strata. For Guinea and SeneGambia, the areas were divided in three (north, central, and south) following the statistical divisions. Two areas were defined for Cape Verde (Boavista shelf and Sal island) and Guinea-Bissau (north and south). With regard to depth, a common division into three strata (< 40 m; 40-80 m; > 80 m) was applied to all the data. The definition of a wet and dry season was relevant only for the Guinean and SeneGambian data, where surveys attempted to cover both seasons. In the case of Cape Verde and Guinea-Bissau, surveys were undertaken once during the year, typically during the dry season.

TABLE III

Sampling intensity in number of hauls for some of the pre-defined strata and the raising factors applied. The raising factors attempt to standardise the area covered for each region, irrespective of vessel, assuming that trawl dimensions are about the same (see discussion on standardisation)

Taux d'échantillonnage en nombre de traits de chalut pour certaines strates pré-définies et facteurs d'extrapolation utilisés ; ces facteurs sont destinés à standardiser la superficie couverte pour chaque zone, sans tenir compte du navire, considérant que les dimensions du chalut sont sensiblement équivalentes (voir la discussion sur la standardisation)

REGION	VESSEL	YEAR	SURVEYS	NUMBER OF HAULS			RAISING FACTORS		
				by season		*by year*	*by season*		*by year*
				dry	*wet*		*dry*	*wet*	
Cape Verde	*Fengur*	1988	1			80			1,000
	Islandia	1994	1			61			1,311
Guinea	*Nizery*	1985	2	81	80	161	1,963	2,863	
		1986	2	90	80	170	1,767	2,863	
		1987	1		79	79		2,899	
		1988	2	88	90	178	1,807	2,544	
		1989	2		151	151		1,517	
		1990	2	25	65	90	6,360	3,523	
		1991	5	145	229	374	1,097	1,000	
		1992	3	159	114	273	1,000	2,009	
		1993	2	110	123	233	1,445	1,862	
		1994	1		43	43		5,326	
		1995	1	96		96	1,656		
	Antea	1997	2	105	95	200	1,514	2,411	
		1998	1		90	90		2,544	
Guinea-Bissau	*Noruega*	1988	1			35			4,286
		1989	1			93			1,613
		1990	1			107			1,402
		1991	1			34			4,412
	Capricórnio	1995	1			77			1,948
SeneGambia	*L.-Sauger*	1986	1		105	105		1,048	
		1987	2	115	108	223	1,000	1,019	
		1988	1	107		107	1,075		
		1989	2	113	110	223	1,018	1,000	
		1990	1	110		110	1,045		
		1991	1	104		104	1,106		
		1992	1	110		110	1,045		
	L.-Amaro	1970	9	67	83	150	1,716	1,325	
		1971	2	36		36	3,194		
		1972	2	15	16	31	7,667	6,875	
		1974	1	22		22	5,227		

The procedures adopted for the standardisation of data included the calculation of catches and numbers by half an hour, exclusion of invalid or problematic hauls, exclusion of non-fish species (ex. cephalopods, crustaceans, but including sharks), and exclusion of pelagic fish species. Furthermore, as sampling intensity varied considerably per year, an approximate way of standardising this was to consider the number of hauls in each survey. Assuming that trawl characteristics and haul duration are the same over the years in each country, the number of hauls expresses an approximate area covered. Thus, in order to compare over different years, raising factors were calculated relative to the highest number of hauls carried out in a specific country/region, considering differences between seasons in the case of Guinea and SeneGambia (table III).

Analysis of Covariance (Ancova) was applied to all size spectra by country or region, implying a regression of the abundance in numbers as the dependent variable and length (expressed as interval midpoint-mid) as the independent variable, including the effect of factors such as Year, Season, Depth, and Area The specified models take into consideration the factor Year and an interaction term Year/Length (ln.mid), corresponding to the additive terms on the intercept and slope. Stepwise regression was used to identify the best model by removing redundant predictors (factors) based on the Akaike Information Criterion (AIC) (FARADAY, 2000). The relationship between abundance and length was made approximately linear by calculating the natural logarithm of both continuous variables, abundance and length interval midpoint, and eliminating the first length interval, corresponding to fish smaller than 10 cm. This first interval was eliminated, assuming that trawl selectivity is below 100 per cent for these sizes. Also, the last length interval was defined as a sum group, including all fish larger than 160 cm. Figure 1 shows a plot of the full data set, showing the inherent variability in the data.

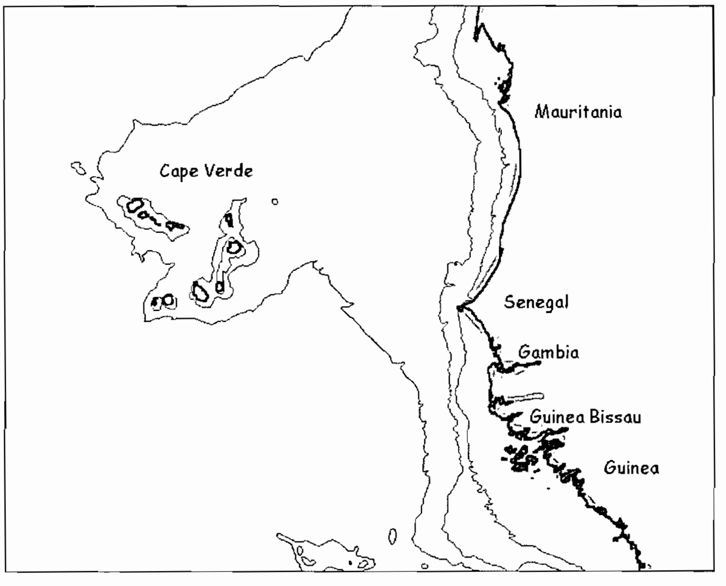

FIG. 1. — Map of the study area including the bathymetric lines corresponding to depths of 200 m, 1000 m, and 4000 m, respectively. Most trawl stations were situated in depths down to 200 m, although some hauls were undertaken in depths down to 500 m. Note the limited continental shelf in the Cape Verde Archipelago.

Carte de la région d'étude comprenant les courbes bathymétriques 200 m, 1 000 m et 4 000 m. La plupart des traits de chalut ont été effectués sur des fonds jusqu'à 200 m, même si quelques chalutages ont été pratiqués jusqu'à 500 m. À noter, dans l'archipel du Cap-Vert, l'exiguïté du plateau continental.

RESULTS

THE first step in the analysis was a validation of the isometric growth model by testing data from the two surveys undertaken in Cape Verde, in 1988 and 1994. As these two surveys provided the most detailed information, size spectra were constructed by using both the isometric growth model and the observed length measurements. The Anova test resulted in non-significant effects (F=0.644; Pr (>F)=0.42; n=168) due to the method used in constructing size spectra, whether it was based on actual length measurements or the isometric growth model for allocating individuals based on the average weight.

Table IV shows the Ancova results pertaining to Cape Verde. The significant relationship between abundance and length is seen as an intercept and slope that are significantly different from zero, which was expected. Of more interest is the fact that there was a significant Year effect, resulting in a higher intercept for 1994 regression line on size spectra (12.115+11.626). Also, the significant year/length interaction (ln.mid:year) resulted in steeper decreasing slope (-2.157-3.04) (fig. 2). The effects Depth and Area were found to be non-significant on the size structure of demersal communities (Pr > 0.05).

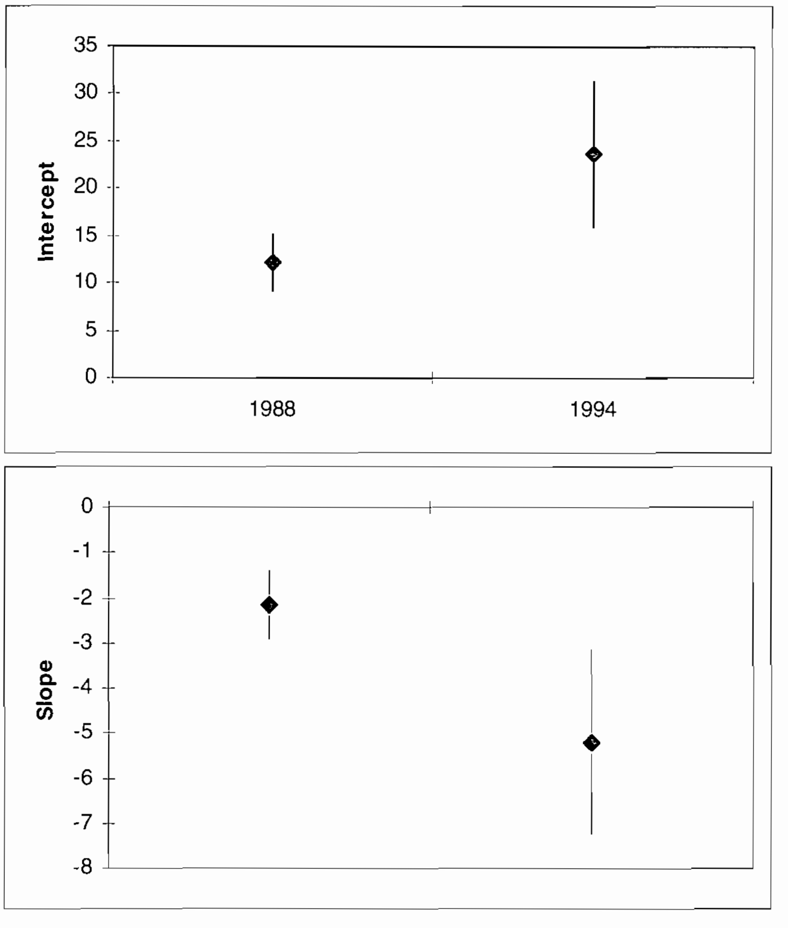

FIG. 2. — Plot of intercept and slope of the size spectra regressions over time for the Capeverdean data. Error bars represent ± 2 x standard errors.

Graphe de l'ordonnée à l'origine et de la pente des régressions sur les spectres de taille dans le temps pour les données du Cap-Vert. Les barres d'erreur représentent ± 2 x les erreurs standard.

TABLE IV

Regression coefficients of the Ancova model for Cape Verde. Area and Depth effects were disregarded, based on the AIC criterion in stepwise regression
*Significance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1*

Coefficients de régression du modèle Ancova pour le Cap-Vert. Les effets Superficie et Profondeur ont été négligés, sur la base du critère A.I.C. dans une régression pas à pas
Seuils de signification des codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

COEFFICIENTS	ESTIMATE	STD. ERROR	T VALUE	PR(>|T|)	SIGNIF. CODES
Intercept	12,1147	1,5217	7,961	2,15E-11	***
ln.mid (Slope)	-2,157	0,3888	-5,548	4,82E-07	***
year1994	11,6257	3,5389	3,285	0,00159	**
ln.mid:year1994	-3,0397	0,9487	-3,204	0,00204	**

Residual standard error: 2.314 on 70 degrees of freedom; Multiple R-Squared: 0.4972, Adjusted R-squared: 0.4757; F-statistic: 23.07 on 3 and 70 DF, p-value: 1.706e-010.

The R software [1] was used for statistical analysis. A short note on the coding of qualitative predictors (factors) may be helpful for the interpretation of the Ancova results. The default "Treatment Coding" treats level one as the standard level to which all other levels are compared. R assigns levels to a factor in an alphabetical or numerical order by default (FARADAY, 2000). For example, the year 1988 is treated as the standard level in the Capeverdean data (and therefore not included in the analysis in Table IV as it is set to zero) against which the year 1994 is compared. Similar results were obtained in relation to Guinea-Bissau (table V). However, the effects of Depth were significant, seen as a significantly higher intercept in deeper waters (> 80 m) (Pr(>|t|) = 0.01), which indicates higher abundance. figure 3 shows that there was a trend for increasing intercept and decreasing slope over time, except for 1995. A different vessel was used in 1995, but the data was included in the analysis as the trawl characteristics were the same and haul duration was standardised.

1. — Software available at www.R-project.org

TABLE V

*Regression coefficients of the Ancova model for Guinea-Bissau. Area effects were disregarded, based on the AIC criterion in stepwise regression. Significance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1*

Coefficients de régression du modèle Ancova pour la Guinée Bissau. Les effets Superficie ont été négligés, sur la base du critère A.I.C. dans une régression pas à pas.
Seuils de signification des codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

Coefficients:	ESTIMATE	STD. ERROR	T VALUE	PR(>|T|)	SIGNIF. CODES
Intercept	19,8851	1,7721	11,221	< 2e-16	***
ln.mid (Slope)	-3,9583	0,4624	-8,561	3,77E-15	***
year1989	1,8609	2,2135	0,841	0,4016	
year1990	5,5334	2,3232	2,382	0,0182	*
year1991	6,1227	2,5175	2,432	0,0159	*
year1995	0,9341	2,6777	0,349	0,7276	
depthbMedium	0,296	0,2898	1,022	0,3082	
depthcDeep	0,7577	0,2884	2,627	0,0093	**
ln.mid:year1989	-0,6008	0,57	-1,054	0,2932	
ln.mid:year1990	-1,4592	0,6064	-2,406	0,0171	*
ln.mid:year1991	-1,7415	0,6715	-2,593	0,0102	*
ln.mid:year1995	-0,4454	0,7175	-0,621	0,5355	

Residual standard error: 1.683 on 191 degrees of freedom; Multiple R-Squared: 0.7799, Adjusted R-squared: 0.7672; F-statistic: 61.52 on 11 and 191 DF, p-value: 0

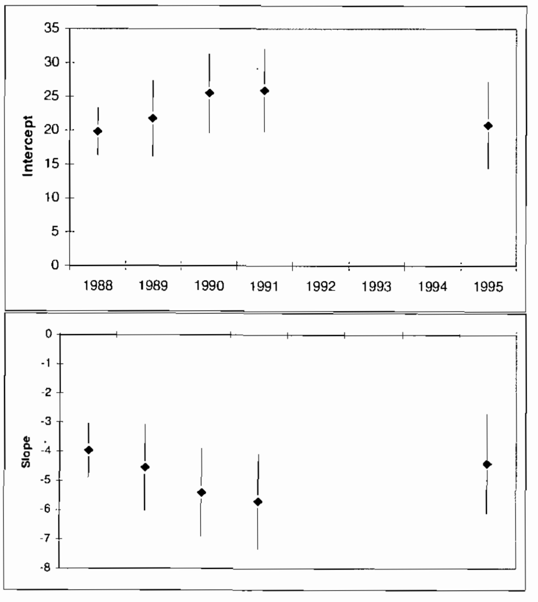

FIG. 3. — Plot of intercept and slope of the size spectra regressions over time for the Guinea-Bissau data. Constructed for shallow waters only (<40m). Error bars represent ± 2 x standard errors.

Graphe de l'ordonnée à l'origine et de la pente des régressions sur les spectres de taille dans le temps pour les données de la Guinée Bissau. Réalisé pour les eaux peu profondes seulement (< 40 m). Les barres d'erreur représentent ± 2 x les erreurs standard.

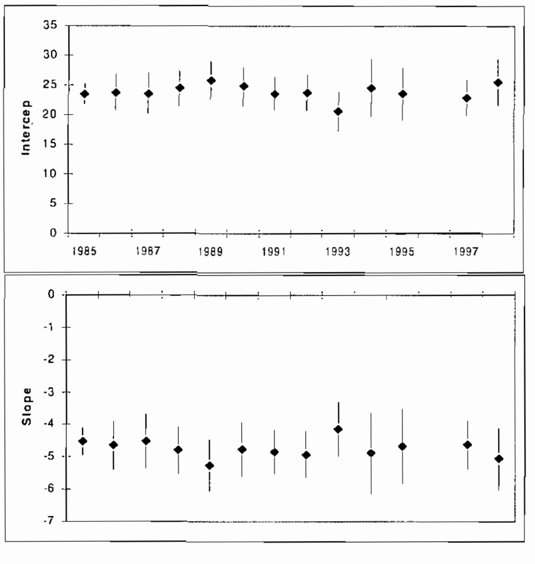

FIG. 4. — Plot of intercept and slope of the size spectra regressions over time for the Guinean data (includes shallow waters only; Area effects disregarded).
Error bars represent ± 2 x standard errors.

Graphe de l'ordonnée à l'origine et de la pente des régressions sur les spectres de taille dans le temps pour les données de la Guinée (comprenant les faibles profondeurs, effet Superficie non considéré). Les barres d'erreur représentent ± 2 x les erreurs standard.

TABLE VI

Regression coefficients of the Ancova model for Guinea.
*Analysis applied only to shallow depths. Significance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1*

Coefficients de régression du modèle Ancova pour la Guinée
L'analyse s'applique seulement aux faibles profondeurs
Seuils de signification des codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

COEFFICIENTS:	ESTIMATE	STD. ERROR	T VALUE	PR(>|T|)	SIGNIF. CODES
Intercept	23,445437	0,874847	26,799	<2e-16	***
ln.mid (Slope)	-4,524633	0,213809	-21,162	<2e-16	***
year1986	0,331065	1,264126	0,262	0,7935	
year1987	0,147977	1,484387	0,1	0,9206	
year1988	1,02775	1,225465	0,839	0,4019	
year1989	2,390225	1,364241	1,752	0,0801	.
year1990	1,333525	1,426405	0,935	0,3501	
year1991	0,168755	1,066194	0,158	0,8743	
year1992	0,334269	1,187294	0,282	0,7784	
year1993	-2,8782	1,407545	-2,045	0,0412	*
year1994	1,09608	2,282375	0,48	0,6312	
year1995	0,071713	2,032586	0,035	0,9719	
year1997	-0,60124	1,258015	-0,478	0,6328	
year1998	2,088484	1,730884	1,207	0,2279	
areaNorth	-0,183117	0,109161	-1,677	0,0938	.
areaSouth	-0,216864	0,105032	-2,065	0,0393	*
ln.mid:year1986	-0,11965	0,312521	-0,383	0,7019	
ln.mid:year1987	-0,003846	0,363472	-0,011	0,9916	
ln.mid:year1988	-0,267231	0,296096	-0,903	0,367	
ln.mid:year1989	-0,730595	0,336123	-2,174	0,03	*
ln.mid:year1990	-0,231058	0,351059	-0,658	0,5106	
ln.mid:year1991	-0,324854	0,26278	-1,236	0,2167	
ln.mid:year1992	-0,400685	0,294603	-1,36	0,1742	
ln.mid:year1993	0,386219	0,361735	1,068	0,286	
ln.mid:year1994	-0,363242	0,586819	-0,619	0,5361	
ln.mid:year1995	-0,142146	0,528155	-0,269	0,7879	
ln.mid:year1997	-0,096652	0,313486	-0,308	0,7579	
ln.mid:year1998	-0,534241	0,426377	-1,253	0,2106	

Residual standard error: 1.297 on 842 degrees of freedom; Multiple R-Squared: 0.8568, Adjusted R-squared: 0.8522; F-statistic: 186.6 on 27 and 842 DF, p-value: 0

In the case of Guinea, the factors Year and Aera are mildly significant (Pr(F) < 0.05). Only shallow waters were included in the analysis as these depths (<40 m) were sampled consistently throughout the time period. Table VI shows that this is primarily a result of 1993, where a lower intercept resulted in a mildly significant effect (Pr(>|t|) = 0.04).

The interaction term length/year was not significant, which indicates that the size spectra regression lines can be considered parallel lines, most of them on top of each other, except for 1989. The effect of Area was not significant in the overall Anova model, but a mildly significant effect can be seen due to the southern area in Table VI (Pr(>|t|) = 0.04). Figure 4 illustrates this in a different way with no trend in the intercept or slope over time. It is interesting to note that in spite of including surveys undertaken by two different vessels, the R/V *Nizery* and R/V *Antea*, for the period 1985 to 1998, this did not result in any significant differences in the survey years 1997 and 1998, which were carried out by the R/V *Antea*.

Table VII shows the results for the SeneGambian data, indicating significant effects for all factors such as Year, Season, Area, and Depth, including the interaction term that influences the slope of the regression line on size spectra over time (Pr(|t|) < 0.05). These results show significantly higher abundance in the dry season, shallow waters, and in the northern area (Pr(|t|) < 0.001).

Time had a generally significant effect on the intercepts and slopes of the regression lines, but this is compared to the size spectra in 1970, which appears to be an anomalous curve (fig. 5).

The removal of 1970 data resulted in non-significant Year effects although the plots of intercepts and slopes indicate that there is in fact no clear trend over time. This is surprising as the data covers a period from 1970 to 1992, including two series of surveys by two different vessels, R/V *Laurent-Amaro* and R/V *Louis-Sauger*.

TABLE VII

Regression coefficients of the Ancova model for SeneGambia.
*Significance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1*

Coefficients de régression du modèle Ancova pour la Séné-Gambie
Seuils de signification des codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

COEFFICIENTS:	ESTIMATE	STD. ERROR	T VALUE	PR(>|T|)	SIGNIF. CODES
Intercept	21,6359	0,7236	29,898	< 2e-16	***
ln.mid (Slope)	-4,7018	0,1856	-25,339	< 2e-16	***
year1971	-4,6883	1,3613	-3,444	0,000595	***
year1972	-3,0795	1,2761	-2,413	0,015971	*
year1974	-0,7997	1,7115	-0,467	0,640406	
year1986	-1,8482	1,2939	-1,428	0,153436	
year1987	-3,4011	1,0376	-3,278	0,001078	**
year1988	-3,6279	1,2301	-2,949	0,003253	**
year1989	-6,5002	1,0767	-6,037	2,14E-09	***
year1990	-2,4141	1,402	-1,722	0,085369	.
year1991	-2,9877	1,3273	-2,251	0,024584	*
year1992	-7,7839	1,386	-5,616	2,47E-08	***
seasonwet	-0,5069	0,1272	-3,984	7,21E-05	***
depthbMedium	-0,5204	0,1105	-4,709	2,80E-06	***
depthcDeep	-0,66	0,1144	-5,771	1,02E-08	***
areaNorth	0,5602	0,1262	4,44	9,90E-06	***
areaSouth	0,4121	0,1257	3,279	0,001073	**
ln.mid:year1971	1,3189	0,3629	3,634	0,000291	***
ln.mid:year1972	1,1321	0,3454	3,277	0,001081	**
ln.mid:year1974	0,5334	0,4561	1,17	0,242425	
ln.mid:year1986	0,8423	0,3345	2,518	0,011934	*
ln.mid:year1987	1,1086	0,2683	4,131	3,88E-05	***
ln.mid:year1988	1,0703	0,3178	3,368	0,000783	***
ln.mid:year1989	1,8093	0,2806	6,447	1,70E-10	***
ln.mid:year1990	0,748	0,3651	2,049	0,040731	*
ln.mid:year1991	0,7816	0,3508	2,228	0,026072	*
ln.mid:year1992	1,9515	0,3675	5,31	1,33E-07	***

Residual standard error: 1.543 on 1108 degrees of freedom; Multiple R-Squared: 0.6898, Adjusted R-squared: 0.6825; F-statistic: 94.76 on 26 and 1108 DF, p-value: 0

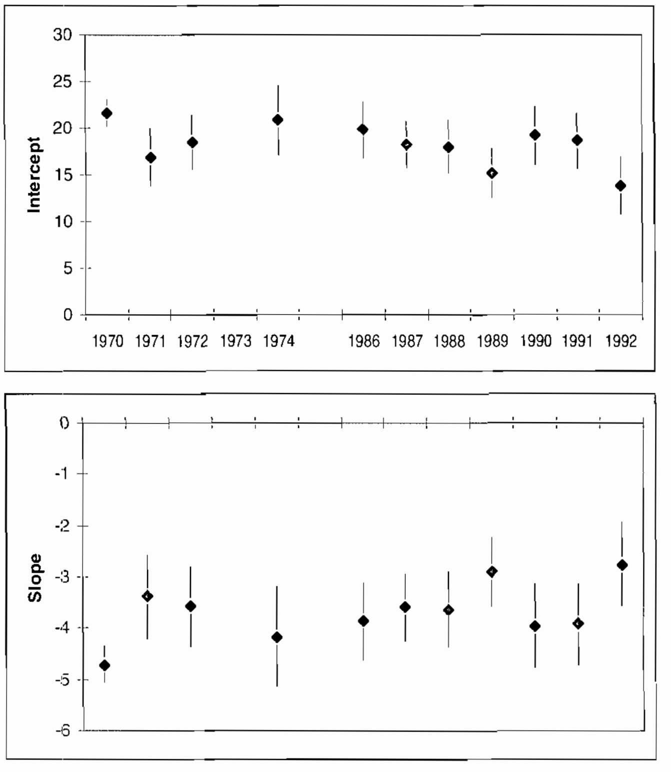

FIG. 5. — Plot of intercept and slope of the size spectra regressions over time for the SeneGambian data. Constructed for the central area in SeneGambia, for shallow waters, and during the dry season. Notice jump from 1974 to 1986 in the x-axis. Error bars represent ± 2 x standard errors.

Graphe de l'ordonnée à l'origine et de la pente des régressions sur les spectres de taille dans le temps pour les données de Séné-Gambie. Elaboré pour la zone centrale de Séné-Gambie, pour les faibles profondeurs et pendant la saison sèche. À noter l'absence de données entre 1974 et 1986 sur l'axe des x. Les barres d'erreur représentent ± 2 x les erreurs standard.

DISCUSSION

AN ANALYSIS was carried out on the estimated size spectra based on the isometric growth model. Ideally, actual length measurements are preferable, but the sampling methodology of many surveys included only length measurements of commercially important species. However, the two surveys undertaken in Cape Verde, which undertook extensive length measurements, made it possible to test for differences between the two estimation methods, namely size spectra based on actual length measurements or estimated by using average weight by species and allocating to length intervals according to the isometric growth model. Differences between these two methods were shown to be non-significant, which indicates that the isometric growth model is applicable when good length measurements are lacking (*e.g.* BIANCHI *et al.*, 2000).

The type of analysis that could be undertaken was determined by the available data. Survey objectives were generally to assess demersal resources, but the methodology varied over time in terms of sampling strategy, area coverage, and vessel used. The data was often not balanced in terms of samples by factor level (Year, Season, Depth, Area) [table I], which made it necessary to carry out analysis on data subsets in order to obtain the necessary samples (hauls) by factor level. For example, the Guinean data subset included only shallow depths (< 40 m), which were consistently sampled over the time period 1985 to 1998. The Capeverdean data subset included only two areas, the Boavista shelf and Sal island, as these were sampled in both years, 1988 and 1994. Also, the dry season was better represented in terms of samples and the number of surveys varied over time in Guinea and SeneGambia (table III), analysis was applied to the full data set in these cases.

The data from the various countries/regions were analysed separately for various reasons such as problems in standardisation and the very strong differences in terms of exploitation as fishing intensity over time has been different for each country/region. Of course, we are assuming that the increase in catches is proportional to effort, but other studies deal with this issue explicitly (these proceedings; BARRY *et al.*; GASCUEL; SIDIBÉ *et al.*). One should also bear in mind that the present study covers what can be considered as three separate ecosystems, are distinct in terms of demersal fish assemblages and oceanographic conditions as well as climatic conditions (*e.g.* LONGHURST, 1998). For example, of importance is upwelling in the waters off Senegal, river run-off in the Guinean ecosystem, and the strong oceanic influence in the Cape Verde Archipelago. Furthermore, numerous studies indicate important spatial structure in demersal fish assemblages where factors such as the position of the thermocline and temperature differences across a depth gradient as well as bottom sediment type play an important role in defining the structure of this assemblages such as these (*e.g.* DOMAIN *et al.*, 1999; LONGHURST & PAULY, 1987; FAGER & LONGHURST, 1968).

The models that were used to explain the relationship between the abundance of individuals and length (transformed with the natural logarithm) can be considered successful, explaining 48 to 85 per cent of the variance (adjusted R^2 values) in the data depending on the region. Due attention was given to the distribution of model residual errors, which were generally slightly skewed normal distributions. However, we consider analysis of covariance to be a robust method, allowing slight deviations in terms of error distributions. The results indicate a strong relationship with higher abundance of the smaller individuals and linear decrease in abundance (transformed!) as a function of length or size, but this was expected. What is more interesting are the effects of the various predefined factors.

Depth had a significant effect on the size composition of demersal fish communities in Guinea-Bissau and SeneGambia. However, the results are contradictory, indicating higher abundance in deeper waters in Guinea-Bissau and higher abundance in shallow waters in SeneGambia. An explanation for this contradiction would require further study and may be related to a combination of physical factors such as upwelling and the position of the thermocline in relation to shelf topography (*e.g.* AMORIM *et al.*, this proceedings; BIANCHI 1992; LONGHURST & PAULY 1987). Depth had no effect in Cape Verde, which is consistent with another study concerning demersal fish assemblages in this region (STOBBERUP *et al.*, these proceedings).

Area had a significant effect on the size composition in SeneGambia, but not for the other countries. This may be related to the effects of seasonal upwelling, which are particularly strong in this area as observed through satellite images of seas surface temperature and productivity [1] (*e.g.* TROADEC & GARCIA, 1979).

These upwelling effects are expected to play an important role, for the northern area in particular, leading to seasonal changes in demersal fish assemblages as a result of temperature changes and migration (*e.g.* DOMAIN, 1979).

The present study focuses primarily on the effect of time on size spectra in the region. Thus, the specified models take into consideration the factor Year and an interaction term Year/Length (ln.mid), corresponding to the additive terms on the inter-

1. — Images available from the European Joint Research Centre (www.jrc.it)

cept and slope, respectively. A trend of increasing intercept and decreasing slope was observed for Cape Verde and Guinea-Bissau, which is an expected result of increasing fishing pressure; larger individuals become increasingly scarce. However, the available information as well as the time period were limited. In the case of Guinea-Bissau, the trend breaks down with the inclusion of the 1995 size spectrum (fig. 3).

Longer time series were available for Guinea and SeneGambia, which make these data more appropriate for the study of possible changes in size spectra over time. The results show that Year had a significant effect, indicating that the regression line on size spectra shifted upwards or downwards. However, the interaction term was non-significant, which has bearing on the slope of the regression line. These results were presented in two ways, the results of the Ancova models as well as plots of intercepts and slopes following the procedure by BIANCHI *et al.* (2000). No trends were observed in the plots of intercepts and slopes for Guinea and SeneGambia (fig. 4 and 5).

Other studies involving size spectra have found a relationship between fishing intensity, where the intercept tends to increase and the slope decrease as fishing intensity increases (*e.g.* ICES, 2002; BIANCHI *et al.*, 2000; GISLASON & RICE, 1998; Rice & GISLASON, 1996). However, it is important to point out that these results are based primarily on high-latitude regions. Fishing intensity has indeed increased in the north-western African region, particularly for countries such as Senegal and Guinea, but this effect on the size spectra is not apparent in the present study. In fact, the increase in intercept and decrease in slope was observed for Cape Verde, where fishing intensity has been relatively stable over the period under study (INDP, 2001).

GISLASON & LASSEN (1997) showed that the rate of change of the slope under a given fishing pressure is inversely proportional to a weighted average of the von Bertalanffy growth parameter K of the constituent species. Considering that K values tend to be higher in tropical regions, which has implications in terms of size and size at first maturity (*e.g.* PAULY, 1998), the slope is expected to be less sensitive to changes in fishing (BIANCHI *et al.*, 2000). However, the present study indicates that change in size structure may not be a suitable indicator for the effects of fishing in tropical areas, following the same line of reasoning. The plots of intercepts and slopes appear instead to show natural variability in the system, which may be a result of numerous biotic and abiotic factors.

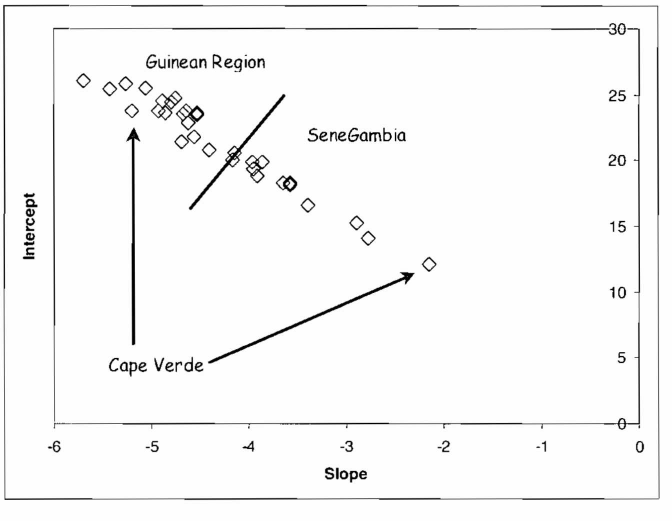

FIG. 6. — Plot of intercept against slope for some of the results (mostly shallow waters), identifying the geographic location of each point or group of points.

Graphe de l'ordonnée à l'origine par rapport à la pente pour quelques résultats (principalement dans les eaux peu profondes) indiquant la position géographique de chaque point ou groupe de points.

A plot of intercept and slope for the whole region results in a consistent pattern, analogous to the cross-system comparison presented in BIANCHI *et al.* (2000) [fig. 6]. Following the reasoning presented in BIANCHI *et al.* (2000), the intercept appears to reflect productivity and slope has been related to fishing intensity, despite inter-correlation. Figure 7 shows a pattern of higher intercepts and steeper negative slopes for the Guinean region compared to SeneGambia. Steeper negative slopes for SeneGambia would be more consistent with higher fishing intensity. However, it appears instead to show ecosystem characteristics such as the importance of the Guinean region as a productive nursery ground, Guinea-Bissau in particular, dominated by abundant small individuals. An apparent shift can be observed in Cape Verde, but this cannot be related to fishing intensity. However, migration was not considered in the present study and may be a determining factor in the region.

The confounding effects of different vessel/gears as well as sampling strategy over time may have lead to the present results. The whole time series was included for each country/region in the analysis of time effects, including data from surveys undertaken by different vessels.

However, it is interesting to note that the results indicate that the size spectra were comparable over time, irrespective of vessel, which implies that the lack of trend is not a result of standardisation procedure. For example, significant year effects did not show up in 1997 and 1998 for Guinea, when a different vessel carried out the surveys (R/V *Antea*). Also, the significant year effect in the SeneGambian data was the result of an anomalous size spectrum in 1970 despite the same vessel being used in the subsequent three years. The two time series for SeneGambia, referring to the two survey vessels R/V *L.-Amaro* (1970-1974) and R/V *L.-Sauger* (1986-1992), were comparable in terms of slopes and intercepts of the size spectra. Thus, the standardisation of data appears to have been successful, making it possible to compare over time, but some improvements could be made. Further, the incorporation of fishing intensity in the analysis would lead to more conclusive results on the effects of fishing on the size structure of demersal communities.

We consider it important to continue this line of study in order to determine the usefulness or not of size structure as an indicator of fishing effects as well as other proposed aggregate community indicators. If such aggregate indicators prove to be useful, their application is particularly convenient in tropical areas because of data limitations. In the case of Cape Verde and Guinea-Bissau, fishing intensity was relatively stable or less accentuated over the study period, but it was only in these cases that an increase in intercept and a decrease in slope were observed, which was an unexpected result. Changes have been related to fishing in several studies involving tropical areas and the present results should be verified by applying other proposed methods (*e.g.* JENNINGS *et al.*, 2001), considering issues such as the effect of migration and environmental factors.

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BIBLIOGRAPHY OF SOURCES CITED

AMORIM (P.), S. MANÉ, & K. A. STOBBERUP, 2004. — « Demersal Fish Assemblages Based on Trawl Surveys in the Continental Shelf and Upper Slope off Guinea-Bissau », *in* CHAVANCE *et al.* (ed., 2004): pp. 281-298.

BARRY (M. D.), M. LAURANS, D. THIAO & D. GASCUEL, 2004. — « Diagnostic de l'état d'exploitation de cinq espèces démersales côtières sénégalaises », *in* CHAVANCE *et al.* (éd., 2004) : pp. 183-194.

BIANCHI (G.), 1992. — « Study of the Demersal Assemblage of the Continental Shelf and Upper Slope off Congo and Gabon, Based on the Trawl Surveys of the RV "Dr Fridtjof Nansen" », *Marine Ecology Progress Series*, 85: pp. 9-23.

BIANCHI (G.), H. GISLASON, K. GRAHAM, L. HILL, K. KORANTENG, S. MANICKCHAND-HEILEMAN, I. PAYA, K. SAINSBURY, F. SANCHEZ, X. JIN & K. ZWANENBURG, 2000. — « Impact of Fishing on Size Composition and Diversity of Demersal Fish Communities », *ICES Journal of Marine Sciences*, 57: pp. 558-571.

BLANCHARD, F. & J. BOUCHER, 2001. — « Temporal Variability of Total Biomass in Harvested Communities of Demersal Fishes », *Fish. Res.*, 49: pp. 283-293.

CHAVANCE (P.), M. BÂ, D. GASCUEL, J. M. VAKILY & D. PAULY (éd.), 2004. —*Pêcheries maritimes, écosystèmes & sociétés en Afrique de l'Ouest : Un demi-siècle de changement*, [Marine Fisheries, Ecosystems and Societies in West Africa: Half a Century of Change], actes du symposium international, Dakar (Sénégal), 24-28 juin 2002, Bruxelles, Office des publications officielles des Communautés européennes, XXXII-532-XIV p., 6 pl. h.-t. coul., (coll. *Rapports de recherche halieutique* A.C.P.-U.E., n° 15 Vol. 1).

CURY (P.) & V. CHRISTENSEN, 2001. — « Quantitative Ecosystem Indicators for Fisheries Management », *in* IOC/SCOR Working group 119, ICES CM 2001/T:02, 9 p.

DOMAIN (F.) & A. SIDIBE, 1998. — *Rapport préliminaire de la campagne du N.O.* Antea, *20 sept.-1er oct. 1998*, Doc. C.N.S.H.B.-Orstom, 4 p. + annexes.

DOMAIN (F.), 1979. — « Les ressources démersales», *in* TROADEC & GARCIA (éd., 1979) : pp. 79-122.

DOMAIN (F.), 1989. — Rapport des campagnes de chalutage du N.O. A. *NIZERY* dans les eaux de la Guinée de 1985 à 1988, Doc. scient. Cent. Rech. Halieut, Boussoura (Conakry), 1989, 5, 81 p.

DOMAIN (F.), M. KEITA, & E. MORIZE, 1999. — « Typologie générale des ressources démersales du plateau continental », *in* DOMAIN *et al.* (éd., 1999) : pp. 53-86.

DOMAIN (F.), P. CHAVANCE & A. DIALLO (éd), 1999. — *La pêche côtière en Guinée : ressources et exploitation*, I.R.D.-C.N.S.H.B., 393 p.

FAGER (E.W). & A. R. LONGHURST, 1968. — « Recurrent Groups Analysis of Species Assemblages of Demersal Fish in the Gulf of Guinea », *J. Fish. Res. Board. Can.*, 25 (7): pp. 1405-1421.

FARADAY (J.), 2000. — Practical Regression and Anova using R. Manuscript, 203 p.

GASCUEL (D.), 2004. — « Cinquante ans d'évolution des captures et biomasses dans l'Atlantique Centre-Est : Analyse par les spectres trophiques de captures et de biomasses », *in* CHAVANCE *et al.* (éd., 2004) : pp. 415-420.

GISLASON (H.) & H. LASSEN, 1997. — « On the Linear Relationship Between Fishing Effort and the Slope of the Size Spectrum », ICES CM 1997/DD: 05, 11 p.

GISLASON (H.) & J. RICE, 1998. — « Modelling the Response of Size and Diversity Spectra of Fish Assemblages to Changes in Exploitation », *ICES Journal of Marine Science*, 55: pp. 362-370.

GOBERT (B.), 1994. — « Size Structures of Demersal Catches in a Multispecies Multigear Tropical Fishery », *Fish. Res.*, 19: pp. 87-104.

HAEDRICH, R.L. & S. M. BARNES, 1997. — « Changes Over Time of the Size Structure in an Exploited Shelf Fish Community », *Fish. Res.*, 31: pp. 229-239

I.N.D.P., 2001. — *Boletim estatistico nº9, Ano 2000, Dados sobre pesca artesanal, pesca industrial, conservas e exportações*, Mindelo, I.N.D.P., 111 p.

ICES, 2001. — *Report of the Working Group on Ecosystem Effects of Fishing Activities*, ICES CM 2001/ACME:09 Ref: ACE, ACFM, DEG, 102 p.

ICES, 2002. — *Report of the Working Group on Ecosystem Effects of Fishing Activities*, ICES CM 2002/ACE: 03 Ref: DEG, 102 p.

INIP & L.B.M., 1989. — *Campanha do NI "Noruega" nas águas da Républica da Guiné-Bissau, Abril-Maio de 1988*, Relatório Técnico Científico, Lisbonne, Instituto Nacional de Investigação das Pescas, 18, 196 p.

INIP & L.B.M., 1990. — *Campanha do NI "Noruega" nas águas da Républica da Guiné-Bissau, Março-Abril de 1989*, Relatório Técnico Científico, Lisbonne, Instituto Nacional de Investigação das Pescas, 30, 236 p.

INIP & L.B.M., 1992. — *III Campanha do NE "Noruega" nas águas da Républica da Guiné-Bissau de Abril a Junho de 1990. Relatório Técnico Científico*, Lisbonne, Instituto Nacional de Investigação das Pescas, 63, 344 p.

IPIMAR & CIPA, 1993. — *IV Campanha do NE "Noruega" nas águas da Républica da Guiné-Bissau de Maio a Junho de 1991. Relatório Técnico Científico*, Lisbonne, Instituto Nacional de Investigação das Pescas, 70, 381 p.

IPIMAR & CIPA, 1996. — *V Campanha do NI "Capricórnio" nas águas da Républica da Guiné-Bissau de Maio a Julho de 1995. Relatório Técnico Científico*, Lisbonne, Instituto Nacional de Investigação das Pescas, 23, 202 p.

JENNINGS (S.) & M. J. KAISER, 1998. — « The Effects of Fishing on Marine Ecosystems », *Advances in Marine Biology*, 34: 201-352.

JENNINGS (S.), M. J. KAISER & J. D. REYNOLDS, 2001. — *Marine Fisheries Ecology. Blackwell Science*, Oxford, 417 p.

LONGHURST (A. R.) & D. PAULY, 1987. — *Ecology of tropical oceans*, Academic Press, 407 p.

LONGHURST (A.), 1998. — *Ecological Geography of the Sea*, Academic Press, 398 p.

MORIZE (E.) & A. DIALLO, 1997. — *Rapport préliminaire de la campagne du N.O.* Antea, 27 sept.-8 oct., 1997. Doc. C.N.S.H.B.-Orstom, 6 p. + annexes.

MORIZE (E.) & A. DOUMBOUYA, 1997. — *Rapport préliminaire de la campagne du N.O.* Antea, 21 mars-2 avr., 1997, Doc. C.N.S.H.B.-Orstom, 6 p. + annexes.

PALSSON (O. K.), 1989. — *Random Stratified Survey of Demersal Fish Stocks in the Waters off Cape Verde*, Report of the survey in August 1988, 1989, Icelandic Intern. Develop. Agency, Mar. Res. Inst., Reykjavik, 45 p.

PAULY (D.), 1998. — « Tropical Fishes: Patterns and Propensities », *J. Fish Biol.*, 53 (Supplement A): pp. 1-17.

PAULY (D.), V. CHRISTENSEN, J. DALSGAARD, R. FROESE, F. TORRES Jr., F., 1998. — « Fishing Down Marine Food Webs », *Science*, 279: pp. 860-863.

RICE (J.) & H. GISLASON, 1996. — « Patterns of Change in the Size Spectra of Numbers and Diversity of the North Sea Fish Assemblage, as Reflected in Surveys and Models », ICES, *Journal of Marine Science*, 53: pp. 1214-1225.

RICE, (J.) 2000. — « Evaluating Fishery Impacts Using Metrics of Community Structure », ICES, *Journal of Marine Science*, 57: pp. 682-688.

SIDIBÉ (A.), M. LAURANS, D. GASCUEL & F. DOMAIN, 2004. — « Évolution comparative de l'abondance des ressources halieutiques démersales en Guinée entre 1985 et 1998 », *in* CHAVANCE *et al.* (éd., 2004) : pp. 393-398.

STOBBERUP (K. A.), C. MONTEIRO & O. TARICHE, (2002). — « Demersal Fish Assemblages in the Cape Verde Archipelago: Changes over the Period 1981 to 1994 », Poster presented at the Symposium "Marine Fisheries, Ecosystems, and Societies in Northwest Africa: Half a Century of Change", 24-28 June 2002, Dakar (Senegal).

THORSTEINSSON (V.), V. M. S. MONTEIRO & E. O. ALMADA, 1995. — *Ground Fish Survey in the Waters off Cabo Verde 1994*, INDP/ICEIDA, Mindelo, 26 p.

TROADEC (J. P.) & S. GARCIA, 1979. — « Les ressources halieutiques de l'Atlantique Centre-Est », « Première Partie : Les Ressources du Golfe de Guinée de l'Angola à la Mauritanie », *F.A.O. Fisheries Tech. Pap.*, n° 186, Rome, F.A.O.

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Un demi-siècle de changement

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