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Analysis of Ten Years Surveil of Industrial Fisheries in Senegal, 1998-2007

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Abstract

The present study makes the current situation of the surveillance (supervision) of fisheries in Senegal. So, it allows measuring the impact of the implementation of the Vessels Monitoring System (VMS) in the strategies of inspection and control. The state of exploitation of the resources appears through the reduction in the landings, what denotes of a pressure supported on the main stocks exploited by the small-scale fishing and the industrial fishing boat. This reduction requires the implementation of various strategies regarding management and regarding development of the resources. The fisheries surveillance appears in this respect as a tool working to the correct application of laws and regulations governing the activities of fishing. So, during the decade 1998-2007, period when this study was confined, the exploitation of the boardings database allowed to determine the evolution of the noticed breaches, which will have to serve as medium to judge the options and the strategies of control. On the basis of statistical tools, satisfactory results were obtained in consideration of the objectives of departure. From the interpretation and the discussion of the results ensue the necessity of strengthening and even of perpetuating the VMS which, coupled with the other systems of inspection would act as transverse solution to the troubles of the surveillance. This is consolidated by its positive impacts from the point of view of the optimization of the means of surveillance, of its efficiency through the targeting of the inspections and finally its dissuasive effect with an almost permanent follow-up. However, the fisheries surveillance calls on to a conjugation of efforts in the scale subregional even worldwide for a long-lasting management of the resources.

Keywords: Fishery, Surveil, breaches, control, VMS.

1. Introduction

In Senegal, fishing is a key economic, sociological and nutritional sector. After the decline in the export of groundnut and phosphates in the 1970s fishing gained an important place in the economy of the country (Ganapathiraju and Pitcher, 2006). With 36 kg per year, Senegal has the second highest fish consumption per capita in Africa (York and Gossard, 2004). The fishing sector currently employs more than 600 000 people, about 20 000 pirogues and 100 industrial fishing vessels. It ensures the satisfaction of more than 75% of protein consumption of animal origin of the population of the country (York and Gossard, 2004). Furthermore, the motorization of pirogues combined with the increase in market demand for fishery products and free access for artisanal fisheries contributed to the increase in the volume of landings (Lenselink, 2002). Subsequently, these favorable conditions led to a decline in the fishing sector in Senegal (Dahou et al., 2001). The resulting overcapacities in fisheries have led to the overexploitation of several stocks (Thiao et al., 2012 and Laurans et al., 2004).For all these reasons, fishing must therefore be subject to special protection and surveil. Fisheries surveil is defined as the correct application of rules governing fishing activities.

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It aims to work towards the protection of ecosystems and the restoration of overexploited resources. Sustainable fisheries resources are renewable by reproduction of individuals. The success of sustainable fisheries development therefore depends fundamentally on the existence of a legal framework guaranteeing the best conditions for a more rational and rigorous management of fisheries resources and effective surveil of fisheries. The particularity of fisheries surveil, especially in developing countries such as Senegal, is the requirement of adequate means that are very costly. For that purpose Senegalese State has made significant investments in order to achieve the protection and sustainable management of fisheries resources. In the balance sheet, there have been deep changes in the fisheries surveil system, particularly in means and methods of inspection and control. The global objective of this study is to provide an update on infractions during the decade 1998-2007.The specific objectives are based on measuring the level of performance of the means and surveil system and ultimately propose the best strategies for limiting infractions whose total disappearance is certainly illusory. This publication will contribute (i) to a better knowledge of the dynamics of the infringements noted over the years (ii) to the improvement of surveil and protection system currently in use in Senegalese fisheries.

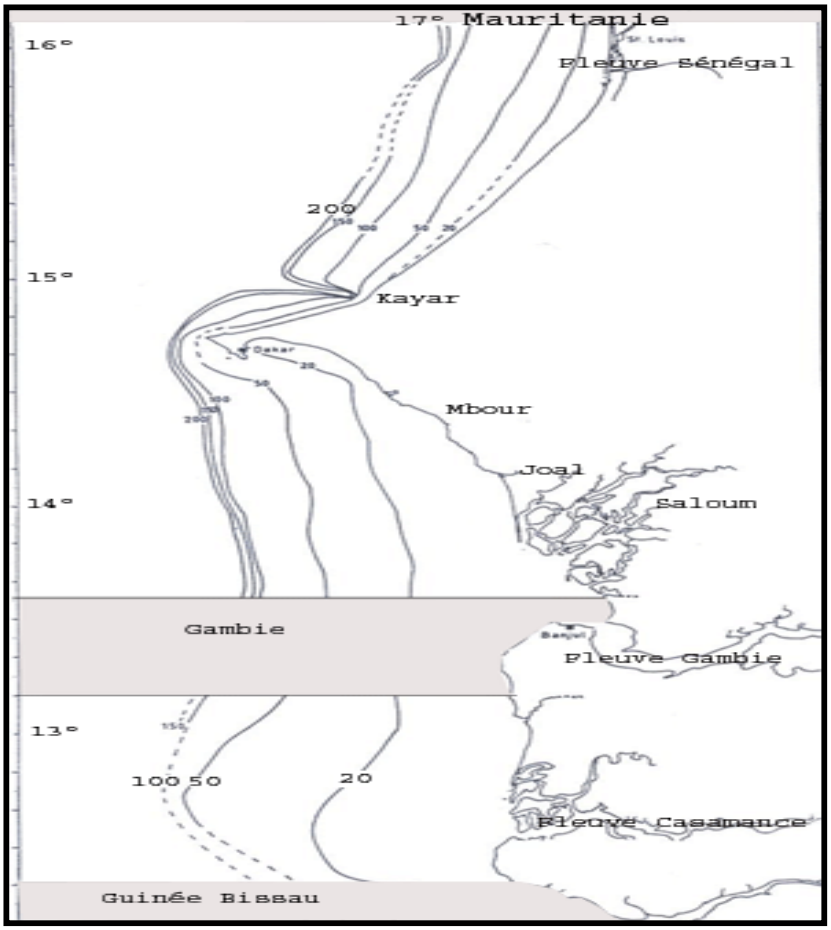
2 Materials and Methods

2.1 Materials

2.1.1 Site of the Study

The study covers all marine waters under Senegalese jurisdiction, including coastal areas where the Fisheries Protection and Surveil head office (DPSP) and its related structures carry out fisheries surveil activities. In this regard, Senegal has a continental shelf of 196 000 km² area and a coastline of 718 km long (Figure 1).

Figure 1. Study location



2.1.2 Data Source

The data analyzed comes from the computer service of the DPSP where there are 4 operational databases, mainly in ACCESS® format:

- An "industrial vessel" database containing the characteristics of the vessels and the history of their fishing licenses. This database is compiled from (i) the information contained in the register of vessels maintained by the Merchant Navy; and (ii) information on the issuance of fishing licenses from the DPM (Maritime Fisheries Head Office). It is used to establish the list of duly authorized industrial vessels and is used for the control operations of the Navy, the Air Force and the DPSP. "Authorizations" are defined in terms of areas, type of fishing and fishing gear;
- a "boarding" database, which is a fundamental management and monitoring tool of the DPSP;
- an "observer" database centralizing the details of observer reports, including catches by haul;
- a "wharf inspection and other databases" database to track the work of wharf inspectors.

Since the monitoring of air and maritime operations was not computerized, the data were obtained from the operation of the registers through the various offices. These databases are not linked (no use as relational databases) between them. The other data come from the survey questionnaires to assess the impact of the Vessel Monitoring System (VMS) in the survey process.

2.1.3 Nature Of Data

2.1.3.1 Annual Infringements

The data consists of a contingency table comprising 26 rows and 10 columns:
- the lines / records correspond to infringements
- columns / variables are years from 1998 to 2007, i.e. a decade (10 years)
- Input data are numbers of annual infringements (Table 1)

Table 1. Infringements from 1998 to 2007

Infringements	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
ALIC	1	4	4	6	1	5	0	0	5	0
FAUD	1	0	0	0	0	0	0	1	0	0
MANC	10	6	12	12	8	14	9	5	7	4
ALIB	4	4	3	6	0	0	1	2	0	1
OBST	4	4	5	3	3	2	6	2	3	2
PNAU	6	0	7	4	8	7	0	3	0	3
ZINT	23	16	9	16	20	7	7	7	7	2
CINT	0	1	0	0	0	0	0	0	0	0
REFO	0	1	0	0	0	1	1	0	0	0
TRAN	0	2	0	1	2	1	0	0	0	4
DFIL	0	0	2	0	0	0	0	0	0	0
AJDP	0	0	4	1	0	0	1	0	1	0
LINC	0	0	0	10	2	0	1	0	0	1
JUVE	0	0	0	4	1	3	1	1	0	0
POBS	0	0	0	0	2	0	0	0	0	0
MQNC	0	0	0	0	7	0	0	0	0	0
DIPR	0	0	0	0	1	0	0	0	0	0
MERL	0	0	0	0	0	2	0	1	0	0
PERB	0	0	0	0	0	13	0	1	0	0
ZIAL*	0	0	0	0	0	0	0	1	0	0
ZIOB*	0	0	0	0	0	0	0	1	0	0
CHAU	0	0	0	0	0	0	0	0	1	0
FAPO	0	0	0	0	0	0	0	0	1	0
MNUC*	0	0	0	0	0	0	0	0	1	0
FJDP	0	0	0	0	0	0	0	0	1	0
PIMM	0	0	0	0	0	0	0	1	2	1

The 26 infringements consist of 23 simple infringements and 3 double infringements (marked with an asterisk *), themselves, combinations of simple infringements, the description of which is as follows:

- ALIC = no license. Here, the vessel, not yet licensed, begins fishing after having started the administrative procedure, including payment of a receipt to the public treasury;
- FAUD = false statements. Example: Species and tonnages declared by the Commanding Officer are not in compliance with what is noted in the holds;
- MANC = non-conforming mesh. It is an infringement found after determining the average of 25 consecutive meshes, which is lower than the regulatory average. Example: For a vessel targeting fish and cephalopod, a mesh of 70 mm is required. If an average of 65 mm is found on a net that has fished, the vessel is in violation;
- ALIB = no license on board. In this case, the vessel holds a license but does not have it on board;
- OBST = obstructions. This involves the use of a device that obstructs the net and thus reduces its selectivity;
- PNAU = unauthorized fishing. This is the case for vessels not authorized to fish in the Senegalese Exclusive economic zone (EEZ). Ex: ship engaged in piracy along maritime borders and making inroads at the appropriate time;
- ZINT = prohibited area. Depending on the type of license and the GRT, the vessel must operate in a well-defined area. It is an offense if it operates elsewhere. For example, a 150 GRT targeting fish and cephalopod operates in the 6/7/6 zone, that is: a) beyond the 6 nautical miles between the Mauritanian border and Cape Manuel Point b) beyond Of the 7 miles from Cape Manuel to the Gambia's northern border and c) beyond the 6 miles of the southern border of the Gambia to the Guinean Bissau maritime boundary;
- CINT = freezing prohibited. It is an offense noted on board fresh fishing vessels engaged in freezing; which is a deliberate change of option without prior authorization;
- REFO = refusal to comply. Here, the ship's commander deliberately refuses to execute the order from a surveillance vessel;
- TRAN = transshipment. This is the case of the transfer of catches at sea from ship A to another vessel B without prior authorization;
- DFIL = double wire. It is the use of a net of thread, the meshes of which are made with a double thread instead of a thread; Which may cause a reduction in the mesh opening;
- AJDP = no fishing log. The vessel does not have a log for the transcription of its fishing positions;
- LINC = non-compliant license. A vessel engaged in fishing activities that is not in compliance with its class of license;
- JUVE = capture of juveniles, i.e. capture and possession of species whose size and weight are lower than those authorized by regulation;
- POBS = no observers on board. Foreign vessels authorized to operate in the Senegalese EEZ are required to take on board an observer of the DPSP during all their fishing activities, failing which they engage in illegal fishing;
- DIPR = concealment of evidence. The Commanding Officer commits an offense of which he tries to conceal the evidence from the inspection team;
- MERL = unauthorized fishing of hake Merluccius sp. There is normally a "merlus" fishing option granted only to vessels that own it ("merluttiers"). The holding of by-catches of hake is strictly prohibited to fish-and-shrimp vessels "coastal demersal" option;
- PERB = fishing during biological rest;
- ZIAL * = no zone + no license. It is a double offense noted with a fishing vessel, not only in the prohibited zone (ZINT), not having an additional license on board (ALIB); Hence, ZIAL = ZINT + ALIB;
- ZOOB * = prohibited area (ZINT) + obstructions (OBST). It is also a double offense; Where ZIOB = ZINT + OBST;
- CHAU = use of "sock", a term meaning a cod-net with a very small mesh size, but also a specific net obstruction device;
- FAPO = transcription of false positions. The commander transcribes in his fishing log positions which, after verification and confrontation with other means, prove to be false;
- MNUC * = mesh not conforming (MANC) + use of socks (CHAU); Hence MNUC = MANC + CHAU;
- FJDP = fishing log fraud. The ship's commander tries to overload or alter his fishing positions, for example;
- MQNC = not conforming marking. The marks on the ship, with a view to better identification, are not in conformity;

• PIMM = fishing for immature octopus. It is strictly forbidden to fish Octopus vulgaris of less than 350 grams of uneviscerated weight.

2.1.3.2 Other Parameters

In addition, we took into account a second table of data (Table 2), taking us back to the same years 1998 to 2007 (columns) and taking into account online:
• vessels authorized to fish (AUTO)
• Various inspection alternatives: at wharf (QUAI), at sea (MER), over flight (AIR)
• noted infringements (INFR)
For INFR, special attention was given to offenses in the prohibited zone (ZINT).

Table 2.Vessels authorized to fish which were inspected and having committed infringements from 1998 to 2007

Vessels	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Authorized to fish (AUTO)	332	292	286	289	252	235	212	196	164	137
Inspected at wharf (QUAI)	138	124	165	419	408	714	694	464	631	647
Inspected at sea (MER)	82	34	166	101	33	27	33	60	33	20
Inspected by over flight of an aircraft (AIR)	545	657	833	380	157	386	258	569	282	364
Infringement (INFR)	49	38	46	63	55	55	27	26	29	18
Infringement by entering a prohibited zone (ZINT)	23	16	9	16	20	7	7	7	7	2
ZINTinfringement detected by DPSP (DPSP)	6	3	2	5	5	6	6	2	7	2

2.2 Methods

2.2.1 Univariate Treatments

An elementary statistical treatment, limited to calculation of the sum, the mean, the average (m), the standard deviation (e) and the coefficient of variation which is the ratio of the mean to the standard deviation (m / δ) expressed in percent, is applied to the data in Tables 1 and 2.

2.2.2 Bivariate Treatments

The PEARSON linear correlation coefficient is determined between the 7 variables in Table 3. Its r value varies between -1 and +1. It can indicate a positive (r ~ 1), zero (r ~ 0) or negative (r ~ -1) linear linkage. The significance rate is set at <5%. Beyond this, there is no effect, ie no significant correlation.

2.2.3 Mulvariate Treatments

The data in Table 1 were the subject of a factorial correspondence analysis taking simultaneously into account the 26 lines (infringements) and the 10 columns (years). The term "correspondence" comes from the fact that one seeks to characterize the resemblance / dissimilarity between infringements and years via the metric of khi².
Factorial correspondence analysis is a specific technique for studying enumeration tables (contingency tables). It uses comparisons of profiles or proportions, independently of the particular abundance of a variable or a line (Pages, 2005). Thus, here:

• the total numbers of each infringement and each year are first calculated
• each box of an infringement (line) is divided by the total number of infringements
• each one-year box (column) is divided by the total number for that year
• In this way, instead of the gross starting numbers, we have now percentages (%)
• the distance of Khi² is calculated on these profiles

Like all factorial methods, the Factorial correspondence analysis creates artificial variables (factors or factorial axes) of maximum variance, uncorrelated to each other and closely related to the initial variables that they summarize. The Eigen values (VP), quantify the part of the inertia or the initial variance explained by the different axes created. They are expressed as raw numbers and percentages (simple and cumulative) of the initial variance. The VPs are between 0 and 1. Any factor associated with a VP ~ 1 translates a strong link between the rows and the columns.

Values too low, close to 0, suggest the opposite. The greater the contribution (CTR) and the coordinates (COORD) of a row or column to the variance of a created axis, the better is the interpretation of this axis. The different elements (row or column) can be visualized on the correlation circles of the variously combined factorial planes: axes 1,2, axes 1,3, axes 3,4, and so on. The closer an element is to the end of the circle on a factorial axis, the better its quality of representation, the greater its CTR and COORD, and vice versa. Thus, it is difficult to decide on the elements too close to the center of the circle of a given factorial plane because of their poor quality of representation. The univariate analyzes were carried out using the EXCEL ® software. The software for the processing of bivariate and multivariate analyzes is STATBOX version 6.4 available under EXCEL®.

3. Results

3.1. Elementary Statistics

3.1.1. Gross Infringements

In total, 406 infringements were recorded during the 1998-2007 decade, the most frequent of which were for fishing in prohibited zone (ZINT, 28%) and non-conforming mesh (MANC, 21%). Thus, these two infringements alone account for almost half (49%) of the total. They are, with obstructions (OBST), the least subject to variation because their coefficients of variation (CV) do not exceed 60%. This is evidence of a greater tightening of their values around their respective averages. On the other hand, the other infringements show a very high variability ($93\% \leq CV \leq 316\%$) (Table 3).

Table 3. Basic statistics for infringements (* Double infringements)

Infringements	Total	%	Mean	Standard deviation	Coefficient of variation
ALIC	26	6 %	2,6	2,41	93%
FAUD	2	0 %	0,2	0,42	211%
MANC	87	21 %	8,7	3,30	**38%**
ALIB	21	5 %	2,1	2,08	99%
OBST	34	8 %	3,4	1,35	**40%**
PNAU	38	9 %	3,8	3,12	82%
ZINT	114	28 %	11,4	6,85	**60%**
CINT	1	0 %	0,1	0,32	316%
REFO	3	1 %	0,3	0,48	161%
TRAN	10	2 %	1	1,33	133%
DFIL	2	0%	0,2	0,63	316%
AJDP	7	2%	0,7	1,25	179%
LINC	14	3%	1,4	3,10	221%
JUVE	10	2%	1	1,41	141%
POBS	2	0%	0,2	0,63	316%
MQNC	7	2%	0,7	2,21	316%
DIPR	1	0%	0,1	0,32	316%
MERL	3	1%	0,3	0,67	225%
PERB	14	3%	1,4	4,09	292%
ZIAL*	1	0%	0,1	0,32	316%
ZIOB*	1	0%	0,1	0,32	316%
CHAU	1	0%	0,1	0,32	316%
FAPO	1	0%	0,1	0,32	316%
MNUC*	1	0%	0,1	0,32	316%
FJDP	1	0%	0,1	0,32	316%
PIMM	4	1%	0,4	0,70	175%
Total	**406**				

3.1.2. Annual Infringements (Table 4)

The most notable infringement shares are registered before 2004: 16% in 2001, 14% in 2002, 14% in 2003, 12% in 1998 and 11% in 2000. These 5 years together represent 2/3 (67 %) of infringements. Annual proportions decline beyond 2004 to their lowest level in 2007 (4%).The variability of infringements is very high in any year, based on their CV between 170% in 2005 and 261% in 1998.If we consider the years prior to 2005, on the one hand, after 2005, on the other hand, the average infringements committed during the 1st period, 48 in number, are reduced by half during the second period. Fishing infringements in prohibited zone are reduced to 1/3 between the two periods. It should be noted that the year 2005 corresponds to the introduction of the VMS in the surveilsystem of industrial boats in Senegal.

Table 4. Basic statistics of annual infringements

Years	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Infringements number	49	38	46	63	55	55	27	26	29	18	**406**
Percentage	12 %	9 %	11 %	16 %	14 %	14 %	7 %	6 %	7 %	4 %	**100**
Mean	1.88	1.46	1.77	2.42	2.12	2.12	1.04	1.00	1.12	0.69	
Standard deviation	4,9	3,4	3,2	4,3	4,4	4,0	2,4	1,7	2,1	1,3	
Coefficient of variation	261%	233%	183%	177%	208%	187%	230%	170%	187%	182%	

3.1.3. Other Studied Parameters

The mean, standard deviations and coefficients of variation calculated for the other studied parameters (AUTO, QUAI, SEA, AIR, INFR, ZINT and DPSP) are shown in Table 5. Thus, during the period 1998-2007, on average and per year we have:

- 240 vessels authorized to fish
- 440 inspections at wharf
- 59 inspections at sea
- 443 inspections by over flight
- 41 infringements
- 11 infringements by entering prohibited zone
- 4 infringements identified by the DPSP in the prohibited zone.

Table 5. Means, standard deviations and coefficients of variation of other parameters

Parameters	Means	Standard deviations	Coefficients of variation (%)
AUTO	240	62	26 %
QUAI	440	233	53 %
MER	59	46	78 %
AIR	443	205	46 %
INFR	41	15	37 %
ZINT	11	7	64 %
DPSP	4	2	50 %

The number of vessels authorized to fish is the least changing variable with a variation around its mean (CV of AUTO = 26%), unlike the number of inspections at sea (MER CV = 78%) which, from one year to another, experience levels:

- sometimes too high (166 and 101 inspections, respectively in 2000 and 2001);
- sometimes too low (20 and 27 inspections, respectively in 2007 and 2003).

3.2. Linear Correlations

In terms of linear correlation (Table 6):

a) there is a significant negative correlation at 5% between QUAI and AUTO (r = -0.79), QUAI and AIR (r = -0.70), QUAI and ZINT (r = -0.69). Clearly, the same variable, inspections at wharf, evolves in the opposite direction of:

• number of vessels authorized to fish;
• air inspections;
• infringements related to fishing in prohibited zone.

b) there is a significant 5% positive correlation between AUTO and INFR (r = + 0.74), AUTO and ZINT (r = + 0.82), MER and AIR (r = + 0.68) and INFR and ZINT +0.67), i.e.:

• the greater the number of vessels authorized to fish, the more violations and those committed in the prohibited zone increase;
• the higher the number of air inspections (over flights), the more those carried out at sea;
• the more infringements increase, the more those in the prohibited zone increase

Table 6. Values of the correlation coefficient

		AUTO	QUAI	MER	AIR	INFR	ZINT	DPSP
AUTO	Pearson Correlation	1	-0.794**	0.557	0.453	0.743*	0.824**	0.094
	Sig. (bilateral)	-	0.006	0.095	0.188	0.014	0.003	0.796
	N	10	10	10	10	10	10	10
QUAI	Pearson Correlation	-0.794**	1	-0.592	-0.702*	-0.343	-0.689*	0.336
	Sig. (bilateral)	0.006	-	0.071	0.024	0.332	0.028	0.343
	N	10	10	10	10	10	10	10
MER	Pearson Correlation	0.557	-0.592	1	0.679*	0.394	0.211	-0.303
	Sig. (bilateral)	0.095	0.071	-	0.031	0.260	0.559	0.395
	N	10	10	10	10	10	10	10
AIR	Pearson Correlation	0.453	-0.702*	0.679*	1	0.014	0.035	-0.609
	Sig. bilateral)	0.188	0.024	0.031	-	0.970	0.923	0.062
	N	10	10	10	10	10	10	10
INFR	Pearson Correlation	0.743*	-0.343	0.394	0.014	1	0.667*	0.325
	Sig. (bilateral)	0.014	0.332	0.260	0.970	-	0.035	0.360
	N	10	10	10	10	10	10	10
ZINT	Pearson Correlation	0.824**	-0.689*	0.211	0.035	0.667*	1	0.277
	Sig. (bilateral)	0.003	0.028	0.559	0.923	0.035	-	0.438
	N	10	10	10	10	10	10	10
DPSP	Pearson Correlation	0.094	0.336	-0.303	-0.609	0.325	0.277	1
	Sig. (bilateral)	0.796	0.343	0.395	0.062	0.360	0.438	-
	N	10	10	10	10	10	10	10

** The correlation is significant at level of 0.01 (bilateral).
* The correlation is significant at the 0.05 level (bilateral)

3.3 Multivariate Analyzes

3.3.1 Eigenvalues

The first 4 factorial axes, which capture nearly 68% of the initial point cloud, are retained for the remainder of the analysis. This choice can be justified by the satisfactory nature of the captured proportion of initial inertia, ie more than 2/3 of the latter (Table 7, Figure 2).

Table 7. Raw eigenvalues in %

Factorial axes	Axe F1	Axe F2	Axe F3	Axe F4	Axe F5	Axe F6	Axe F7	Axe F8	Axe F9
Eigenvalues	0.27	0.22	0.16	0.13	0.12	0.10	0.09	0.04	0.03
Variance (%)	23.21	19.19	14.10	11.22	9.96	8.44	7.60	3.67	2.62
Cumulative variance (%)	23.21	42.40	56.49	67.71	77.67	86.12	93.72	97.38	100.00

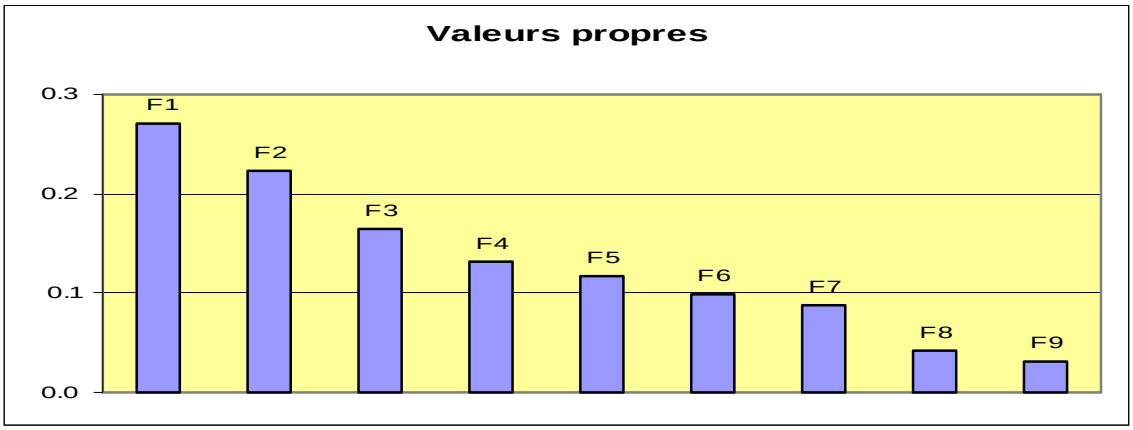


Figure 2. Diagram of eigenvalues

3.3.2 Contributions

A single criterion for helping to interpret factors for factorial axes is considered, namely the condition: contribution or CTR> 10% for each type of infringement and for each year.

3.3.2.1 Contributions Of Infringements (Table 8)

The main infringements that contributed to the creation of the 4 factorial axes were:

• PERB, fishing during biological rest, up to 66% on the first axis, i.e. nearly 2/3 of the contributions on this axis;

• MQNC, non-conforming marking, credited with 23% on the 2nd axis, i.e. close to ¼ of the contributions on this axis;

• MQNC (non-compliant marking) and ALIB (no license) with 24% and 13% of contributions on this axis, i.e. cumulatively 37% (about 2/5);

• LINC (non-compliant license) with 28%, ZIAL (zone forbidden + no license) with 16%, ZIOB (zone forbidden + obstructions) and FAUD (false declarations) with 14%, i.e. cumulatively 64% of the contributions on this axis. The infringements ZIAL and ZIOB are of double type.

Table 8. Contribution of infringements

Infringements	Axe F1	Axe F2	Axe F3	Axe F4
ALIC	0.50	7.33	0.43	7.12
FAUD	0.01	0.01	0.47	14.21
MANC	0.76	1.19	0.19	0.02
ALIB	1.65	0.31	13.46	0.41
OBST	0.97	1.76	0.43	0.76
PNAU	0.50	5.48	0.24	1.02
ZINT	6.10	0.83	0.01	4.05
CINT	0.21	0.08	0.49	0.04
REFO	0.85	0.03	0.44	0.07
TRAN	0.45	1.87	0.22	2.68
DFIL	0.10	0.66	0.95	0.11
AJDP	0.48	4.34	0.71	0.27
LINC	2.53	0.88	8.12	27.54
JUVE	2.35	0.65	1.32	3.08
POBS	1.41	6.61	6.83	0.06
MQNC	4.95	23.14	23.92	0.21
DIPR	0.71	3.31	3.42	0.03
MERL	8.66	0.18	0.05	2.48
PERB	65.76	1.65	1.71	1.35
ZIAL	0.26	0.00	0.20	16.11
ZIOB	0.26	0.00	0.20	16.11
CHAU	0.11	8.06	7.45	0.18
FAPO	0.11	8.06	7.45	0.18
MNUC	0.11	8.06	7.45	0.18
FJDP	0.11	8.06	7.45	0.18
PIMM	0.07	7.47	6.38	1.54

3.3.2.2 Contributions of Years (Table 9)

The main years that contributed to the creation of the 4 factorial axes were:

- The years 2003 (78%) and 2002 (11%) on the first factorial axis. The year 2003 contributes for more than ¾ and the two years for almost 9/10 (89%) on this axis;
- The years 2006 (52%) and 2002 (41%) on the 2nd factorial axis. The year 2006 contributes for more than half, the two years for more than 9/10 (93%) on this axis;
- The years 2006 (36%), 2002 (31%) 2001 (19%) on the 3rd factorial axis. These 3 years contribute overall to nearly 9/10 (86%) on this axis;
- The years 2005 (55%), 2001 (29%) and 1998 (11%) ensure almost all the contributions - 95% overall on the 4th factorial axis.

Table 9. Contributions of years

Years	Axe F1	Axe F2	Axe F3	Axe F4
1998	2.12	0.13	2.25	**11.15**
1999	2.18	0.66	3.07	0.20
2000	0.62	3.38	3.58	0.33
2001	2.30	0.00	**18.99**	**28.49**
2002	**10.53**	**40.72**	**30.92**	0.21
2003	**78.47**	1.69	1.53	2.98
2004	0.41	0.89	3.25	0.00
2005	1.82	0.00	0.84	**54.86**
2006	0.90	**52.34**	**35.56**	0.68
2007	0.64	0.19	0.00	1.10

3.3.3 Correlation Circles

Circles of correlations are plane charts where both infringements / lines and years / variables can be projected. The coordinates of these elements (infringements and / or years) as well as their degree of linkage (correlations) are visible in particular. The factorial plane 1.2 - the most instructive of all - is illustrated in Figure 3.
For description of plan 3,4, we will limit ourselves to examining the coordinates of the infringements (Table 10) and the years (Table 11).

Figure 3. Circles of correlations of factorial plane 1, 2

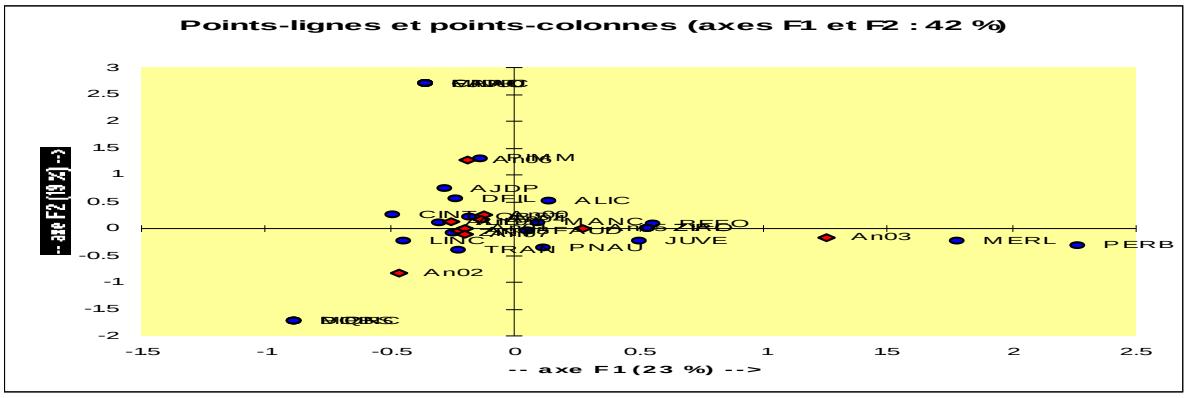


Table 10. Coordinates of infringements for the first 4 factor axes

Infringements	Axe F1	Axe F2	Axe F3	Axe F4
ALIC	0.15	0.51	0.11	-0.38
FAUD	0.06	-0.05	-0.40	1.94
MANC	0.10	0.11	-0.04	-0.01
ALIB	-0.29	0.12	-0.65	0.10
OBST	-0.18	0.22	-0.09	0.11
PNAU	0.12	-0.36	0.07	0.12
ZINT	-0.24	-0.08	-0.01	0.14
CINT	-0.48	0.27	-0.57	0.15
REFO	0.56	0.09	-0.31	-0.11
TRAN	-0.22	-0.41	0.12	-0.38
DFIL	-0.23	0.55	-0.56	0.17
AJDP	-0.28	0.75	-0.26	-0.14
LINC	-0.45	-0.24	-0.62	-1.02
JUVE	0.51	-0.24	-0.30	-0.40
POBS	-0.88	-1.73	1.51	-0.13
MQNC	-0.88	-1.73	1.51	-0.13
DIPR	-0.88	-1.73	1.51	-0.13
MERL	1.78	-0.23	0.10	0.66
PERB	2.27	-0.33	0.29	-0.23
ZIAL	0.53	0.00	-0.36	2.93
ZIPO	0.53	0.00	-0.36	2.93
CHAU	-0.35	2.71	2.23	-0.31
FAPO	-0.35	2.71	2.23	-0.31
MNUC	-0.35	2.71	2.23	-0.31
FJDP	-0.35	2.71	2.23	-0.31
PIMM	-0.14	1.30	1.03	0.45

Table 11. Coordinates of years on the first 4 factor axes

Years	Axe F1	Axe F2	Axe F3	Axe F4
1998	2.12	0.13	2.25	**11.15**
1999	2.18	0.66	3.07	0.20
2000	0.62	3.38	3.58	0.33
2001	2.30	0.00	**18.99**	**28.49**
2002	**10.53**	**40.72**	**30.92**	0.21
2003	**78.47**	1.69	1.53	2.98
2004	0.41	0.89	3.25	0.00
2005	1.82	0.00	0.84	**54.86**
2006	0.90	**52.34**	**35.56**	0.68
2007	0.64	0.19	0.00	1.10

Axis 1 is at first very characteristic of the PERB (fishing during biological rest) or even MERL (capture of hake) infringement, with respective positive coordinates 2.27 and 1.78. The importance of the year 2003 (An03), closely linked to these two infringements, is also clear. Then, it is more or less opposed to those with the strongest negative coordinates (-0.88) i.e POBS (lack of observer on board), MQNC (non-conforming marking) and DIPR (concealment of evidence) that are linked to year 2002 (An02).The 2nd factorial axis contrasts the variables CHAU (use of "socks"), FAPO (false fishing positions), MNUC (non conforming mesh + use of socks) and FJDP (fishing log fraud) with uniform positive coordinate 2.71), rather related to the year 2006 (An06), the variables POBS, MQNC and DIPR already seen, with uniform negative coordinate (-1.73), rather correlated with the year 2002 (An02).

This axis is in general opposing infringements involving the use of socks to those of shortages (on-board observers, markings) or concealment of evidence. The 3rd factorial axis contrasts globally the variables CHAU (use of "socks"), FAPO (transcription of false fishing positions) and MNUC (mesh not conforming + use of "socks") with positive coordinate (2.23) linked to year 2006 and the variables ALIB (License not on board) and LINC (non-compliant license), with negative coordinates (-0.65 and -0.62 respectively) linked to the year 2002.The 4th factorial axis contrasts ZIAL (zone forbidden + no licensing) and ZIOB (zone forbidden + obstructions) with uniform positive coordinates (2.93), linked to the year 2005 to the variable LINC (non-compliant license) of negative coordinate (-1.02), related to the year 2001.

4. Discussion of results

In the light of the findings of this study, the discussion focuses on the evolution of infringements and, in turn, on the performance of the inspection and control strategies implemented for their detection.

4.1. Elementary statistics

The univariate analysis clearly shows a consistency of the ZINT (prohibited zone fishing), MANC (non-conformal mesh) and OBST (obstructions) infringements. ZINT and OBST infringements, which together account for 36% of boardings, fall under the category of very serious offenses, while the MANC infringement (21%) is classified in serious offenses. Fishing in the forbidden zone infringements detected at the wharf usually reflect the low level of education or carelessness of commanders as they are verbalized on the basis of fishing positions transcribed by themselves in the fishing logbook . They also refer to a certain taste for the risk, even to the opportunism of those commanders who would follow their targets to the point of violating the limits set by the regulations. On an annual average, ZINT offenses increased from 13 in 1997-2005 to 5 in 2006-2007, a reduction of almost 1/3. Although the statistical series analyzed is not important (9 years and 2 years on both sides), there is a reason to believe that the implementation of the VMS noted in 2005, effective as of 2006, contributed to this decline. The VMS surveil device could therefore be a solution to this form of illegal action. This is a good way to reduce conflicts between artisanal and industrial fisheries in the coastal strip. These conflicts are common in Senegal (Dubois and Zografos, 2012).The other two infringements; MANC and OBST are related to attempts to reduce gear selectivity in order to maximize catches.
The offense of non-conforming meshing is subject to discussion. Indeed, given the materials used to make the trawls and the wear and tear of the trawls due to the nature of the bottoms, the nodes of the nets can "move"; Which results in a reduction in the mesh opening. A delay in the renewal of the equipment most often exposes to this type of infringement. The infringement of mesh obstruction, on the other hand, is intentional.

Its constancy is explained by the phenomenon of scarcity of resources and a notable increase in production costs which push the commanders of ships to try to make their fishing operation profitable. Trends in annual percentages of offenses could be related to the major events of the decade in fisheries and surveil:

- 1998 (12%): the passage of the law relating to the sea fishing code from 1987 to that of 1998 would explain this relatively significant proportion due to a lack of appropriation of the provisions of the new code; Hence a real problem of extension.
- 1999 (9%): this slight decrease in infringements could be explained by a better appropriation of the new code, in addition to the abundance of Octopus vulgar is which resulted in significant catches - 38 000 tons - of a resource highly rated on the international market with a minimum of effort.
- 2000 (11%): the slight increase was due to the decrease in the octopus stock.
- 2001 (16%): this record could be justified by the institutional change in the National Project Supervision Structure (PSPS) with new responsibilities and reinforcement of its human and material resources.
- 2002 (14%): this slight decrease would be related to the refurbishment of the "NJAMBUUR" offshore patrol vessel, which is present at sea for surveil purposes.
- 2003 (14%): this year's specialty remains the biological rest (two-month inactivity sequentially planned for each segment of the demersal trawler fishery) that many shipowners were struggling to respect.
- 2004 (7%): halved compared to the previous year due to severe penalties incurred in 2003.
- 2005 (6%): implementation of the VMS in the surveil system, significant reduction of incursions into forbidden zones.
- 2006 (7%): the trend is for stability due to the acquisition of new boats, the operational nature of the VMS and the failure to negotiate Senegal / EU fisheries agreements as of June 2006; hence the cessation of the activity of the European fleets.
- 2007 (4%): lower level thanks to an almost permanent presence at sea of the means of supervision with the "FRONTEX" system. In Spain, all the resources of the state are mobilized at sea to combat clandestine emigration and thereby strengthen fisheries surveil.

This is also the year when there are fewer vessels authorized to fish, a phenomenon related to the suspension of fisheries agreements and the high cost of inputs (especially fuel).

4.2. Bivariate Analyzes

4.2.1 Negative Correlations

The negative correlation between QUAI and AUTO (r = -0.79) reflects a trend towards an increase in inspections at wharf (138 in 1998, 647 in 2007) when the number of vessels authorized to fish decreases (332 in 1998, 137 in 2007) (Figure 4). The explanation is that, over the years, there is a inspection at wharf pressure - the first level of control - increased because of the concern to reduce the violations to an acceptable level, if not to stop them. The decline in the size of the fleet is linked to the willingness of the ministry to freeze the nominal effort (mainly in the coastal demersal fishery) and the scarcity of resources (in this respect, some boats have abandoned Senegalese waters To the neighboring countries of Mauritania, Guinea and Guinea-Bissau, which are known to be more fishy) and to the non-renewal of the Senegal-European Union fisheries agreements.

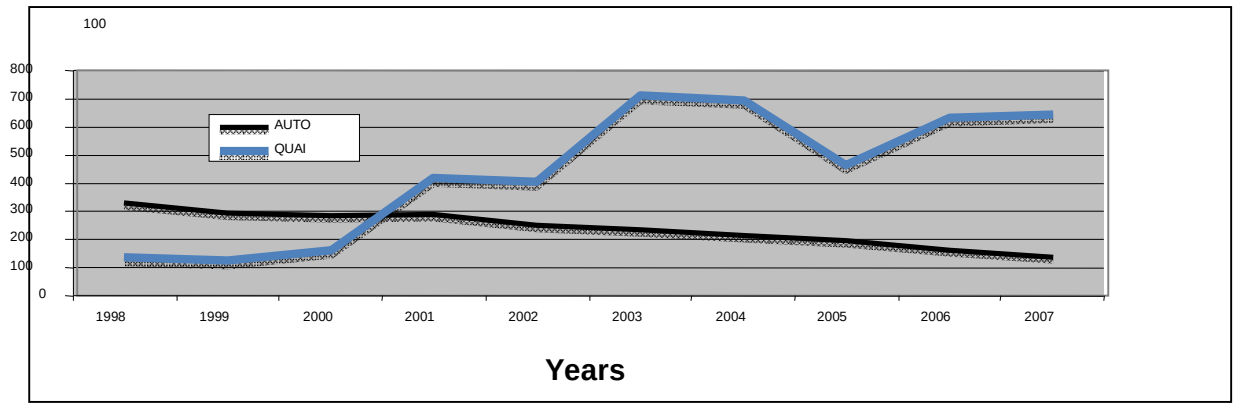


Figure 4. Evolution of the number of vessels authorized to fish and inspected at wharf

The negative correlation between QUAI and AIR (r = -0.70) indicates a certain upward trend in inspections at wharf as air inspections fall (from 545 in 1998 to 364 in 2007) (Figure 5). The decline in the latter is reflected in the relatively high cost of maintaining and flight of the overflight aircraft, in addition to mechanical difficulties.

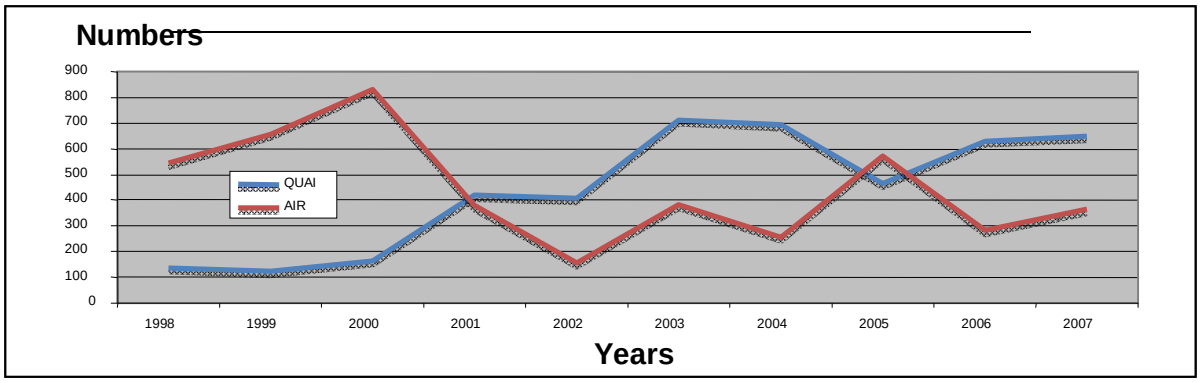


Figure 5. Trends in Inspection at wharf and Air Inspection

The negative correlation between QUAI and ZINT (r = -0.69) reflects a decrease in infringements due to fishing in the prohibited zone while inspections at wharf tend to increase. ZINT-type offenses continue to decline as a result of increased surveil pressure and the introduction of VMS. As an example, the lowest level of ZINT offense (2), in all years, is noted in 2007 (Figure 6).

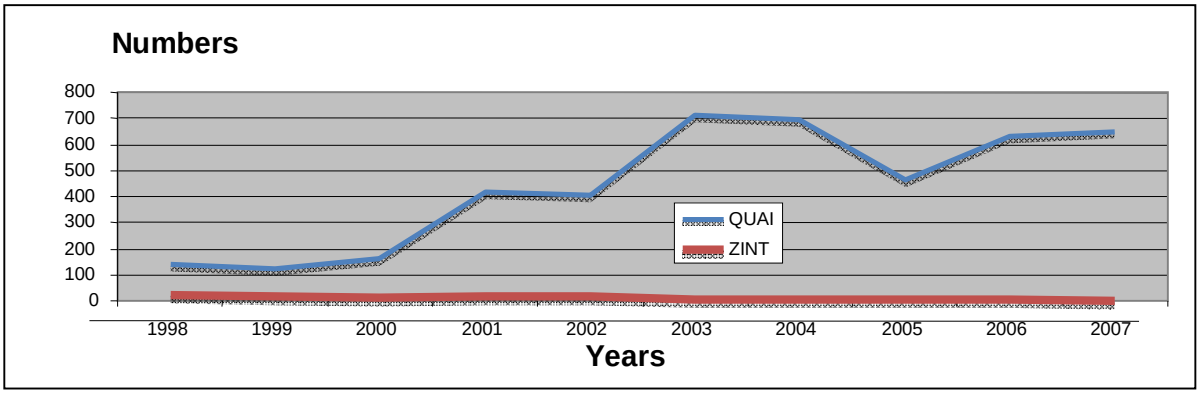


Figure 6. Evolution of the number of vessels inspected at the wharf and fishing in a prohibited zone

4.2.2 Positive Correlations

- Positive correlations between AUTO and INFR (r = 0.74) and INFR and ZINT (r = 0.67) express the trend toward an increase in each of these pairs of variables.

- The first correlation (AUTO / INFR) seems fairly obvious: the more vessels allowed to fish, the more violations; even if a good surveil system should "break" this dynamic.
- The second correlation (INFR / ZINT) is explained by the fact that, generally using new detection technologies, ship commanders follow fish schools beyond authorized limits; Resulting in an increasing number of offenses, mostly of the ZINT type, mostly attributable to coastal shrimp vessels.
- The positive correlation between sea (MER) and air (AIR) inspections with r = 0.68 is due to the combination of these types of actions in order to optimize the means of surveil. Indeed, aerial surveil gives the level of concentration of vessels according to the zones, given from which the patrollers plan their operations. The VMS strengthened this system in 2005.

4.3. Multivariate Analyzes

- Correspondence Analysis (AFC), although purely descriptive, allowed simultaneous consideration of the 26 infringements and the 10 years, thus informing their relations in terms of positive, negative or zero correlations. Such information is impossible to obtain with only univariate analyzes, which are rather burdensome in bivariate analysis. In particular, it highlighted the years 2003 (biological rest), 2005 (establishment of VMS) and 2006 (VMS effectiveness), more or less linked to the infractions of PERB, CHAU, FAPO, MNUC, FJDP, ZIAL, ZIPO ,...
- The limitation to a cumulative inertia of 68% with 4 factorial axes is defensible in AFC where the main aim is to reduce the initial dimension (there were 11 variables at the start). Then, the remaining 32% of initial inertia are not necessarily instructive.
- However, the AFC, based on the calculation of the KHI² distance, is the default for the weakest rows and columns (ie the least numbered years and types of infringement In terms of numbers), in contrast to the Principal Component Analysis (PCA), based on the calculation of the Euclidean distance. The results obtained here are therefore to be analyzed in this light.

4.4 Effect of VMS Installation

At the end of this discussion, the VMS appeared to be an alternative, particularly with regard to infringements in the prohibited zone. For our part, we believe objectively in its effectiveness. The use of the results of questionnaires distributed to all active ship owners and to the personnel of the DPSP confirms this. Its impact is expressed in terms of deterrence, optimization and efficiency of surveil and reliability:

- deterrence: 80% of commanders say they no longer make incursions into the forbidden zone because they feel constantly controlled. In this context, VMS appears much more as a preventive than a curative measure.
  The presence of the VMS equipment on board the vessel is an excellent reminder to the commanders attempting to fish in the forbidden zone to strictly observe the regulations;
- optimization and effectiveness of surveil means: prior to the VMS, it was extremely difficult to determine the position, location and time of landing of a vessel. This allows the task to be carried out reliably in real time and without moving (air and naval patrols); Saving time, fuel, etc. Efforts to confirm the tracking of legal fishing vessels could even be minimized if sea patrollers and the airplane have access to VMS data;
- system reliability: the fishing positions of vessels inspected at the wharf and at sea were recorded. When we confronted these positions with those recorded at the radar radio center of the DPSP, there was a clear agreement; which reflects the reliability of the system but also, in turn, induces the commanders of ships to transcribe fair fishing positions. These results are consistent with those of Graham (2000) who studied 'The Vessel Monitoring System at Country Level of the Subregional Fisheries Commission.

5. Conclusion and Recommendations

At the end of this study, interesting results were obtained both from the analysis of the observed violations and from the effects of the introduction of the VMS. The objectives initially set are achieved with an assessment of the evolution and evaluation of the infringements noted but also of the level of performance of the means and strategies implemented. The evolution of boarding shows a consistency of fishing offenses in the prohibited zone, offenses related to gear and fishing techniques, the human factor and to a lesser extent administrative failings.

This constancy indicates an average level of performance of control methods and strategies at least until the advent of VMS. The combination of control means remains a serious option to achieve this performance. The satisfactory results obtained from 2006 via the VMS can confirm this assertion. Although monitoring, control and surveil (MCS) efforts (FAO, 1996) have been undertaken with the acquisition of surveil boats and the establishment of a VMS system, progress needs to be made to effectively combat unregulated and unreported illegal fishing in the Senegalese EEZ. Furthermore, a better organization of the MCS system could lead to more convincing results with an increase in the time spent at sea and the publication of a procedural manual defining the roles and responsibilities of all the persons and structures involved in the fisheries surveil. It is necessary to evaluate and possibly adjust certain technical measures relating to zoning, size of first capture, mesh size and certain technical specifications of fishing gear. This should be done through coordination mechanisms between the administration, research and industry professionals. Monitoring of vessels would also become more effective by establishing a tagging system for fishing gear. Appropriate marking of all gear can assist in the search and recovery of gear and in the identification of owners, for example, inviolable marks that should be returned for license renewals. This marking would simplify the inspector's task and avoid repetitive checking of gear which, especially at sea, creates an interruption in fishing activities and a lot of time wasted. As part of its mandate, the Ministry of Fisheries should establish a unit on fishing gear technology to study the various characteristics of the gear used. In fact, present-day generations have a moral duty to ensure that the supply of seafood does not diminish in the future due to the excessive exploitation of stocks. Responsible behavior in accordance with FAO recommendations should prevail for the safeguarding and preservation of world fisheries. The concerted implementation of adequate surveil measures at various levels (national, subregional and, above all, global) will undoubtedly achieve these results. Indeed, it is recommended in an Interpol study (2014) to explore avenues for sharing data from VMS or other surveil information in case of suspected illegal activities to enable easier monitoring and adequate repression of these activities and a better appreciation of the maritime situation.

Acknowledgement

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