

## Changes in the trophic structure of fish demersal communities in West Africa in the three last decades<sup>★</sup>

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**Abstract** – West African marine ecosystems are very productive and sustain important fisheries that have developed rapidly in the last decades. The analysis of the fishing impact on exploited resources is usually conducted through single-species assessments. In this study, we propose a complementary approach that enables to account for some ecosystem effects of fishing. In Guinea and Senegal, fisheries have developed relatively recently and at the same time, the collection of landings and surveys data has been carried out. In consequence, the data collection extends from a period where stocks could be considered as non exploited to a situation of overexploitation. This case study is analysed in order to detect shifts in the ecosystem structure in response to increasing fishing pressure. To this aim, trophic spectra and long time series of mean trophic level are examined for demersal fish communities. Trophic spectra display either the distribution of the demersal community biomass or the commercial catches according to trophic level classes. Some substantial and statistically significant changes in the trophic structure of the Senegal and Guinea ecosystems were observed. In particular, the biomass of the high trophic levels decreased whereas the lower trophic levels displayed a relative stability or an increase. This could be linked to a “top-down” fishing effect due to a release of predation on the lower trophic levels of the demersal fish community. In Senegal, the mean trophic level decreased significantly for both the catches and the demersal community biomass. Such a decrease was also observed for the coastal demersal biomass in Guinea. This showed that fishing activities had an impact on the trophic structure of the ecosystem, and a “fishing down marine food web” effect was shown in West Africa for the first time.

**Key words:** Demersal fish community / Fishing effects / Trophic level / Trophic structure / West Africa

**Résumé** – **Changements de la structure trophique des communautés de poissons démersaux en Afrique de l'Ouest au cours des trois dernières décennies.** Les écosystèmes marins en Afrique de l'Ouest sont très productifs et ont permis à d'importantes pêcheries de se développer rapidement au cours des dernières décennies. L'analyse de l'impact de la pêche sur les ressources exploitées est couramment conduite par des évaluations de type monospécifique. Dans cette étude, nous proposons une approche alternative qui permettrait de mieux intégrer la dimension écosystémique. En Guinée et au Sénégal, les pêcheries se sont développées récemment, parallèlement la collecte des données de débarquement et de campagnes scientifiques s'est mise en place. Aussi, les données couvrent toute une période depuis la date où les stocks étaient considérés comme non exploités jusqu'à la situation de surexploitation actuelle. Ce cas d'étude est analysé afin de regarder les changements intervenus dans la structure de l'écosystème, en particulier ceux qui pourraient être expliqués par l'augmentation de la pression de pêche. Pour cela, nous estimons des spectres trophiques et des séries de niveaux trophiques moyens pour les communautés de poissons démersaux. Un spectre trophique permet de montrer la répartition de la biomasse de l'écosystème ou la position des captures commerciales dans la chaîne trophique selon des classes de niveaux trophiques. Nous observons des changements importants dans la structure des écosystèmes guinéens et sénégalais. En particulier, la biomasse des hauts niveaux trophiques diminue tandis que celle des bas niveaux trophiques augmente ou reste relativement stable. Cette observation est peut être liée à un effet « Top-Down » du au relâchement de la prédation sur les bas niveaux trophiques. Au Sénégal, la même tendance est observée avec les données de captures. Par ailleurs, le niveau trophique moyen diminue significativement autant pour les captures que pour la biomasse. En Guinée, seule une diminution de la biomasse est observée en zone côtière. Globalement, ces résultats montrent que les activités de pêche ont un impact sur la structure trophique des écosystèmes et pour la première fois un effet « fishing down marine food web » est montré en Afrique de l'Ouest.

<sup>★</sup> Appendix is only available in electronic form at <http://www.edpsciences.org/alr>

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## 1 Introduction

The main direct consequence of fishing exploitation is generally a decrease in the biomass of target species (Pope and Macer 1996; Millner and Whiting 1996; Haedrich and Barnes 1997). Stock assessments conducted in West Africa confirmed this expected effect (Longhurst 1969; Domain 1980). Most targeted species are currently overexploited (Gascuel and Ménard 1997; Gascuel et al. 2004; Sidibé et al. 2004), and particularly the species of high trophic levels (Laurans et al. 2002). This could be linked to their life-history traits which make them more sensitive to exploitation (Jennings et al. 1999). Fish exploitation in Senegal and Guinea started in the 1950s and fisheries have rapidly developed during the last decades. In Guinea, the demersal fish landings increased from 10 000 tonnes to 62 000 tonnes between 1985 and 2000 (Sidibé 2003). In Senegal, the landings increased from 60 000 tonnes in 1970 to 350 000 tonnes in 2000 (Thibaut et al. 2003). Both marine ecosystems appear thus to be good candidates to explore potential shifts in the trophic structure due to increasing fishing pressure. Our purpose is to show the impact of fishing activities on the demersal fish communities in Senegal and Guinea. First, changes in the trophic structure of the fish community are characterized by comparing the dynamics of the biomass and the catch trophic spectra over three decades. Second, trends in the mean trophic level of catch and abundance are estimated in each ecosystem and compared. Finally, the results are interpreted at a more global scale by comparing the West African ecosystems studied with well-known over-exploited North Atlantic ecosystems.

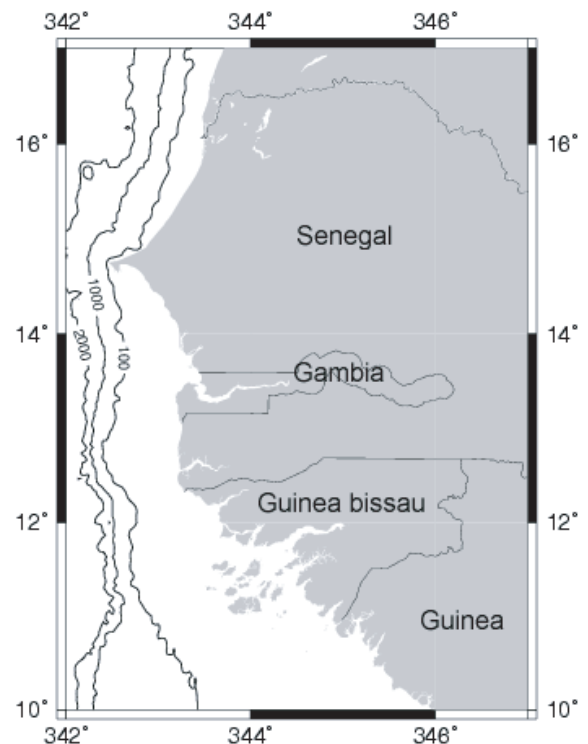
## 2 Materials and methods

Trophic spectra and mean trophic level were estimated in Senegal and Guinea from two different data sets: demersal fish survey data and commercial fishery data.

### 2.1 Demersal fish survey data

#### *Senegal*

Since 1970, surveys were conducted in order to improve current knowledge on the biology, distribution and abundance of all the species that can be sampled by bottom trawl. For each survey, a bottom trawl is towed at approximately 3.5 knots at each station during 30 min. Catch numbers, weight and length compositions were recorded for almost each haul conducted. However, only weight data by species are complete. Only hauls comprised between 0 and 100 m deep were considered in the analysis because deeper hauls are rare. Trawling surveys have been performed on the continental shelf (Fig. 1). Twenty-eight surveys covering the whole continental shelf and using the same sampling protocol were used in the study. They included 1593 hauls on a period extending from 1971 to 1995 (Table 1). Trawl stations were selected using a stratified random sampling design. Within each stratum of latitude and bathymetry, stations were randomly assigned, the number of stations allocated by stratum being proportional to the extent of the area of each stratum. The area of coverage extends



**Fig. 1.** Map of the continental shelves of Senegal and Guinea.

from 12 °N to 16 °N excluding the area between 13.1 °N and 13.6 °N which corresponds to the Gambia EEZ. Other surveys were performed in Senegal between 1974 and 1986 but data were not available for the study.

#### *Guinea*

Survey objectives and characteristics are similar as those in Senegal. From 1985 onwards, two scientific surveys have been performed each year, during the dry and rain seasons. For technical reasons, some surveys were cancelled. In the period 1991-1992, surveys have been carried out every three months in order to improve current knowledge on the migration patterns of some fish species. Twenty six surveys were included in the present study, representing 2291 hauls (Table 1). The area of coverage mainly includes the littoral zone above 30 meters deep, from 9 °N to 11 °N, except for 3 surveys which are excluded from the analysis.

Senegalese and Guinean surveys both use a bottom trawl which mainly targets the demersal fishes. Therefore, the results obtained from these data should adequately represent the dynamics of the demersal fish community. In this sense, the survey catches are considered as an index of the biomass of the demersal fish community present in the ecosystems. No technical modification affected the general method of the survey over the whole investigated period.

In Senegal and in Guinea, the surveys were performed owing to the collaboration of IRD (Institut de Recherche pour le Développement). All data are stored in the national Trawlbase-SIAP database (Guitton and Gascuel 2004). In Guinea and Senegal, databases are managed respectively by the CNSHB

**Table 1.** Surveys used in the analysis. Year, month and haul number are indicated for each survey.

Year		1971	1972	1974	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1997	1998
Month- Number of hauls	Senegal	12-28	2-27 5-29 9-29	1-38		11-107	5-116 10-108	3-108	4-115 11-112	3-118	3-106	5-111 10-113	4-111	3-109	5-108		
	Guinea				3-81 10-80	3-90 10-80	11-79	4-88 10-90	9-75 11-76	4-25 7-65	1-65 3-80 6-80 9-80 11-69	1-80 4-80 10-164	2-159 5-156	5-57	2-96	3-110 9-95	9-91

(Centre National des Sciences halieutiques de Boussoura) and by the CRODT (Centre de Recherche océanographique de Dakar-Thiaroye) and the data are considered as public.

## 2.2 Demersal fish landing data

In Senegal, the time series of catch data is complete from 1981 onwards, and is provided by the CRODT. The statistics of the artisanal fishery are estimated by extrapolation from the landings sampled in the main harbours of each region, and the landing data of the industrial fishery (Ferraris 1994) are also complete. Observers are present onboard the foreign boats to record their catches and at the Dakar harbour to record the landings of the national boats.

In Guinea, the statistics of the artisanal fishery are estimated with a similar method as in Senegal (Damiano 2000). Because of fewer observers, catches of the foreign industrial fishery are estimated by extrapolation (Lesnoff et al. 2000). The Guinean statistics are available since 1995 (Sidibé 2003) and are provided by the CNSHB.

## 2.3 Trophic level and trophic spectrum

The mean trophic levels used for each species came from the Fishbase database which is available online ([www.fishbase.org](http://www.fishbase.org)) (Froese and Pauly 2000). These trophic levels were estimated from gut contents. All species considered in this study and their corresponding trophic levels (Appendix) are given in electronic form at <http://www.edpsciences.org>

The plot of a trophic spectrum was proposed by Gascuel (2004). Based on scientific survey data, the Biomass Trophic Spectrum (BTS) describes the distribution of the demersal community biomass according to trophic classes (Table 1). Here, the biomass corresponds to an index of abundance estimated from the catches harvested by the scientific trawler during 30 min. Besides, the Catch Trophic Spectrum (CTS) established with commercial fishing data enables to describe at which level of the food web the species are harvested. All the species for which the mean trophic level was available were included in the trophic spectrum plot. These species represented between 80% and 90% of the total biomass and catches. For the survey data, 185 species were considered in Guinea, and 249 in Senegal. For the commercial catch data, 58 species were taken into account in Guinea and 129 in Senegal. BTS were plotted both for individual hauls or for aggregation of hauls.

**Table 2.** Year classes used in the Linear Models (LM).

Data		Year class	Period
		70s	1971 to 1974
Survey		80s	1985 to 1989
		90s	1990 to 1995
Senegal		81-84	1981 to 1984
Commercial		85-89	1985 to 1989
Catch		90-94	1990 to 1994
		95-99	1995 to 1999
Guinea		85-89	1985 to 1989
Survey		90-95	1990 to 1995
		97-98	1997 to 1998

The variables retained for the analysis were the date (year, month, season), the bathymetry and the geographical position. CTS were plotted from annual landing data. In all cases, the species biomasses or catches were distributed by trophic class of 0.1 step according to their trophic level. A smoothed spectrum was calculated with a three points moving average to take into account the variability of the species trophic level inherent to the variation of the diet (Davenport and Bax 2002) and the uncertainty of the estimation (Pinnegar et al. 2002). This approach was applied to both Senegalese and Guinean data.

## 2.4 Biomass Trophic Spectrum (BTS)

Linear models (LMs) were used to investigate the annual variation of BTS. The biomass by trophic class was used as individuals, and trophic classes, year, season, latitude classes and bathymetric classes were used as categorical variables. Biomass values were obtained from aggregated hauls by stratum, to smooth the variability between the hauls characterized by the same combination of factors. In order to better visualize the temporal variations between trophic spectra and because of missing years, some year classes were created (Table 2).

Analyses were carried out under R free software R Development Core Team (2004). The following LM model was tested:

$$B = \mu + TC + Y + L + Ba + S + \varepsilon. \quad (1)$$

Where  $B$  is the log-transformed biomass by trophic class,  $\mu$  is the intercept,  $TC$  is the trophic class (between 2.1 and 4.5),  $Y$  is the year class,  $L$  is the class of latitude,  $Ba$  is the class of bathymetry,  $S$  is the season and  $\varepsilon$  is the residuals (Table 3).

**Table 3.** Variable class used in the Linear Models (LM).

	Bathymetric Class	Season Class	Latitude Class
Senegal	1: 0–20 m 2: 20–50 m 3: 50–100 m	1: November to May 2: June to October	1: >14.75 °N 2: 13.6 to 14.75 °N 3: <13.1 °N
Guinea	1: 0–15 m 2: 15–30 m	1: November to May 2: June to October	1: >D1 2: >D2 and <D1 3: <D2  D1: Long = -Lat + 24.6 D2: Long = -Lat + 23.38

Long = Longitude; Lat = Latitude.

Interaction effects were tested between the variables, in particular those between *TC* and *Y* or *TC* and *L*. These interaction effects should reflect a different evolution of the biomass according to each trophic class, between year or latitude classes. Identity-link functions were used to relate the condition indices to the predictors. In this case, the link function is simply the mean response of the model. An analysis of deviance was performed to select the significant variables (F-test). The models were selected according to the deviance explained and the degrees of freedom considered after having tested the full range of potential interactions in the LM. The final models were checked through inspection of the scatterplots showing the relationships between residuals and predicted values and the histograms of residuals.

## 2.5 Catch Trophic Spectrum (CTS)

The same approach was used to investigate the variation of the CTS. Only 2 categorical factors were considered, the trophic classes and the year classes (Table 2), other information being not available.

## 2.6 Mean Trophic Level

Mean trophic levels (MTL) of the demersal fish community were calculated for each year from the survey data following the equation:

$$\overline{TL}_k = \frac{\sum_{i=1}^m Y_{ik} TL_i}{\sum_{i=1}^m Y_{ik}} \quad (2)$$

where  $Y_{ik}$  is the landing of species  $i$  in year or survey  $k$  and  $TL_i$  is its trophic level. The MTLs of the demersal fish catches were also estimated by applying the same equation to the landings data. Catches and indices of abundance were plotted against mean trophic levels. To test for significant long-term trends in the time-series of survey or landing MTL, non parametric Mann-Kendall tests were performed (Scherrer 1984). The Mann-Kendall test is particularly useful because data do not

need to conform to any particular statistical distribution. Differences were judged significant when  $p < 0.05$ . When a significant linear trend was found out, the true slope (change per unit time) was estimated using the procedure developed by Sen (1968).

## 3 Results

### 3.1 Trophic spectra

#### Senegal

The LM for the surveys data explained 84.5% of the deviance of the biomass by trophic class (Table 4a). There was a significant interaction between trophic class (*TC*) and year (*Y*), showing that the structure of the biomass trophic spectra has been modified since the beginning of the 70s (Fig. 2). The period considered was characterized by a decrease in the biomass for the high trophic levels (4.1–4.5) and an increase in the medium trophic levels (3.4–3.6).

The trophic structure of the catches has changed since 1981 (Fig. 3). The weight of the small pelagic fishes (trophic levels between 2.5 and 3.1) became more and more predominant in the landings (Fig. 3a). In order to analyse the variations of the trophic structure of the demersal fish community, the small pelagic species (*Ethmalosa fimbriata*, *Sardinella maderensis* and *Sardinella aurita*) were excluded from the analysis. The changes were significant according to the LM results performed on the landings data without the small pelagic species (Table 4b). The spectrum displayed a continuous decrease in the catches for the high trophic classes (4.1–4.5) during the whole period (Fig. 3b). Such a decrease was also observed from 1985 to 1999 for the trophic classes between 3.4 and 4.5.

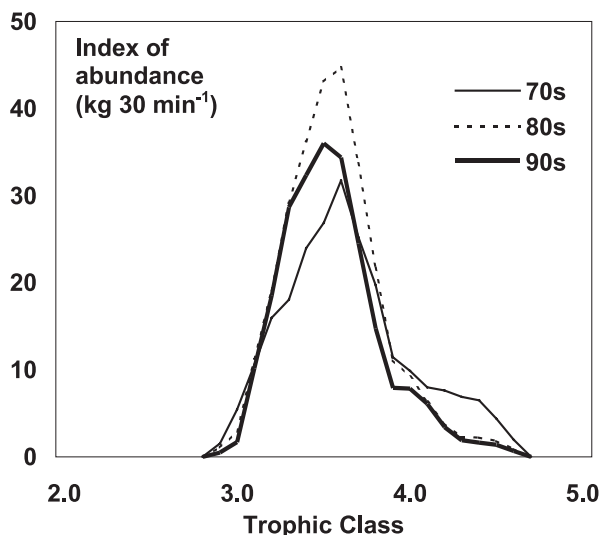
#### Guinea

The selected LM explained 72.3% of the deviance of the biomass by trophic class (Table 4c). The significant three-dimensional interaction effect showed that the temporal changes in the trophic spectra differed according to the bathymetric classes considered. For the bathymetric class 1,

**Table 4.** Linear Model (LM) results, for the biomass trophic spectra in Senegal; the catch trophic spectra in Senegal, and the biomass trophic spectra in Guinea.

Variable	Source	d.f.	<i>p</i>	Residual deviance	% Explained
<b>SENEGAL</b>					
<b>Biomass</b>					
B	Null			82.2	
	S	1	0.003	81.7	0.6
	TC	15	<0.00	20.1	75
	Y	2	<0.00	18.4	2.1
	TC*Y	30	<0.00	12.8	6.8
<b>SENEGAL</b>					
<b>Catch</b>					
B	Null			3151.6	
	Y	2	<0.00	3120.7	1
	TC	25	<0.00	352.1	87
	TC*Y	50	<0.00	60.7	9
<b>GUINEA</b>					
<b>Biomass</b>					
B	Null			2443.5	
	L	2	<0.00	2432.6	0.4
	TC*Y*B <sub>a</sub>	107	<0.00	663.6	72.3

*d.f.* = Degrees of freedom; *p* = Probability; *S* = Season; *TC* = Trophic class; *Y* = Year; *L* = Latitude; *B<sub>a</sub>* = Bathymetry.

**Fig. 2.** Biomass trophic spectra of the demersal fish community in Senegal for 3 different decades.

the biomass decreased for the trophic levels comprised between 3.2 and 4.3 from the period 1985–1989 to the period 1990–1995 (Fig. 4a). Between the periods 1990–1995 and 1997–1998, the decrease continued for high trophic levels whereas the biomass remained relatively stable for the trophic classes between 3.2 and 3.7. A different trend was observed for the bathymetric class 2 (Fig. 4b): the biomass of the high trophic classes remained at the same level and the biomass between the trophic levels 3.3 and 3.7 showed no clear trend.

For the short period covered by available data, no substantial change was visible in the structure of the catch trophic spectra (Fig. 5). The proportion of small pelagic fishes in the total landings was as important as for the Senegalese landings and seemed to increase during the period (Fig. 5a). In

**Table 5.** Mean trophic level (MTL) trend of landing with an without the small pelagic fishes.

	Mann-Kendall	Sen's slope (Trophic Level year <sup>-1</sup> )
without the small pelagic fishes	$Z = -1.6945$ $p = 0.049$	0.006
with the small pelagic fishes	$Z = -2.7143$ $p = 0.003$	0.009

the meantime, the catches of the trophic classes between 3.4 and 4.1 decreased (Fig. 5b).

### 3.2 Trends in the mean trophic level

#### Senegal

There was a significant decline in the mean trophic level estimated from the surveys for the period covering years 1971 to 1995 (Mann-Kendall  $Z = -2.05$ ,  $P = 0.02$ ; Fig. 6a). The Sen's non-parametric estimator of the slope indicated a decline of about 0.003 trophic level *TL* per year. This arose from both the biomass decrease of the high trophic levels and the biomass increase of the lower trophic levels (Fig. 2). The mean trophic level decreased significantly with the increase of the index of biomass (Mann-Kendall  $Z = -1.98$ ,  $p = 0.024$ ; Fig. 6b).

Mean trophic levels trends with or without small pelagic fish were compared. The slope of the trend was steeper when considering the small pelagics in the analysis (Fig. 7a; Table 5).

The mean trophic level of the landings decreased significantly with the increase of the landings (Mann-Kendall  $Z = -2.53$ ,  $p = 0.006$ ; Fig. 7b).

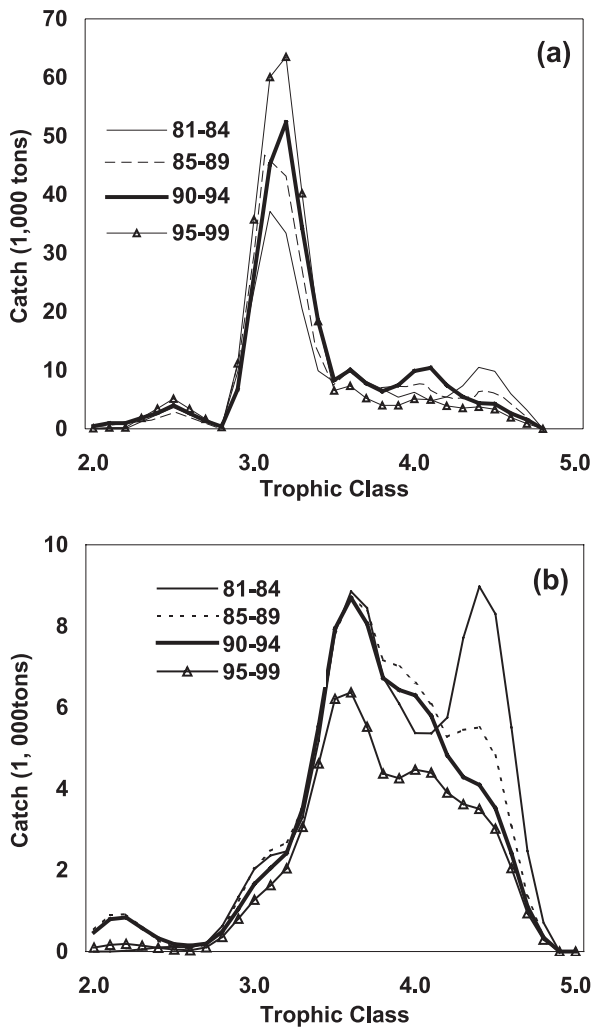


Fig. 3. Catch trophic spectra in Senegal for different periods; (a) all Senegalese landings; (b) without small pelagic species.

Guinea

No significant trend for the mean trophic level was shown from the scientific survey data (Fig. 8a). However, some significant results were obtained when considering the data by bathymetric class. The MTL of the shallower fish community (depth <15 m) showed a significant decrease (Mann-Kendall  $Z = -1.73, p = 0.04$ ; Fig. 8b). Sen's non-parametric estimator of the slope indicated a decline of about 0.006 TL per year. No significant trend was found out for deeper communities (Mann-Kendall  $Z = -0.28, p = 0.39$ ; Fig. 9). The landing catch series did not show any trend in the mean trophic level, but its extent was too short (1995-1998) to derive firm conclusions.

4 Discussion

4.1 Trophic Spectra and changes in the trophic structure

The mean trophic levels of each species considered were estimated from gut contents. This method of estimation is

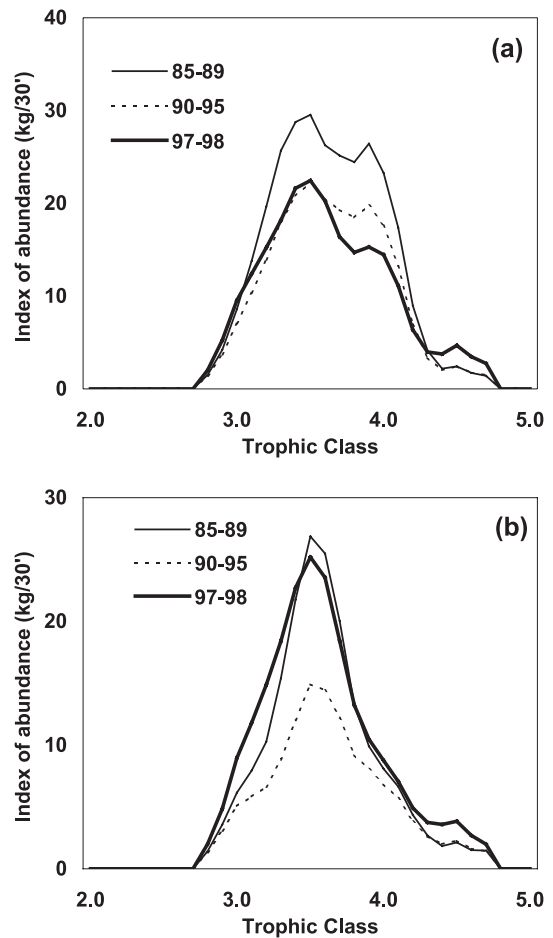


Fig. 4. Biomass trophic spectra in (BTS) Guinea in function of bathymetric classes and different periods; (a) BTS in the bathymetric class 1; (b) BTS in the bathymetric class 2.

considered to be incomplete (Pinnegar et al. 2002). It is based on snapshots of fish feeding behaviour, and temporal variations in diets are rarely taken into account (e.g. Vander Zanden and Vadeboncoeur 2002). Moreover, gelatinous plankton, detritus and polychaete species which can be important in the diet of many fishes are also rarely considered. Indeed, this part of the diet is quickly digested and therefore is difficult to identify or does not even appear in the gut contents. Many studies use stable isotopes of nitrogen for determining the trophic levels of aquatic organisms (Vander Zanden et al. 1997; Jennings et al. 2001; Post 2002). This method has the great advantage to provide a more time-integrated indication of energy provenance (Hesslein et al. 1993; Vander Zanden and Vadeboncoeur 2002). This technique could have improved our results, in particular when the slope of the mean trophic level was close to the degree of precision of the species trophic level. However, some comparisons of trophic levels estimated by stable isotope nitrogen and gut contents showed great correlations between the two approaches (Vander Zanden et al. 1997; Kline and Pauly 1998; Davenport and Bax 2002). Even if the stable isotopes of nitrogen method is considered to be more accurate, its use would likely not have changed the general results of our study. A strong assumption is that trophic levels used in the

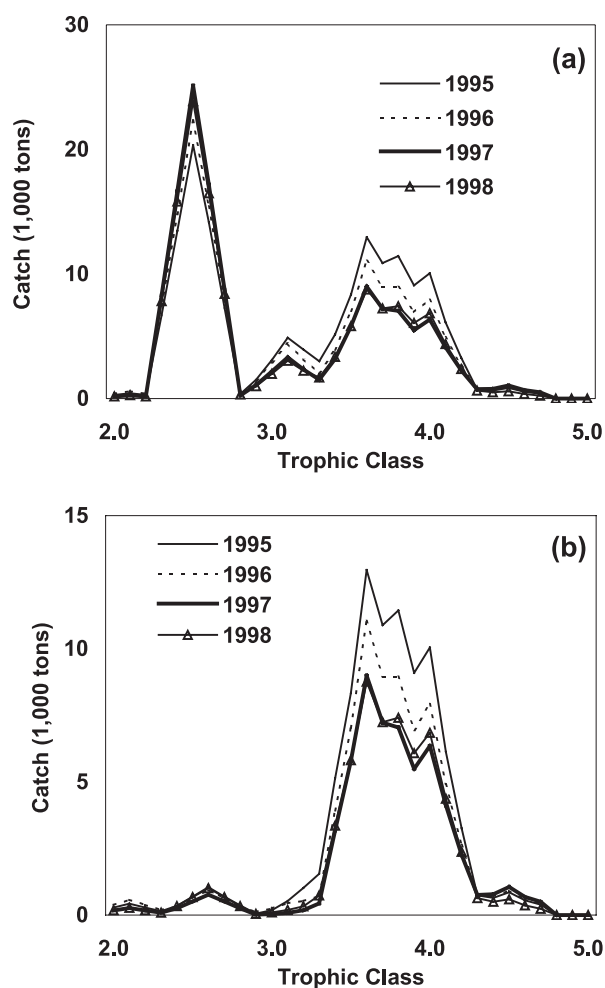


Fig. 5. Catch trophic spectra of the Guinea; (a) Total landings; (b) Landings without small pelagic species.

analysis were supposed to be constant. The same assumption was made by Pinnegar et al. (2002) and Pauly et al. (1998a, 1998b, 2001), although it was shown that species trophic levels can change with time (Adlerstein et al. 2002; Bode et al. 2003). We consider however that our results remain valid despite these necessary assumptions.

Biomass Trophic Spectra (BTS) were used in order to characterize the trophic structure of the ecosystem. A similar approach was proposed by Froese et al. (2001), defining the “trophic signature” as the plot of numbers of species in function of trophic level. Bozec et al. (in press) applied the BTS to coral ecosystems to describe human disturbances such as pollution and fishing activities. The Senegalese and Guinean BTS showed strong modifications of the demersal fish community. In Senegal, the biomass of the highest trophic levels (4–4.5) decreased while the biomass of lower trophic level (3.2–3.6) increased. This type of evolution could characterize a “top-down” effect of fishing pressure which induces a release of predation from the higher trophic levels on the trophic levels comprised between 3.2 and 3.6. Such effects inherent to fishing were observed at a high diversity of scales (Pinnegar et al. 2000) and for a few species at an ecosystem scale (Cury et al. 2000; Gucu 2002). In Guinea, the same process was only

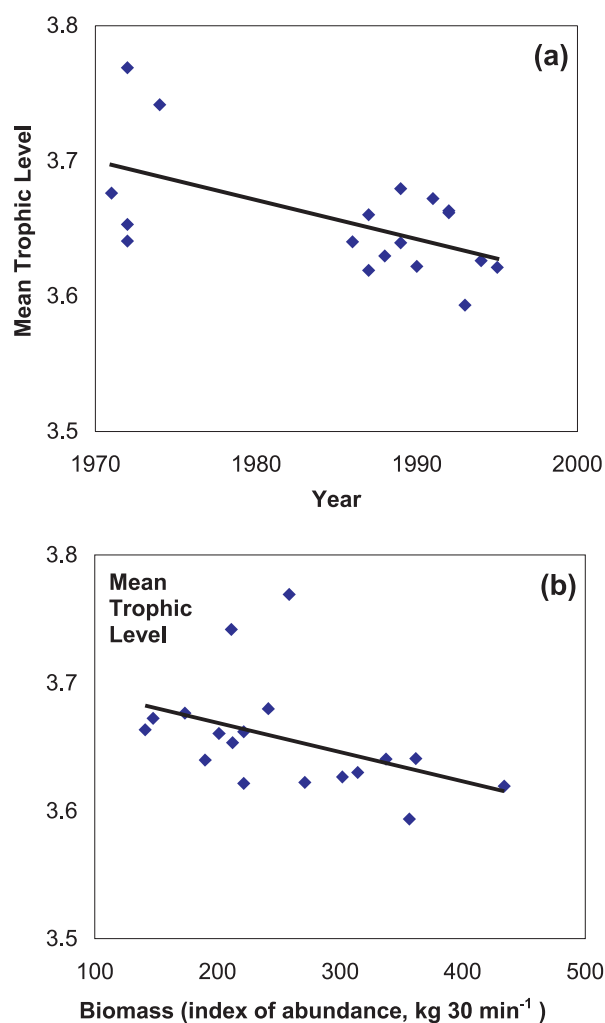
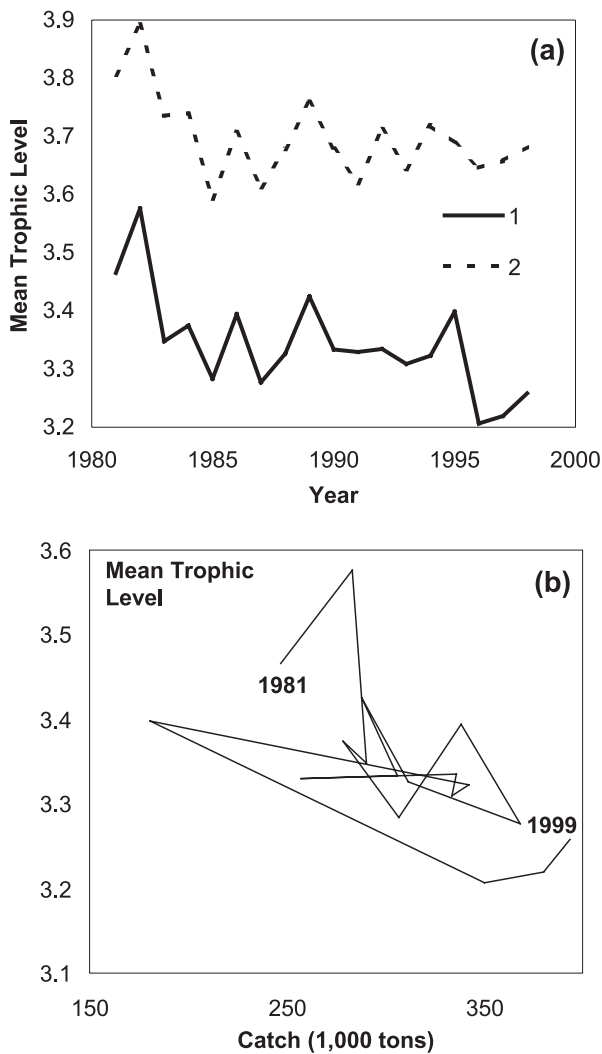


Fig. 6. (a) Trend of the mean trophic level of the biomass for the demersal fish community in Senegal estimated from survey data; (b) Relationship between mean trophic level estimated from survey data and biomass in Senegal. Linear regression model (solid lines) are used to visualise the trends.

observed in the ecosystem part comprised between 0 and 15 m. It is interesting to notice that most stocks in this area were still virgin or unexploited in 1985 whereas the offshore area was already highly exploited (Sidibé et al. 1999). First, the total biomass decreased as a response to fishing pressure. Then, the biomass of high trophic levels kept decreasing whereas the biomass of lower trophic levels increased. This could be linked to a release of predation in the demersal fish community. On the other hand, no shift was shown when the exploitation was already high in the offshore area in Guinea and in the whole shelf of Senegal during the 80s and 90s.

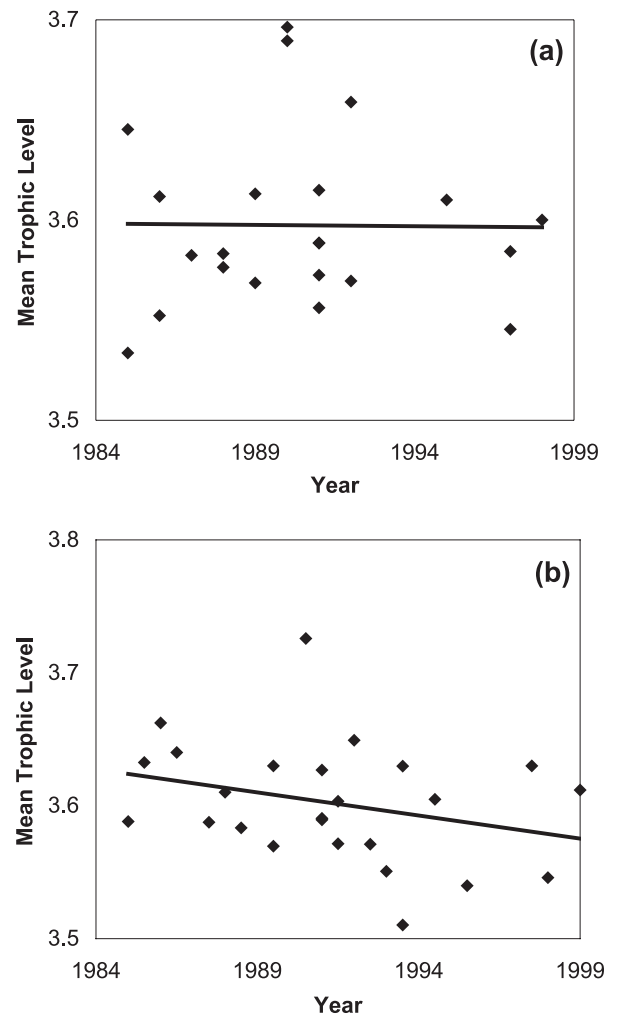
However, fishing activities are not the only factor that can influence the total biomass or the structure of an ecosystem. The influence of the climate (Planque and Taylor 1998; Faure 2000), modifications of some migration patterns, epidemic diseases or pollution could potentially affect the recruitment or the spatial distribution of fish species and hence modify the biomass trophic spectra. But in our case, the rapid development from a very low fishing activity to an intense exploitation



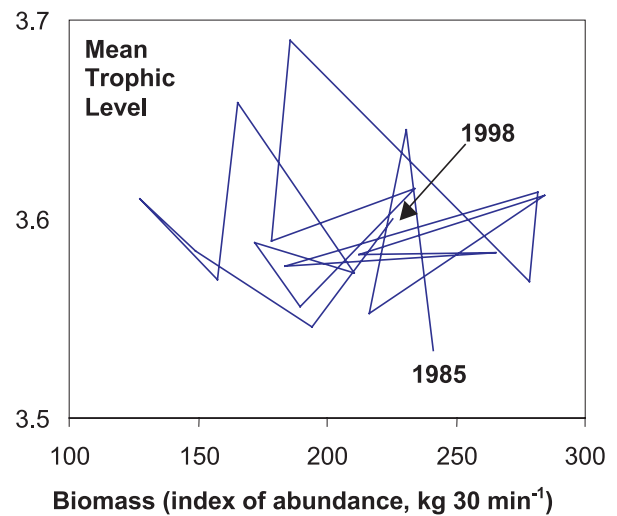
**Fig. 7.** (a) Trend of the mean trophic level estimated from landings in Senegal (1: small pelagic fishes are excluded; 2: all fishes included); (b) Relationship between the mean trophic level estimated from catches data and landings in Senegal.

points out the fishing pressure as being the main factor having affected the structure of one part of the ecosystem. However, in Senegal no trend was observed for the total biomass of demersal fish communities (Fig. 10), which then appears as being rather resistant to exploitation.

Catch Trophic Spectra (CTS) summarize the position of the targeted species and the magnitude of catches harvested in the food web (Gascuel 2004). The estimation of a CTS at different time periods enables to analyse the evolution of a fishing exploitation. A similar approach is used by Pauly et al. (2001). There are many causes which could explain the changes in a CTS structure: changes in targeted species and fishing efforts, environmental evolution, spatial and temporal variations of the biomass. Taking into account these elements enables to analyse the evolution of the CTS structure. In Senegal, the increase in biomass observed at lower trophic levels was not recorded in the demersal catches. This could mean that the available biomass is mainly based on fish species which are

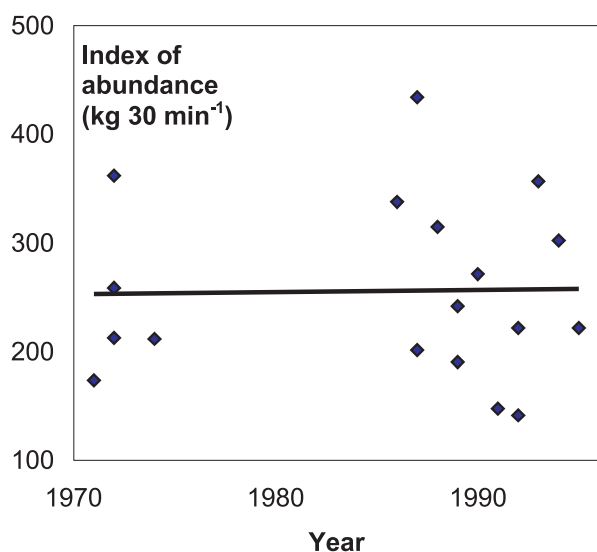


**Fig. 8.** (a) Trend of the mean trophic level estimated from biomass in Guinea; (b) Trend of the mean trophic level of biomass in Guinea for the coastal fish community (depth < 15 m). Linear regression model (solid lines) are used to visualise the trends.



**Fig. 9.** Relationship between mean trophic level estimated from survey data and biomass in Guinea.





**Fig. 10.** Trend of the total biomass of the demersal fish communities in Senegal. Linear regression model (solid lines) are used to visualise the trends.

not targeted by the fisheries for reasons of commercial interest or inaccessibility. The decrease of the high trophic levels in the Senegalese community was partly explained by the over-exploitation of species such as the thiof (*Epinephelus aeneus*) (Laurans et al. 2003). The abundance of several species belonging to the shark, ray and skate families decreased in large proportions. These species characterized by high trophic levels are very sensitive to fishing pressure (Rogers and Ellis 2000).

Combining the Biomass and Catch Trophic Spectra in an analysis seems therefore useful to describe a whole community or ecosystem structure. The plots summarize a large amount of information and allow to easily visualize potential shifts occurring in the food web of interest. However, many factors can contribute to a potential change observed and good knowledge of the evolution of the fishery as well as current stock assessments are required to explain the phenomena encountered.

## 4.2 Fishing down marine food webs

Several studies using trophic level approaches have been carried out for a better understanding of the functioning of ecosystems (e.g. Pauly et al. 2002; Post 2002; Bode et al. 2003). In marine ecosystems, they showed that the mean trophic level of fish community in a given ecosystem decreases when fishing activities are intense (Christensen 1998; Pinnegar et al. 2002). The same trend was found to occur for the mean trophic level of the catches landed (Pauly et al. 1998a,b; Pauly et al. 2001; Pinnegar et al. 2002). The results for the demersal fish community in Senegal and Guinea show a decline of the mean trophic level, correlated in time with a well-known increase of the fishing effort. To our knowledge, this is the first time that this has been observed in West Africa where the fishing exploitation is relatively recent.

In a context of global overexploitation of the main targeted demersal fishes (Gascuel et al. 2004), an increase in the demersal fish biomass corresponds to a decrease in the mean trophic

level. This could be linked to environmental factors for which species of low trophic level would react more quickly. Thus, the variation in the demersal fish biomass is associated with a reorganisation of the trophic structure of the community in which the low trophic level fishes seem to be more sensitive.

Regarding the mean trophic level trend of the Senegal landings, similar results were found on the East and West coasts of Canada from landing data (Pauly et al. 2001). Nevertheless, the decline observed from both landing data and scientific survey data was lower than the trends observed in the Celtic Sea (Pinnegar et al. 2002). In the case of the Senegal, the decline was more evident in the fishery data. This seems in contradiction with studies carried out in the Celtic Sea (Pinnegar et al. 2002) and the Gulf of Thailand (Christensen 1998), which suggested that the changes in fishery preferences are lower than the changes occurring in an ecosystem. However, the results observed in West Africa only dealt with the most exploited part of the ecosystem. In Guinea, the effect was only significant for the most coastal part of the demersal fish community, which is also the most exploited. Therefore, Guinea appears less over-exploited than Senegal regarding this type of indicators. This is in accordance with comparative analyses of single species assessment (Gascuel et al. 2004). Besides, the decrease in the mean trophic level observed in West Africa is lower than in heavily exploited ecosystems such as North Atlantic ecosystems. This could suggest that West Africa is for the moment less overexploited than North Atlantic.

The decline of  $0.009 \text{ TL year}^{-1}$  for the Senegal landings is similar to the trend of  $0.1 \text{ TL per decade}$  estimated on the global level by Pauly et al. (2001) for the last decades. In order to analyse this decrease, it is important to take into consideration the changes that occurred in the Senegalese fishery during the period (Caddy et al. 1998; Christensen 1998). Kébé (1994) showed the development of the artisanal purse seine fishery targeting small pelagic fishes. The development of this fishing activity could influence the mean trophic level of the landings (Laë et al. 2004). Therefore, the data used put into relief that a decrease in the mean trophic level of the landings can be linked to other factors than a decrease in the mean trophic level of the ecosystem.

## 5 Conclusion

Monospecific approach used in fisheries science is being criticized because it neglects important ecological issues that should be integrated in fishery management (Caddy and Cochrane 2001; Link 2002; Garcia 2004). Here, the analysis used both catch and scientific survey data and took into account 249 fish species in Senegal and 185 species in Guinea. To our knowledge, very few comparative studies on trophic structures have been carried out with so many species. The multispecific approach combined with a consideration of the trophic position of the species emphasized strong modifications in the demersal fish community, which seems to be strongly associated with the rapid evolution of the fishing effort in West Africa. But it is important to recall that this type of approach must be conducted in complement of current monospecific assessments, which remain valuable tools to characterize the potential overexploitation of the stocks.

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