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Evaluation of factors of loss on stocks of smoked fish in three subdivisions of the Cameroon maritime coastal zone in Littoral region

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Abstract
During its storage in the maritime coastal zone in Littoral-Cameroon region, the treated fish is destroyed by various factors. These factors can be the source of poisoning for the populations. The objective of the study was to evaluate the post-smoking losses of fish in 3subdivisions in maritime coastal area: Youpwé (Douala II), Manoka (Douala VI) in Wouri Division and Mouanko in Sanaga Maritime Division. The identification of the fish species smoked was made in these 3subdivisions by permanent monitoring at the level of landing points and smoking units. 429 stakeholders were surveyed and 305 storage facilities were inspected and then characterized. Three *in vivo* collections of 7 species of smoked fish from each of the localities were collected and put in observation at the laboratory for 6 weeks. From these collections, molds and insect pests emerged. For each collection, the factor of loss is observed, the insects emerged were counted, identified and the damage assessed. For this study, it appears that 31 marine fish species belonging to 17 families have been identified. The Clupeidae (27%), the Sciaenidae (18%), the Polynemidae (12%) and the Ariidae (10.1%) are the most represented families. *Ethmalosa fimbriata* (Clupeidae), *Cynoglossus senegalensis* (Cynoglossidae), *Trichiurus lepturus* (Trichiuridae), *Arius heudelotii* (Ariidae) and *Raja africana* (Rajidae) are the most smoked species. The racks and baskets are the most widespread and used storage tools. Molds and Insects (Coleoptera: *Dermestes maculatus*, *Necrobia rufipes* and Diptera (*Calliphora* sp) are the main biotic factors of loss of stored smoked fish in the three localities. *N. rufipes* is the major pest with 772 individuals on the 911 counted. The study presents the main loss factor which depreciates the quantity and quality of smoked fish during storage.

Keywords: maritime coastal zone, storage, smoked fish, loss factors, insect pests, littoral-Cameroon

1. Introduction
The fishing sector offers an advantage in terms of food and nutritional security. Part of the fishes catch is eaten fresh, and another is processed in various ways: salted, dried, fermented and smoked to supply local and national markets. The fishes are a very fragile resource, their degradation begins as soon as they die, that don't exceed one day in a tropical environment, by the action of their own enzymes, attacks by the bacterial flora present on their skin, external contamination, and the action of heat [1] [2] [3]. It therefore very quickly becomes unfit for consumption if no conservation measures are taken. However, the local processing and conservation infrastructures are inadequate. This inability to secure the resource in sub-Saharan Africa generates fish losses estimated at around 25% of production [4]. Traditional heat preservation processes such as drying and smoking, curing and cold are observed locally.

The consumption of fish per inhabitant is estimated at 20 kg / year, i.e., an annual requirement of 400,000 tons per year; in Cameroon, this fish consumption was around 11 kg / inhabitant / year [5]. The annual production does not cover this need, because 55% of this tonnage is imported mainly in the form of frozen fish for around 100 billion FCFA [6].

The post captured losses of fish are about 20% [7]. These losses lead to a loss of income and of fish available for food [8]. For catching against post captured losses, many treatments are developed to preserve the sanitary quality of fish and to increase the duration of its conservation as well as to limit the losses of nutritional elements and its organoleptic quality. Amongst these treatments, this is smoking. Smoking fish can be considered as a permanent and well-paid job [9], because 75 to 80% of landings are transformed by smoking and contributes 16.8 billion to the Cameroonian economy [10]. The smoked fishes continue to be attacked during the processing and storage by many biotic factors, mainly the insects and may

be a source of poisoning for populations [11, 12, 13]. Indeed, as fisheries management systems improve and resource-related wealth begins to be produced on a sustainable basis, it may be possible to reduce estimated losses [14]. As this fish is an important food resource for African coastal countries, post-processing losses represent not only a threat to food security, but also to the livelihoods of actors involved in the value chain as well as to the sustainability of natural resources.

Reasonable use of already scarce development resources, as well as the planning and implementation of effective loss reduction strategies, in addition, the scarce information on post-processing losses is unreliable. There are hardly any recent data on the control of insect pests of smoked or dried fish stocks in Cameroon and in the Central Africa sub-region [12]. Reducing these losses by strengthening the performance of players in the sector would require generating objective data that makes it possible to identify truly feasible and effective solutions. This study looks at the best way to generate more benefits in the study areas through the control of post-smoking loss factors to improve the livelihoods of the direct actors involved.

2. Materials and Methods
2.1. Presentation of the study area
The study took place in three subdivisions of the Littoral Region: Douala II (Youpwé), Douala VI (Manoka) and Mouanko (Figure). Youpwè (923 Km^2) is located in the subdivision of Douala II, Division of Wouri between the geographical coordinates 4° and 4°8'North latitude and 9° and 9°49' East longitude. It is limited to the south by the Doctor's cove, to the north by the Bonapriso and Bonadouma II, to the west, it is bordered by the Wouri River and to the east by the Douala International Airport and the Bois des Singes. Mouanko (1538 Km²) is located in the Mouanko on the banks of the Sanaga River, Department of Sanaga Maritime, in the Douala-Edéa National Park, 70 km from Edéa to Dizangué, between the geographical coordinates 3°35' and 3°39' North latitude, and 9°43' and 9°47' East longitude. It is bounded to the north by the subdivision of Manoka, to the south by the subdivision of Edéa, to the east by the subdivisions of Dizangué and Edéa and to the west by the Atlantic Ocean [15]. Manoka (365 km^2) is an island located at the estuary of the Wouri River, in the Wouri division, subdivision of Douala VI, between the geographical coordinates 3°50' Nord and 9°38' East. It is bounded to the north by the subdivisions of Douala III and Douala IV.

The hydrographic network of the subdivisions of Douala II and Douala VI consists of its main river, the Wouri, which divides the city into two parts and covers an area of 11,700 km^2. The reduction in the beds of this watercourse is due to the anarchic occupation of space by populations and various wastes [16]. The Mouanko subdivision is watered by the Sanaga basin which has a dense hydrographic network to which is added the Atlantic Ocean which borders the coast [17]. It is characterized by many rivers including the Sanaga, Dibamba, Nyong, Dombé and a few lakes including Lake Tissongo Lake Nsah Lake Ossa which form ecosystems from the point of view of fauna and flora [18, 19]. It is characterized by annual precipitation of the order of 2000 to 3000 mm and an annual temperature ranging from 25 to 30 °C.
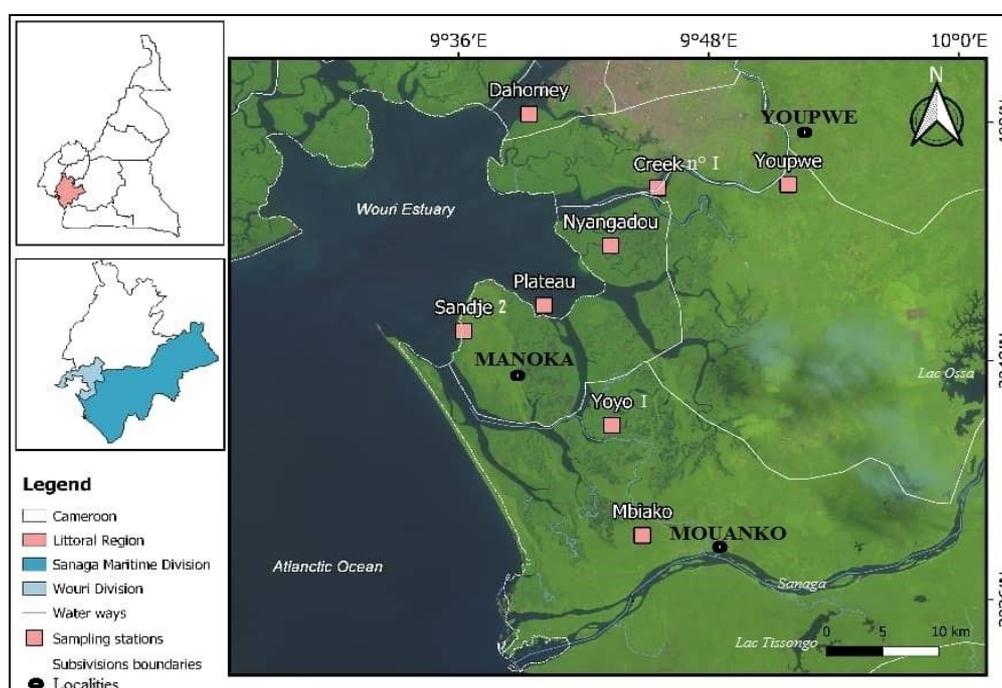
Fig 1: Location of sampling points in Youpwé, Mouanko and Manoka

Youpwé and Manoka are characterized by an equatorial climate of the humid coastal Cameroonian type, influenced by the Atlantic Ocean at the level of the Gulf of Biafra. However, the proximity of Mount Cameroon (4100 m altitude) influences the climate which becomes very rainy. It is a particular climate, marked by almost permanent rains. There is a long rainy season of about 9 months (March to November) and a relatively short dry season of about 3 months (December to February). The rainfall is regular and strong (4000 mm / year). The annual average temperature fluctuates around 27.5 °C. August is the coldest month (25.5° C), while February is the hottest (28.9 °C) [16]; the thermal amplitude is 3.3° C and the humidity is high at 71.3%. There is a large dry season from December to mid-March and a small dry season from mid-March to April; the short rainy season from May to June and the long rainy season from July to November [15].

2.2. Inventory of smoked fish species processed in Youpwé, Mouanko and Manoka

The inventory of fresh fishes landed was carried out by continuously monitoring fishermen's landings using monitoring sheets previously established, questionnaires administered to fishermen, traders, and processors in each locality as well as interviews with the heads of centers. 429 direct actors were surveyed: 197 fishermen, 67 processors, 148 traders and 17 consumers. Using monitoring sheets, the determination of the landed species has been carried out in 4 weeks in Youpwé and in the Mouanko and Manoka camps by permanent monitoring of landings. By landing point, the total catches per fishing unit were sorted and arranged by species. The total number of individuals per species was recorded then weighed using a mechanical balance with a capacity of 500g and a sensitivity of 0.1. The names of the species were given in French, in English or in the local language:"Duala or Bassa" in Youpwé, "Malimba" in Mouanko, "Iladja or Ijaw" in Manoka depending on the personalities. In situ, some fish species have been identified immediately using the identification key [20]. For specimens for which immediate identification was not possible *in situ,* photos were taken using a Samsung S6 edge camera and a specimen by species was collected, tagged, and conserved in 70% alcohol for laboratory to future identification. With processor (67), traders (148) and consumers (17), the collected information concerning the names of the species of fish smoked as a priority, the nature of the storage units, the methods used to limit post-smoking losses, special attention has been paid smoking operations by observing the species placed on the racks or another storage unit.

2.3. Characterization of smoked fish storage tools

The characterization of storage tools has been done to processors, traders, and consumers according to the method used by Tamgno *et al.* [12]. The inspection of the tools for storage of smoked fish was carried out considering several elements: the nature of the tool, the size, the duration of storage (short term, medium term, long term), scope (occasional, local, regional) and dimensioning (length, width, weight). At the same time, any insect present in the structures inspected were collected, preserved in alcohol at 70%, then identified in the laboratory.

2.4. Determination of natural infestation of collected smoked fishes, the diversity of their pests and damages observed by insect pests

The *in vivo* collection of smoked fish was carried out following inspections of storage tools with processors (67) and traders (148) in the three localities of the Littoral region. Indeed, during the characterization phase of the storage tools, samples of seven (07) smoked fish species showing no initial apparent infestation were collected and stored in white plastic films before being introduced into a bag to bring back to the laboratory. In total 51 samples (17 per locality) including 9 of *E. fimbriata* (Ethmalose), 9 from *P. senegalensis* (bar), 6 from *T. lepturus* (Belt), 6 from *C. elongatus (*sole), 9 of *P. elongatus* (hunchback), 6 of *P. quadrifilis (*captain) and *A. heudelotii* (machoiron) were collected and returned to the laboratory. Once in the laboratory, the samples were weighed using an electric balance and then introduced into labeled glass jars with a capacity of 900 ml to observe for 06 weeks in each jar the presence of potential molds and insects.

2.4.1. Natural infestation rate of smoked fish and diversity of their pests

The infestation of smoked fish by insects was assessed by counting the number of insects (larvae and adults) that emerged at the end of the session. The fish were weighed and then crumbled to be able to extract the insects. Larvae greater than 0.5 cm (white and black) as well as living adults are counted and the whole is then weighed. It was a question of determining by the calculation of the rate of infestation of each collection *in vivo* of the smoked fish brought back according to the formula:

Infestation rate (%) = (number of pots attacked X 100) (total number of pots in the collection)

The identification was made according to the method adopted by Tamgno *et al.* [12]. The insects that would emerge from the different collections were removed, counted, preserved, identified using a Novex brand magnifying glass. Confirmation of species and their families was done using the beetle insect family identification key, and the identification catalogs insects from products stored in the tropics [21, 22, 23]. The confirmation of these was made with reference to the collection of the Royal Museum for Central Africa.

2.4.2. Evaluation of losses caused by insect pests on collections

The evaluation of losses due to the actions of insect on different collections has been done by counting the number of insects, the mass of borer flour and the mass of fish after six weeks of observation in different pots at laboratory. Borer flours are weighed separately and observations on changes are noted, any part not attached to the fish as well as damaged fish are considered like borer flour. The determination of the density of harmful insect per gram of each of the foodstuffs under observation made it possible to estimate the nuisance of each insect in the study areas according to the formula:

Density of a species = (number of insects) / (mass of fish)

3. Results

3.1. Taxonomic composition of species smoked fishes in Youpwé, Mouanko and Manoka

The study carried out in the divisions of Wouri and Sanaga Maritime revealed 31 species of fishes belonging to 17 families: 24 species shared to 17 families in Youpwé, 15 species divided to 12 families in Mouanko and 17 species to 11 families in Manoka (Table 1).

The most diversified families are those of Clupeidae and Carangidae with respectively 5 and 3 species. Three (03) of these families are more representative with more 50% of individuals: Clupeidae (27.8%), Sciaenidae (18.4%) and Polynemidae (11.6%) and the three families less abundant are Charcharinidae (0.003%), Rajidae (0.09%) and Tetraodontidae (0.4%) (Table 1). 14 species *A. heudeloti*, *P. senegalensis*, *P. elongatus*, *G. decadactylus*, *E. fimbriata*, *R. africana*, *C. hippos*, *C. senegallus*, *S. cameronensis*, *P. leonensis*, *P. quadrifilis*, *G. decadactylus*, *S. piscatorum*, and *T. lepturus* belong to three zones at the same time. The most smoked specie fish in the three subdivisions is *E. fimbriata* which represents 75% of smoked species of fishes.

Table 1: Fish families (%) and species inventoried in Mouanko, Manoka and Youpwé

Families (%)	Scientific names	Common names	Youpwe (1) Local name (Duala / Bassa)	Mouanko (2) Local name (Malimba)	Manoka (3) Local name (Iladja / Ijadja)
Clupeidae (27.8%)	*Ethmamosa fimbriata* (Bowdich, 1825)	Ethmalose * 1,2,3	Bounga	Bîpaga	Forlo (Iladja)
	Sardinella cameronensis Regan, 1917	Sardinella 1,2,3	Bepa / Mouandja motoh	Bilolo	Bilolo
	Pellonula leonensis Boulenger, 1916				
	Alosa alosa (Linnaeus, 1758)	Shad * 3			
	Ilisha africana (Bloch, 1795)	Razor 1,2,3	Kanda	Munyannya	
Scianidae (18.4%)	*Pseudotolithus elongatus* (Bowdich, 1825)	Hunchback * 1,2,3	Nyiendeh	Nyendi	Ona (Ijaw)
	Pseudolotithus senegalensis (Valenciennes, 1833)	Bar * 1,2,3	Musubo	Broke marrate	
Polynemidae (11.6%)	*Polydactylus quadrifilis* (Cuvier &Valenciennes, 1829)	Fat Captain 1,2,3	Sèh Pel		Nda (Ijaw)
	Galeoids decadactylus (Bloch, 1795)	Little captain * 1,2,3			
Cynoglossidae (8.6%)	*Cynoglossus senegalensis* (Kaup, 1858)	Sole * 1,2,3	Nyomoh	Nyomo	Obolebo (Iladja)
	Cynoglossus browni Chabanaud, 1949				
Lutjanidae (1%)	*Lutjanus eutactus* Bleeker, 1863	Carp 1,2,3	Wanga		
Carangidae (2.3%)	*Caranx hippos* (Linnaeus, 1766) *Caranx senegallus* Cuvier, 1833	Trevally * 1,2,3	Motondoh / mutungu	Mutungu	
	Trachinotus teraia (Cuvier & Valenciennes, 1832)	Miss 1	Ngope		
Ariidae (9.2%)	*Arius heudelotii* Valenciennes, 1840	Machoiron * 1,2,3	Yendah / kwakoro	Kwakoro	Egangan (Iladja)
	Chrysichthys nigrodigitatus (Lacepède, 1803)				
Pristipomatidae (1.2%)	*Plectorhinchus macrolepis* (Boulenger, 1899)	Sea bream 1,3	Ponjoh		
	Ponasys jubelini (Cuvier & Valenciennes, 1832)	Gray sea bream 1,2			
Monodactylidae (3.2%)	*Psettias sebae* (Cuvier, 1829)	Elongated Disc 1	Ekeké		
	Drepane africana Osorio, 1892	Disc 1			
Mugilidae (3.5%)	*Mugil cephalus* Linnaeus, 1758	Mulet 1.3	Mboh		Ijeghe (Ijaw)
	Mugil auratus Risso, 1810	Mullet 1			
Rajidae (0.09%)	*Raja africana* Bloch & Schneider, 1801	Line * 1,2, 3	Ydouba	Idouba	cover pot or luwe
Cichlidae (7.6%)	*Oreochromis niloticus* (Linnaeus, 1758)	Nile Tilapia 1,2	Tabalah	Babala	
Serranidae (1%)	*Epinephelus* spp (Bloch, 1793)	Grouper 1	Tohtoh		
Sphyraenidae (2.5%)	*Sphyraena piscatorum* Cadenat, 1964	Pike 1,2,3	Waabo	Nwaabo	Kuta (Iladja)
Tetraodontidae (0.4%)	*Ephippion guttifer* (Bennett, 1831)	Tetrodon 1			
Trichiuridae (2%)	*Trichiurus lepturus* Linnaeus, 1758	Belt * 1,2,3	Nyonon	Nyoonon	
Charcharinidae (0.003%)	*Carcharhinus leucas* (Müller & Henle, 1839)	Shark 1,2	Ndom	Dom	

Legend: 1: Youpwé; **2**: Mouanko; **3**: Manoka; *: The most smoked species in Youpwé, Mouanko and Manoka

3.2 Storage facilities used for smoked fishes and duration of storage

Five storage facilities are used in different proportions in the three localities (Youpwe, Manoka and Mouanko) for the conservation of smoked fish (Jute bags, cartons, racks, baskets, and pots) (Table 2). In Manoka and Mouanko, the rack and basket are the most important tools used in the storage of fishes with respectively 65.78 and 27.7% for Manoka and 50.8 and 30.19% for Mouanko. In Youpwe, the tool most used is Basket (35.37%). The jute bag and pots are the tools less used in the different localities. The jute bag is not used in Manoka.

Table 2: Rate of storage tools used in maritime coastal zone in function of localities and users and the duration of storage of smoked fishes

Storage tools	Localities 1(%)	2 (%)	3 (%)	Users (%)	Storage duration (weeks)
Racks	22.71	50.8	65.78	Processors (85.5)	1
Cartons	31.3	10.45	1.45	Traders (75.78)	2
				Retailers (20)	
Basket	37.35	30.19	27.77	Processors (14.5)	3
				Traders (20)	
				Retailers (80)	
Jute bag	4.64	5	0	Traders (4.22)	6
Pots	4.34	3.56	5	Consumers (100)	4

Legend: 1: Youpwé; **2**: Mouanko; **3**: Manoka

The usage of these tools is also in function of users: the processors use mainly racks (85.5%), the cartons are most used by traders (75.78%), the retailers use the baskets at 80% and the consumers the pots at 100% (Table 2). The duration

of post-smoking fish storage depends on the storage tool used and varies from one week to six weeks respectively for rack and jute bag (Table 2).

3.3 Natural infestation of collected smoked fishes, the diversity of their pests and damages observed by insect pests
3.3.1 Natural infestation rate of smoked fish and diversity of their pests
The natural infestation of different collections is function of localities and the species of smoked fishes (Table III). 4 biotic factors are present in different collections taken in the prospected sites: 1 Dermestidae (*Dermestes maculatus*), 1 Cleridae (*Necrobia rufipes*), 1 Calliphoridae (*Calliphora* sp) and the molds. *Calliphora* sp (Diptera: Calliphoridae) is observed in all collections of Youpwe. *E. fimbriata* is the

collection less affected with 5% at Youpwe and 0% at Manoka and Mouanko. At Mouanko, three collections are not infested (*E. fimbriata*, *T. lepturus* and *G. decadactylus)* against only one collection at Manoka (*E. fimbriata*) (Table III). All the four biotic factors are observed to two smoked species of fishes: *P.elongatus* and *T. lepturus*, mold is not developed on *E. fimbriata*, *P. senegalensis* and *C. senegalensis, N. rufipes* has emerged on six of seven species collected (Table III). At Youpwe, and Manoka, the two species most vulnerable are *T. lepturus* and *A. heudelotii* with respectively 94.56% and 89.12% and 87.98% and 79.28%. Mainwhile at Mouanko, *A. heudolitii* (80.18 %) and *P. elongatus* (65.78%) are the most affected.

Table 3: Natural infestation of different *in vivo* collections of smoked fishes (%) according to origin and diversity of their pests

Localities / Smoked fishes	Youpwé (%)	Manoka(%)	Mouanko (%)
Ethmalosa fimbriata [1,3]	5	0	0
Arius heudelotii [2,3,4]	89.12	79.28	80.18
Pseudotolithus senegalensis [2,3]	57.98	34.19	40.11
Pseudolithus elongates [1,2,3,4]	62.07	46.5	65.78
Trichiurus lepturus [1,2,3,4]	94.56	87.98	0
Cynoglossus senegalensis [1,2,3]	56.08	20.5	15.81
Galeoïdes decadactylus [2,3,4],	68.4	20.65	0

Legend: 1= *Dermestes maculatus* (Coleoptera : Dermestidae)
2= *Necrobiarufipes* (Coleoptera : Cleridae)
3= *Calliphora sp* (Diptera : Calliphoridae)
4= Molds

3.3.2. Numerical importance of *Dermestes maculatus* and *Necrobia rufipes* and their damages in different collections
The damages due to the activities of insect pests are materialized by the numerical importance of *D. maculatus* and *N. rufipes,* the loss in masses of smoked fishes and the mass of borer flour obtained after 6 weeks of observation (Table IV). These parameters vary in function of collections of smoked fishes and their origin. *N. rufipes* is the main pest counted in the different collections with 792 individuals on the total of 911. On the other hand, *D. maculatus* which infested 4 species of smoked fishes (*E. fimbriata, A. heudeloti, P. senegalensis* and *T. lepturus*), or 15.26% of all the collections has 119 individuals identified. The most infested species are *A. heudelotii* with 272 *N. rufipes* and 39 *D. maculatus*, *T. lepturus* with 256 *N. rufipes* and 61 *D. maculatus*. *E. fimbriata* and *G. decadactylus* are the species

which are least attacked with respectively 6 *D. maculatus* and 33 *N. rufipes* (Table IV).
Youpwe is the locality that recorded the highest number of insect pests (340), followed by Manoka with 310 individuals and 261 insects for Mouanko. *T. lepturus* (116) and *A. heudelotii* (101) are the smoked species which presents the biggest number of *N. rufipes* at Manoka with also the loss masses of fishes respectively 123.8 g and 138.56 g and the masses of borer flour in order of 79 g and 68.2g consecutively (Table IV). The highest loss masses are observed on *A. heudelotii* from Youpwe (165.84 g) and Manoka (151.42 g). According to the number of insect pest (6), to the loss masses (5.6 g), to the density of insect pest (0.004) and to the mass of borer flour (0), *E. fimbriata* is the smoked fish less affected by insect pests; on the contrary of *T. lepturus* and *A. heudelotii* (Table IV).

Table 4: Numerical importance of insect pests, losses masses of fishes and masses of borer flour in function of smoked fishes and their origin

Collections of smoked fishes	Insect pests	Insect number			Loss masses (g)			Density of insect pests			Borer flour (g)		
		(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Ethmalosa fimbriata	*Necrobia rufipes*	0	0	0	5.5	0	0.1	0.004			0	0	0
	Dermestes maculatus	6	0	0									
Arius heudelotii	*Necrobia rufipes*	87	86	101	165.84	138.56	151.42	0.49	0.59	0.66	79	78.5	68.2
	Dermestes maculatus	15	12	10									
Pseudotolithus senegalensis	*Necrobia rufipes*	23	25	21	62.88	67.47	52.89	0.77	0.56	0.28	45.1	38.78	4.42
	Dermestes maculatus	9	4	6									
Pseudotolithus elongatus	*Necrobia rufipes*	29	21	31	72.6	58.48	51.22	0.25	0.19	0.31	2	0	9.58
	Dermestes maculatus	0	0	0									
Trichiurus lepturus	*Necrobia rufipes*	100	57	116	140.06	114.75	123.8	0.78	0.76	0.84	68.53	48.38	79
	Dermestes maculatus	18	27	12									
Cynoglossus senegalensis	*Necrobia rufipes*	35	14	13	127.99	24.11	159.1	0.15	0.21	0.15	0	0	0
	Dermestes maculatus	0	0	0									
Galeoides decadactylus	*Necrobia rufipes*	18	15	0	86.19	26.2	0	0.26	0.14	0	0	0	0
	Dermestes maculatus	0	0	0									
		340	261	310									
Total		911			1604.95			7.39			521.49		

Legend: (1): Youpwé; (2): Mouanko; (3): Manoka

4. Discussion

The great smoked ichthyological diversity observed in the maritime coastal zones (Youpwé, Manoka and Mouanko) (Table I) could be explained by the fishing effort exerted by the fishermen, the basin hydrographic, the fishing period and the data collection method. This diversity is greater than those obtained in the Bamendjing and Mapé dams in the Noun Division [13] [24] and in the loop of the Dja Biosphere [8] [11]. In fact, 13 species grouped into 5 families in ten (10) camps in the Noun department, and 31 species belonging to 12 families in 04 camps in the North Loop of the Dja Biosphere had been obtained [12] [13]. The differences observed in ichthyological diversity can be explained by the fact that in Youpwé, Manoka and Mouanko, the type of fishing practiced is artisanal maritime fishing and industrial fishing in marine waters where the landed species are marine species, while in continental waters the landed and smoked species are freshwater species from inland fishing. This work on the most represented ichthyological families corroborates those carried out in the Manoka coastal zone which showed that 07 families including Clupeidae, Scianidae, Cynoglossidae, Polynemidae, Ariidae, Mugilidae and Spyraenidae are the most landed and smoked [25]. This result shows that the diversity of species has not changed over time.

The variability of the tools for storing smoked fish developed and used by the different actors of fishing of these three localities (Table II) indicates that processors, traders and consumers have a real concern for post-smoking conservation of their products. Indeed, from one locality to another, the problems of storing fish in appropriate tools arise strongly. Storage is successful if at its end, the food does not register a significant loss, both quantitatively and qualitatively. The author already pointed out that storage, conditioning, and transport are part of the phase of the greatest losses of treated fish in Mali [26]. There are 05 storage tools like those identified in the North loop of the Dja Biosphere and 03 tools out of the 05 observed in the Noun department. This difference could be explained by the short duration of storage in the Western region because this region is known for its multiple permanent and rotating markets; on the other hand, in Mouanko, Manoka and Youpwé the fish are smoked and stored while waiting for traders and consumers to come to refuel. The absence of a jute bag in Manoka is explained by the state of the access road to this locality. Indeed, the smoked products of Manoka are shipped by river and sold in Douala.

The high rate of infestations by insect pests and molds observed in the different collections of smoked fish (Table III) can be explained by the fact that the actors in the processing and marketing chain use smoking techniques and unsuitable storage tools due to the high costs of smoking techniques and modern storage tools or the isolation of the area (Mouanko) or difficult living conditions (Manoka). All stages of the food system, quantitative and qualitative losses are possible for many reasons: bacteria, yeasts, molds, insects and rodents can degrade products during harvest, storage, transport and due to faulty or unsuitable packaging; temperature, light, oxygen, humidity, drought, natural enzymes are destructive factors for the quality and shelf life of products throughout the food chain; and that beyond the biological and physical factors, the state of equipment, road infrastructure and storage, the economic context, hygiene standards and finally the modern lifestyles of households lead to losses [27]. Similarly, these results are in the same direction as those obtained on the storage of smoked and / or dried fish

in Malagasy; indeed, they had shown that the infestation can be due to insect pests, molds, and poor storage conditions [28]. Natural enzymes are destructive factors for the quality and shelf life of products throughout the food chain; and that beyond the biological and physical factors, the state of equipment, road and storage infrastructure, the economic context, hygiene standards and finally the modern lifestyles of households lead to losses. The strong use of baskets as storage tools by retailers (Table II) can be explained by the fact that this storage tool has a dual functionality because it is considered as a storage and sales tool by traders and consumers. Despite the relatively short duration between 1 and 6 weeks of storage, the different actors of post smoking fishes report the presence of pests in their stock.

The variation in infestation rates and the numerical importance of insect pests observed in the different collections smoked fish (Table III & IV) betray the poor success of smoking and storing smoked fish in the various localities in the region. Indeed, the storage is successful if at its end, the stored food does not show any depreciation qualitative and quantitative [29]. These infestations are said to be the result of poor processing or poor storage [11] [12] [13]. The high rate of infestation would result by the fact that sub-Saharan Africa presents the optimal climatic conditions for the proliferation of these insect pests. In fact, in developing countries, especially in countries with a so-called Guinean climate zone, estimates losses vary from 30 to 50% of crops [30] [31].

The pests emerging from the collections belong to three Families of insect pests and two Orders: Dermestidae, Cleridae (Coleopterans) and Calliphoridae (Dipterans) and to Molds (Table III). In other words, a third or half of what is produced never makes it to consumers and the work and money invested is wasted [32]. These results on the infestation rate are perfect agreement with the forecasts of badly treated fish and the observations made on the collections of the Dja Biosphere [8].

Coleopterans (*Necrobia, Dermestes*) are the main insect pests of smoked fish stocks in the three localities visited (Table IV), which could be explained by the archaic artisanal processing techniques used by the processors as well as poor transport conditions and inappropriate storage tools. The studies carried out show sub-Saharan Africa, the dermestes and the necrobia constitute the most harmful insects to the storage of fish in Madagascar, Benin, Nigeria, Chad, Mali, and Cameroon [8] [12] [13][26].

Losses can be total if no protection is made [12] [27]. *N. rufipes* infested almost all of the three smoked fish collections with varying intensities much greater than those of *D. maculatus* (Table III). This result could be explained by the fact that the species *N. rufipes* particularly likes marine fish or smoked salted fish, unlike *D. maculatus* which mainly likes freshwater fish. As a result, the presence of *D. maculatus* would be accidental or this species, to feed and reproduce, would adapt to environmental conditions. This result is different of that obtained in the North loop of the Dja Biosphere and in the western region [11] [24] and similar to that work which showed that a high salt content leads to the mortality of *D. maculatus* and the blooming of *N. rufipes* [28].

The nutrition of larvae and adults leads to considerable losses of smoked fish (Table IV). These losses materialize as the production of boring meal and the loss in mass of stored fish. This growing mass of boring flour from different species testifies to the voracity of the larvae and adults of *N. rufipes*,

main insect pest of marine smoked fishes [28]. The presence of boring flour is explained by the predatory activity of these insects in the collections under observation; the smoked fish will therefore gradually lose its initial weight. Insects tunnel in fish and feed on their flesh, fish tend to break up easily and the friability of fish associated with odors alterations make the fish less attractive and therefore less appetizing.

The strong natural infestation of smoked fish collections in vivo leading to a decrease in the quantities and loss of quality of smoked fish species (Table IV) is explained by the presence of beetles, dipteran, and molds in the stocks of smoked fish. Indeed, for the beetles which usually attack the treated fish, the population is multiplied by a maximum of 25 or 30 after four weeks [32]; that is, under optimal conditions, a fertile female can give birth to 15,625 / 27,000 beetles in 12 weeks and these pests can also cause crumbling of treated fish [33]. Loss of quality may also be due to the presence of insect bodies and remains [12]. In fact, insects tunnel in fish and feed on their flesh, fish tend to fragment easily and the friability of fish associated with spoilage odors make fish less attractive and therefore less appetizing [28]. Thus, the presence of these pests causes irreversible damage to the available stock, making the smoked product immediately unfit for human consumption.

5. Conclusion
Fishery resources are very perishable when no conservation method is applied. To limit losses in the localities of Youpwe, Mouanko and Manoka, smoking is applied to preserve fish intended for later consumption. Scianidae and Clupeidae represent more than 50% of the fresh fish landed in these localities. *E. fimbriata* represents 80% of the 31 smoked species. The rate of infestation depends on the species of fish and their locality of origin. The main insect pest of stored smoked fish is *N. rufipes*. This pest which is 7 times more abundant than *D. maculatus* constitutes 84.74% of the insect pests emerged from the collections. Quantitative and qualitative losses due to damage to these pests during the study carried out were observed. Irreversible degradation of these smoked fish considerably reduces their economic values. However, improving transformation techniques and protection tools can reduce the risk of infestation. Despite heat processing, dried and smoked fish remains a commodity that can be lost during storage due to pest depreciation if no measure is taken to limit the loss. The search for phytopesticides like tools of protection may make it possible to propose new products for the protection of fish treated during storage.

6. Conflict of interest
The authors declare that there is no conflict of interest.

7. Acknowledgment

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