Estimation of a standardized index of abundance of octopus (*O. vulgaris*) from the senegalese's artisanal fishery (1989-1994)

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Introduction

The Senegalese octopus (*Octopus vulgaris*) fishery is relatively recent. This species first appeared in commercial landings in 1986 (Caverivière, 1990), and was established as an important commercial fishery in 1989 (Caverivière, 1994). Octopus off Senegal's coast are exploited both by artisanal (small-scale) and industrial fisheries. The main fishing gears are jigging hooks in the artisanal fishery and the bottom trawl for industrial vessels.

The octopus fishery is an inshore (coastal) fishery. According to government legislation, the fishing area for commercial vessels is 6 miles off the coastline. There is no restriction for artisanal boats, and this depends on their motor-power. They can fish the same grounds as the commercial vessels. The fishing depth range varies greatly from 10 to over 100 meters.

There are two main fishing seasons which vary depending on the geographical area. In northern Senegal, the main season lies between February and May, while in central and southern Senegal, the catches are highest from June to October.

The development of the octopus fishery was strongly dependent on the expansion of new international markets. The species became important first with the appearance of Asian and subsequently of European markets (Caverivière, 1990). Currently the entire octopus catches are exported to these two destinations (Dème *et al.*, 1997).

The main objective here is to present an analysis of annual indices of abundance based on catch and effort data collected from 1989 through 1994 for Senegalese artisanal fisheries exclusively.

Materials and Methods

Observers collected catch and effort observations at the main landing sites along the entire Senegal coast. Daily (Monday to Friday) and extrapolated (Saturday and Sunday) landings were then pooled in periods of two weeks. Thus, each catch data represents total biweekly landings by port, gear and species. Fishing effort is defined as the number of trips per boat during the same period. Senegalese artisanal fishery is multi-gear and multi-species. Primarily jigging hooks capture octopus. Other gears such as traps, hand-lines, long-lines, and gillnets also catch octopus, but as bycatch.

Three areas were defined taking into account the geographical proximity of the landing ports. The first area corresponds to the North with 3 landing ports, the second area to the Central part with 4 ports and the third to the South with 3 landing ports.

Four groups of gears were characterized based on the size of the catches, the type of the boat and whether they return to the landing port daily or not. The first group (gear LC) includes boats that fish for less than 12 hours, the fishermen using jigging hooks (for octopus) and traps. The second group (gear PL) also includes boats that fish for less than 12 hours, but the fishermen use hand-lines. The third group (gear PG) is composed of fishermen fishing for more than 48 hours, using hand-lines, bottom long-lines and sometimes jigging hooks. All the other gears are included in the fourth group (gear AU).

For this analysis, only catch and effort data from the artisanal fishing units that capture octopus were considered. The dataset included a total of 2,237 observations from 1989 through 1994. Catch per unit of effort (CPUE) was estimated as total landings divided by the total number of fishing trips for each port and gear during the two-week periods.

Relative abundance of octopus was estimated using a Generalized Linear Model (GLM) approach. Briefly, observed log of catch rates (logCPUE) were modeled as a function of fixed factors including year, area, season and gear type. The annual index was then estimated from the selected model as the year effect.

The regression procedure used determines a set of systematic factors that significantly explains the observed variability. The deviance difference between two consecutive models follows a $\chi 2$ (Chi-square) distribution; this statistic was then used to test for the significance of an additional factor in the model (alpha = 0.05). The number of degrees of freedom is equal to minus one the number of additional parameters estimated. Table 1 shows the deviance analyses for octopus catch rates (logCPUE), only first degree interactions of systematic factors were considered. Final model factors and interactions were selected based on the proportion of total deviance explained by each factor/interaction and type III F test. The relative index of abundance was estimated as the least square means (LSMs) of the year factor from the selected lognormal GLM model. A back-transformation bias correction was applied to the estimated year-LSMs from the logarithm scale.

Results and Discussion

Figure 1 shows total octopus landings from 1986 to 1994. Higher catches occurred in 1989 (6,720 MT) and 1991 (8,160 MT). Total effort (i.e. number of boat-trips) per year has increased since 1989, to reach double in 1994 (fig. 2). The mean of catches per month

Model	Residual Df	Residual deviance	Change in Deviance	% of total deviance
1	2236	11282		
Year	2231	11161	122	2.6%
Year+Area	2229	11046	115	2.5%
Year+Area+Season	2227	10484	561	12.1%
Year+Area+Season+Gear	2224	8446	2038	43.8%
Year+Area+Season+Gear+Year*Area	2214	8186	261	5.6%
Year+Area+Season+Gear+Year*Area+Year*Season	2204	8030	156	3.3%
Year+Area+Season+Gear+Year*Area+Year*Season+Year*Gear	2189	7890	140	3.0%
Year+Area+Season+Gear+Year*Area+Year*Season+Year*Gear +Area*Season	2185	7359	531	11.4%
Year+Area+Season+Gear+Year*Area+Year*Season+Year*Gear +Area*Season+Area*Gear	2179	6924	434	9.3%
Year+Area+Season+Gear+Year*Area+Year*Season+Year*Gear +Area*Season+Area*Gear+Season*Gear	2173	6628	296	6.4%
*Year+Area+Season+Gear+Area*Season+Area*Gear+Season*Gear	2208	7053		

I Tableau 1
Deviance analysis of explanatory variables in the lognormal GLM model for the octopus artisanal fishery 1989-1994.
* Lognormal GLM selected model.

Analyse de déviance des variables explicatives avec le modèle GLM lognormal pour la pêche artisanale du poulpe, 1989-1994.
**Modèle sélectionné.*

(1989-1994) given in figure 3, shows that the main season occurs from June to October; an intermediate season and a low catch season occur from February to May and from November to January respectively. The distribution of catch by area is shown in figure 4. Figure 5 shows the distribution of catch by gear.

As expected, CPUE shows a highly skewed distribution. We checked that the logarithm transformation of CPUE really normalizes the distribution.

The maximum model (all factors and first-degree interactions) explained up to 41% of the total observed variability with a total of 63 parameters estimated (table 1). In this case all factors and inter-

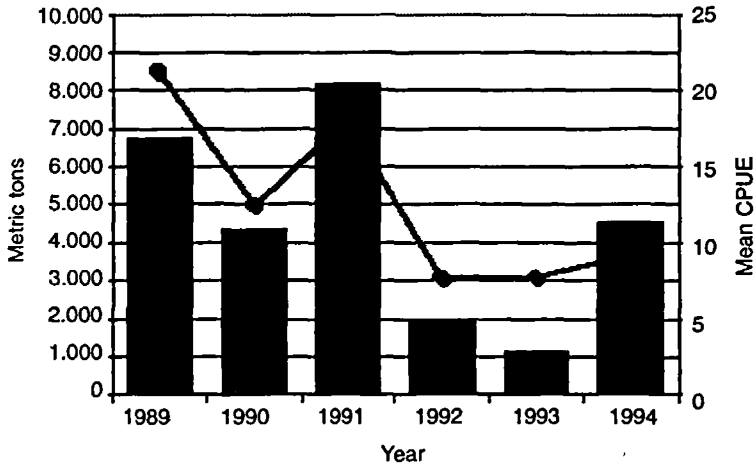

Figure 1
Total annual catches of octopus by the Senegalese artisanal fishery and Catches Per Unit of Effort (CPUE) (kg per boat-trip) (bars = Catches ; curve = CPUE)

Prises annuelles de poulpes de la pêche artisanale sénégalaise et prises par unité d'effort (CPUE, kg par sortie). (barres = Prises; courbe = CPUE).

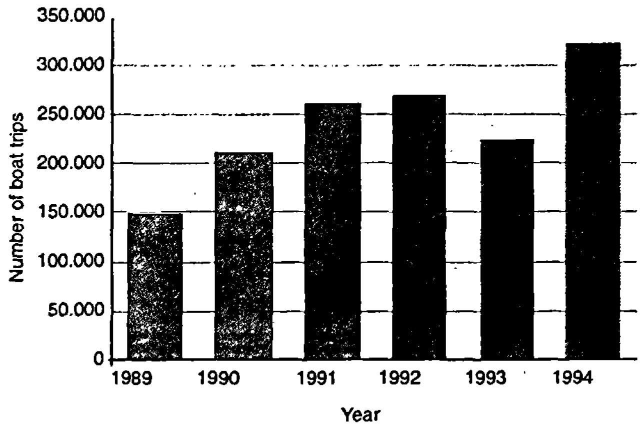

Figure 2
Total fishing effort (number of boat-trips) by year of the Senegalese's artisanal fishery 1989-1994.

Efforts de pêche annuels (nombre de sorties) de la pêche artisanale du poulpe au Sénégal, années 1989-1994.

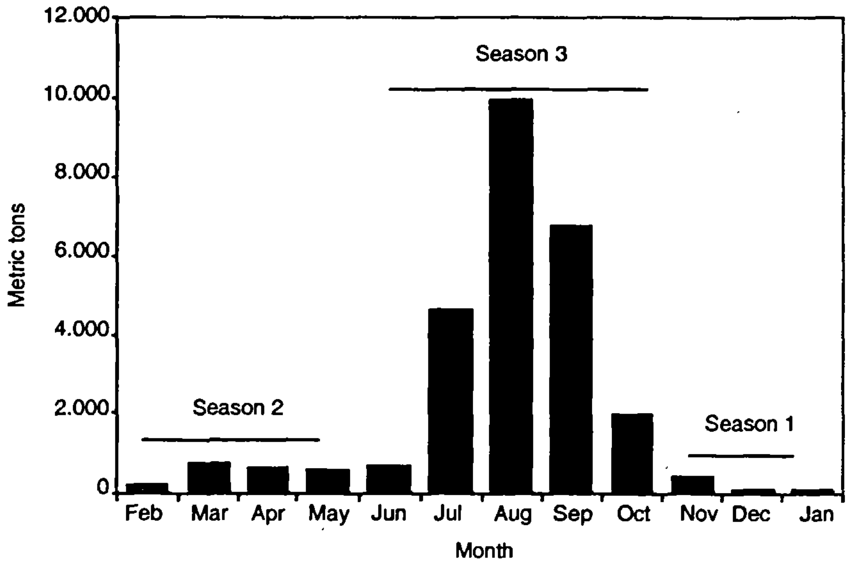

Figure 3
Distribution of octopus catches by month for the Senegalese's artisanal fishery 1989-1994.

Distribution des prises mensuelles de poulpe de la pêche artisanale, période 1989-1994.

actions were statistically significant, mainly due to the large number of degrees of freedom. However, the gear factor explained about 44% of the model's response. Season, area*season and area*gear interactions accounted for 9 to 12% of the model's response. The final model selected was:

LogCPUE = Year+Area+Season+Gear+Area*Gear+Area*Season +Season*Gear

This model explained 37.5% of the total observed variability (table 2), estimating on average 55% less parameters than the full model. Plots of residuals, standardized residuals and normalized cumulative residual plot (McCullagh and Nelder, 1989) confirm the adequacy of the model.

This result confirms the importance of the gear factor as found by


14.000
12.000
South

Summary of Fit			
Mean of response	0.1936	R-Square	0.3749
Root MSE	1.7873	Adj R -Sq	0.3669

Analysis of Variance					
Source	DF	Sum of squares	Mean square	F Stat	Prob > F
Model	28	4229.2099	151.0432	47.2855	0.0001
Error	2208	7052.9726	3.1943		
C Total	2236	11282.1825			

Types III Tests					
Source	DF	Sum of squares	Mean square	F Stat	Prob > F
Year	5	191.8090	38.3618	12.0095	0.0001
Area	2	109.5181	54.7591	17.1428	0.0001
Season	2	244.4379	122.2190	38.2618	0.0001
Gear	3	952.5231	317.5077	99.3988	0.0001
Area*season	4	385.8277	96.4569	30.1968	0.0001
Area*Gear	6	378.5081	63.0836	19.7489	0.0001
Season*Gear	6	306.2288	51.0381	15.9780	0.0001

Tableau 2
Summary of fit, deviance table and type III F test for lognormal GLM selected model

Ajustement, tables de déviance et du test type III F pour le modèle GLM lognormal sélectionné.

directly target octopus. PG and PL gear levels include hand-lines and long-lines, which also capture octopus, but mainly as accidental catch. The season area interaction reflects the spatio-temporal distribution of the fishery. Off the North coast of Senegal, the major catch of octopus occurs from February through May, while in the central and southern regions, main catches occur from June through October.

The annual index of abundance shows a high value in 1991 compared to the rest of the time series (table 3; fig. 6). For the years 1992 to 1994, the estimated abundance decreased to an average comparable to the average of 1989 and 1990. Total octopus landings

Figure 6
Annual index of octopus abundance from artisanal fisheries in Senegal.

Index annuels de l'abondance pour la pêche artisanale du poulpe.

Year	Index	CI low	CI upp
1989	1.39	1.08	1.80
1990	1.20	0.92	1.57
1991	2.96	2.35	3.72
1992	1.41	1.14	1.75
1993	1.20	0.96	1.50
1994	1.52	1.26	1.84

Table 3
Annual index of octopus abundance from artisanal fisheries in Senegal.

Index annuels de l'abondance pour la pêche artisanale du poulpe.

rall octopus abundance has remained the same except for 1991. However, no definitive conclusions can be reached in part due to the short time series of the data. It is recommended that catch and effort analysis be carried out for the years after 1994, particularly as total effort shows an increasing trend.

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