Sustainable utilization of mangroves using improved fish-smoking systems: a management perspective from the Douala-Edea wildlife reserve, Cameroon

Authors: Feka, Njisuh Z. , Chuyong, George B. , and Ajonina, Gordon N.

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Research article

Sustainable utilization of mangroves using improved fish-smoking systems: a management perspective from the Douala-Edea wildlife reserve, Cameroon.

Njisuh Z. Feka[1, 2], George B. Chuyong[2], Gordon N. Ajonina[3],

[1] Department of Environmental Science and Policy, Central European University, Nador u 9 1051 Budapest. feka_nz@mespom.org

[2] Department of Plant and Animal Sciences, University of Buea, P.O Box 63 Buea South West Province, Cameroon. chuyong99@yahoo.com

[3] Cameroon Wildlife Conservation Society (CWCS) Douala-Edea Forest & Mangrove Project BP 54 Mouanko, Littoral Province, Cameroon Central Africa. gnajonina@hotmail.com

Abstract

Fuel wood extraction for commercial fish smoking is the most pervasive threat to the sustainability of mangrove ecosystems in the Douala-Edea Wildlife Reserve (DEWR) of Cameroon and most West-Central African coastal states. The high rates of fuel-wood consumption are associated with fish smoking in this region and are chiefly the result of low fuel efficiency systems. In this study, we investigated the relative efficiency of two fish-smoking systems with respect to fuel wood consumption and time required for fish smoking in the DEWR. Using socio-economic and forest surveys in three villages, where mangrove wood is harvested and used, we established that the annual fuel-wood off-take was about 42,839m^3. In addition, most of the wood is used for fish smoking in the Traditional Smoke System (TSS) method, which was assessed to be 70% less efficient than the Improved Smoke System (Eeyed/CWCS). The Eeyed/CWCS consumed on average 50% less wood than the TSS, and reduced fish-smoking time by up-to 65% relative to the TSS. This comparative advantage offers opportunities for reducing the incidence of smoke-related diseases in women and children–most of them involved in the smoking process—by reducing the time spent smoking fish and saving money from avoided additional wood consumption. However, these benefits can only be achieved through the successful introduction of the Eeyed/CWCS. This will require a broad range of sensitization, capacity enhancement, and further research on adapting the current model to local conditions of the area.

Keywords: Douala-Edea, Exploitation, Fuel wood, Fish smoking systems, Mangrove, Reserve, Cameroon

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Introduction

Mangrove forests are a source of livelihood for thousands of coastal communities in developing countries worldwide, who traditionally harvest fish, shrimp, Non-Timber Forest Products (NTFPs), timber, and fuel wood from them [1-4]. The importance of the mangrove ecosystem transcends provisioning services and includes others such as regulatory, ecological, cultural, and aesthetic services, among others [4, 5]. However, these services are diminishing globally, most especially the provisioning service, and this is putting the livelihoods of coastal communities at risk and increasing their vulnerability to tropical storms and surges [6-9]. These trends are the outcome of mounting anthropogenic activities such as brackish water aquaculture, mangrove forest clearing for infrastructure development and varied levels of harvesting for subsistence [10, 11]

Because of these pressures, mangroves in coastal tropical developing countries are being degraded; for instance, 20-30% of mangrove forests have been lost in West-Central Africa since 1980 [12]. Apart from aquaculture and infrastructural developments, the harvesting of mangrove wood is an important factor contributing to this degradation [13, 14]. Since mangrove wood harvesting is not limited to subsistence alone [15, 16], it is probable that the current commercial nature of wood harvesting may be enhancing the degradation of this ecosystem, considering that many factors influence the harvesting and use of mangrove wood [17]. The importance of the impacts of small-scale exploitation on mangrove forests has been documented [17-19]. Nevertheless, while these exploitation levels have different effects on the ecosystem, the un-controlled cutting of mangrove forests for fuel wood, charcoal, construction, and the paper and pulp industry is probably the second most pervasive and intrusive threat on the resource globally after conversion to aquaculture [1].

Similarly, the importance of fuel-wood harvesting as a driver of mangrove forest depletion in West-Central Africa has been recognized [20]. This activity seems to correlate positively with local economic activities related to fish-smoking [16, 20], which play a very important role in the subsistence of most coastal communities in West-Central Africa. In addition, mangrove wood is a valuable source of fuel, and important quantities are being harvested in the region [See: 15, 21-24]. Considering the unenviable socio-economic situation and poor access to sustainable sources of energy among coastal communities in countries of the region, wood (and mangrove wood in particular) has traditionally been important to both people and industry [13, 21]. However, although mangrove wood has gained this level of importance, its harvesting may present important direct threats to the sustainability of this ecosystem, because even small-scale wood harvesting affects the population ecology of mangroves [19]. Hence, the current patterns of over harvesting of mangrove wood in West-Central Africa should not be overlooked because of the potential negative consequences that might accrue [20].

Harvesting from mangrove forests is also an important economic activity and source of energy in Cameroon [15], with most wood harvested in the Douala-Edea Wildlife Reserve (DEWR) being used for fish smoking [26, 27]. The large quantity of wood used for curing and/or fish smoking is chiefly the result of low fuel-efficiency systems which require the use of important quantities of wood [28]. Hence, considering the magnitude of fishing and fish preservation through fish smoking in Cameroon and other West-Central African coastal countries [29, 30], the performance of fish-smoking systems may be an important factor determining the quantities of mangrove wood harvested and used for fish smoking in this region. Fish smoking reduces post-harvest losses, because of the absence of access roads to fishing villages, and the lack of other means of preservation coupled with absence of electricity [31]. Open curing systems hereafter referred to as Traditional Smoke Systems (TSS) are used to smoke fish. In addition to poor fuel-wood economy, TSS are sources of particulate emissions that cause disease and suffering particularly among women and children [32]. Particulates arising from open traditional systems are ten times greater than the standards set by United States Agency for Environmental Protection [33].

One approach to reducing fuel-wood consumption and improving working conditions to avert human health impacts is by introducing improved fuel consumption systems [28]. The efficiency and economy of improved fuel-wood consumption systems (ISS) relative to various kinds of TSS have been demonstrated [31]. However, no comparative study exists on the use of mangrove wood for fish-smoking systems and on mangrove loss in the region. This study intends to evaluate the fuel-wood consumption levels of the (Improved Smoke system (Eeyd/CWCS) hereafter referred to as ISS, introduced by Cameroon Wildlife Conservation Society (CWCS) in 2000 in the region, relative to the TSS, and to assess public acceptance of such a method. This study aims to initiate an explanation for why excessive mangrove wood harvesting may be happening in the DEWR and demonstrate how the use of ISS would contribute towards conservation of mangrove stands and livelihood improvements in the DEWR. The present study will be useful to conservation institutions envisaging the use of ISS for fuel-wood and mangrove forest conservation.

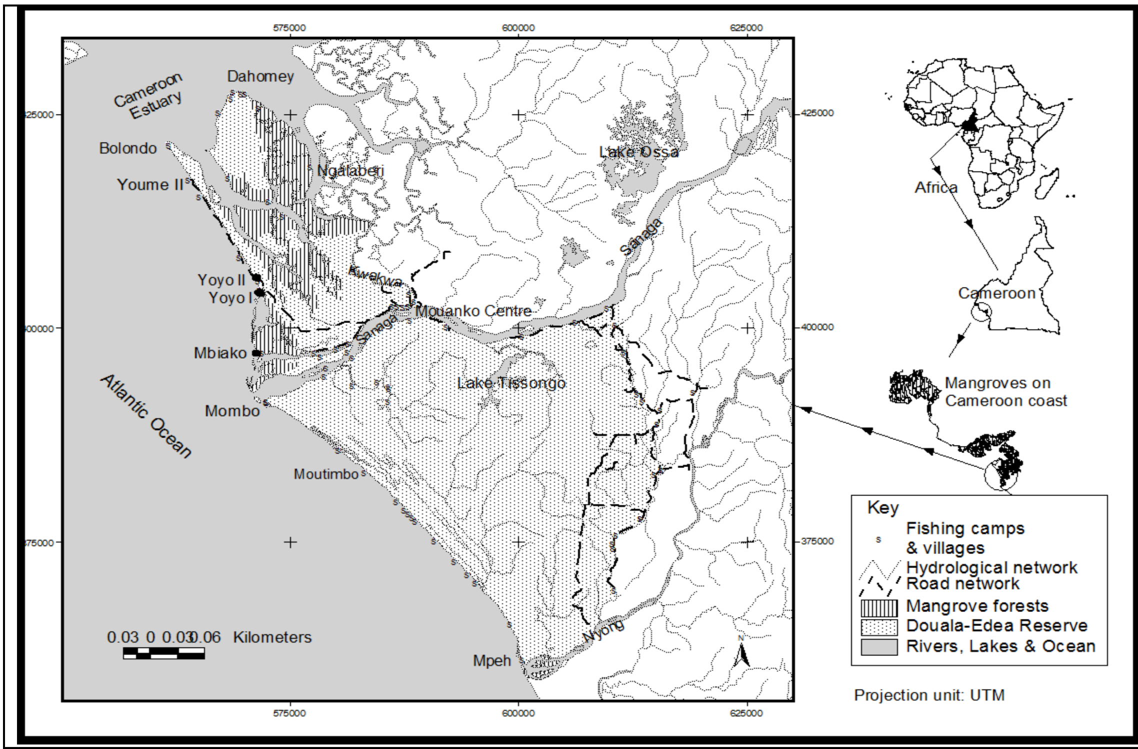

Fig. 1 Location of the mangroves of the Douala –Edea Reserve Cameroon and study sites (Yoyo I, Yoyo II and Mbiako)

Materials and Methods

Description of study site

The DEWR is situated some 75 km south west of Douala in the Districts of Mouanko and Manoka in the Littoral Province within the Douala-Kribi basin of the coastal Atlantic Ocean (Latitude 3° 14' 3°50'N and longitude (9°34'-10°03' E). Covering an area of 160,000 ha, it stretches for 100 km along the Cameroon coastline (Fig. 1). Ever since its creation in 1932, this reserve has been in abandonment and its first resident conservator, and assistant forestry agent was appointed after the creation of the Ministry of Environment and Forests (MINEF) in 1992. Thereafter, the DEWR, along with the Campo Ma'an and Benoue reserve(s), was gazetted following Prime Ministerial decree No 037/CAB/PM of 1994 and transformed into Technical Operation Units (UTO) (Kueté Fidèle, pers-com, 2004 "See *i* in Appendix 2"). In 1997, CWCS, with funding from the International Union for Conservation of Nature (IUCN), initiated management activities in the reserve with the objective of developing a management plan.

The region has an equatorial climate type, characterized by abundant rains (3,000-4,000 mm) and high temperatures with a monthly average range of (24-29)^{o} C. These conditions have favored the development of humid forests and mangrove vegetation of high biological value that serves as a refuge for many seasonal migratory birds [27, 34]. The reserve is host to about 6.4% of the total mangrove stands in Cameroon [35]. The forest is made up of seven floral species, with the dominant species *Rhizophora racemosa* and *Avicennia germinans* clearly displaying a spatial zonation pattern. In addition, the reserve also hosts a varying number of vegetation types, amogst which are freshwater swamps and degraded primary forest.

This reserve has been under threat from encroachment and over-exploitation since its creation, coupled with the lack and/or poor enforcement of policies. The major economic activity is fishing, and about 500 tons of fish are harvested annually by the three fishing localities in which this study was conducted [36]. Fieldwork for this study was conducted from July-September 2005 in the villages of Yoyo I, Yoyo II and Mbiako identified as important fish landing and mangrove wood-use localities within the DEWR [26, 36].

Table 1: Mangrove wood off-take and use in the Douala-Edea Wildlife Reserve, Littoral Province, Cameroon

Locality/ village	Measured parameters	Quantities used as fuel		Quantities used for constructing FS rafts(m^3)
		Fish smoking (1000) m^3/yr	Cooking (m^3/yr)	
Yoyo 1	Number			115.00
	Quantities m^3	26.87	105.5	47.56
	Consumption/smoke house/yr	0.24	0.92	0.41
Yoyo 11	Number of FS rafts			45.00
	Quantities m^3	6.47	42.84	26.2
	Consumption/smoke house/yr	0.41	0.95	0.58
Mbiako	Number of FS rafts			89.00
	Quantities m^3	9.14	84.55	42.49
	Consumption/smoke house m^3 /yr	0.12	0.95	0.477
Total all sites	**Number of FS rafts**			**249.00**
	Consumption/smoke house m^3 /yr	**2.82**	**1.47**	**1.47**
	Wood quantities m^3	**42.49**	**232.89**	**116.25**

Socio-economic Survey

Prior to field visits, a notification letter was sent to the respective village leaders two weeks before hand informing them of our visit and intended socio-economic surveys. Upon arrival in each village, the village head sent out a village announcement informing residents of our arrival and also asking them to help us in our task of data collection. Data were collected using a standard questionnaire, which was administered to households across the three sites, based on involvement in fish-smoking and/or wood-harvesting activities. We used this sampling approach because the family heads of certain households were not willing to co-operate; this strategy enabled us to talk to as many households (within our sampling size of 22 households per site (See *ii* in Appendix 2). This survey enabled us to quantify and understand fuel-wood use, purchase, and harvest dynamics. Constraints and adaptive measures to limit the former were similar to those described in Feka and Manzano [16]. To overcome skepticism that made some households to shy away from the questionnaire and focus group sessions, local guides were hired from the villages. These guides explained upfront to the interviewees that the data collection exercise was for academic purpose, but that the information could further be published elsewhere. Our team did promise confidentiality of all information that was provided. While this approach helped in reducing hostility and suspicion in certain cases, it seriously reduced the number of people who participated in these surveys on the other hand.

Assessment of wood stocks

A seasonal calendar for wood-harvesting intensity was developed for each village, based on a five-point ranking system (0 = no activity—5 = peak activity). Results from this activity were subsequently used to calculate an index used to extrapolate annual wood harvest per site.
This was conducted through three separate focus group discussions involving wood harvesters of the study sites. New mangrove woodpiles were measured on a fortnightly bases over two months (July-August) and findings recorded. The mean monthly measurements were extrapolated over a year using a seasonal calendar index that was developed with the wood harvesters.

Quantities of wood for construction and cooking were directly measured from representative samples and mean(s) multiplied by available number structures, per site (see Table 2). A wood-piling coefficient (p) and tree-form coefficient (f) were determined following approaches described by Phillips [38] and Ajonina [39] and was used to calculate the real volume of round wood logs and piles.

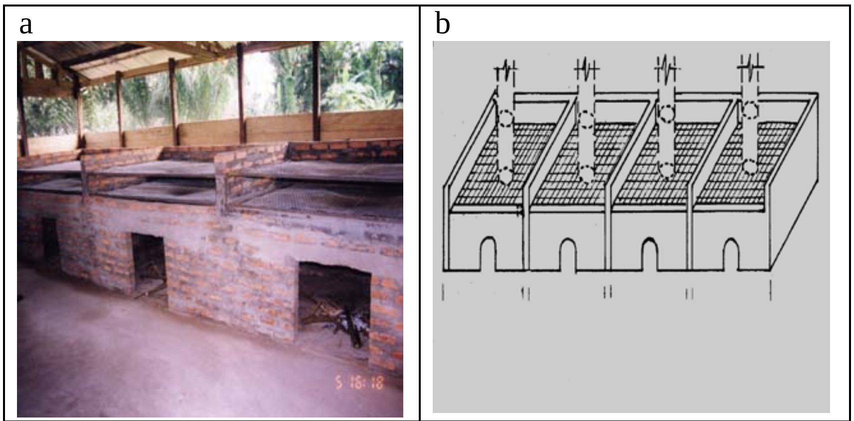

Fig. 2. Fish-smoking systems in use in the Douala-Edea Wildlife Reserve region, (a) Introduced Eeyed/CWCS improved smoke system,(b) Schematic representation of the Eeyed/CWCS improved smoke system

Assessment of wood use levels in fish-smoking systems

The Eeyd/CWCS model (Fig. 2) is a hybrid of the chorkor and the traditional '*banda*' currently in use in the region (Fig. 3). The development of this traditional model along the coast of Cameroon was due to the high fish landings, coupled with the fast fish deterioration rates (as pointed out by community members during fieldwork). The use of this system is thus an adaptive measure to limit fish spoilage. We assessed the performance of ISS and TSS by controlling fish-smoking time, and quantities of wood useded to smoke *Enthomalosa afimloriala* "*Bonga*" to 36-38% (See *iii* in Appendix 2) of the initial moisture content. "*Bonga*" constitutes the most important proportion of fish landings in this area. Efforts were made during the assessment process to maintain equivalent quantities of fish and smoke oven area covered by fish in both types of smoking systems (See Appendix 3). Some fish smokers possessed up to two TSS, enabling them to do parallel fish-smoking sessions, during peak fish seasons. Six TSS (Appendix 3), two from each site, were used.

Table 2: Comparative analysis of the functional characteristics of the Eeyd/CWCS smoke system with the traditional banda smoke system in the Douala-Edea Reserve, Cameroon

Parameter	Sub parameter	Unit	Smoke house system	Mean	SD	F-ratio	P-value	Significance
Area	Area[a]	m^2	TSH	19.60	1.65	0.00	1.00	NS
			ISH	19.60	1.65			
Wood	Volume	m^3	TSH	1.43	0.07	154.35	0.00	***
			ISH	0.90	0.07			
	Weight	10^3kg	TSH	0.89	0.05	154.42	0.00	***
			ISH	0.56	0.04			
	Wood energy	MJ	TSH	14.9	0.79	154.73	0.00	***
			ISH	9.4	0.73			
Fish	Fresh weight[a]	10^3kg	TSH	0.68	0.07	0.00	1.00	NS
			ISH	0.68	0.07			
	Dry weight	10^3kg	TSH	0.25	0.02	0.069	0.79	NS
			ISH	0.25	0.02			
	Weight loss[a]	10^3kg	TSH	0.43	0.04	0.16	0.69	NS
			ISH	0.42	0.04			
	Moisture content	%	TSH	36.0	0.15	55.92	0.00	***
			ISH	38.0	0.63			
	Weight loss	%	TSH	64.0	0.15	55.00	0.00	***
			ISH	62.0	0.63			
Wood/fresh fish ratio			TSH	1.32	0.11	60.39	0.00	***
			ISH	0.84	0.11			
Time		hours	TSH	21.02	0.65	1751.86	0.00	***
			ISH	7.48	0.45			
Relative efficiency		%	TSH	14.29	0.72	23.67	0.001	**
			ISH	20.54	3.07			

[a]Parameters controlled during experimentation include: smoking area of systems, fresh weight of fish, and weight loss of fish.

NS=Not significant (N=6; df =1,10) p>0.05, Significant at *p<0.05, **p<0.01, ***p<0.001

Wood measurements were done after packing fish to full capacity on the surface (see Fig. 3) and displaying wood under the fish-smoking raft. Then the start time was recorded using a stopwatch immediately after a fire was set under the raft. Refueling was done whenever the previous woodpile had completely burnt and the stopwatch time again recorded. Before the complete exhaustion of a wood pile, fish smokers added pieces of wood from time to time. To facilitate the measurement of these additions, the mean volume of wood pieces used at each experimental site was determined from 20 randomly selected pieces. Subsequently, any piece of wood that was added to the system was estimated to be 0.25, 0.5, 0.75, and 1.0 of the mean wood piece. The fish-smoking process took up to four days, after which fish were only occasionally heated for preservation purposes. The same procedure for wood measurement went on until the prescribed moisture content was reached (determined through hand feeling and tasting by fish smokers).

Each ISS is made up of three sub-units, with sub-units functioning independently because of the lack of connectivity between units (see Figure 2a. b). After packing fish accordingly, wood measurements were done following the TSS approach described above. Two ISS, consisting of six units, were used (two exist in the three villages one in Mbiako and the other at Yoyo I). The performance characteristic of each unit is extrapolated to TSS sizes (Appendix 3) by using size ratios of TSS to ISS to obtain equivalent sizes to facilitate functional comparisons between system types.

Fig. 3. Traditional smokehouse in operation in the Douala-Edea Wildlife Reserve region

Data analysis
Data was computed using relevant formulae as outlined in Appendix 1. Seventy (70) questionnaires were administered across the three sites but 62 were analyzed (i.e., 88.6% of the administered questionnaires). Eight were discarded because respondents did not complete answers to certain questions. Analyses were carried out to categorize mangrove wood use, harvest patterns, cost of wood, and the performance of fish-smoking systems. The functional characteristics of the TSS and ISS (being treatments) were done using a one-way analysis of variance (ANOVA) with six replicates of two treatments per site. Socio-economic data were subjected to descriptive statistical analysis.

Results

Quantity of mangrove wood exploited and uses in the Douala-Edea Wildlife Reserve
Wood harvesting and purchase frequencies varied across sites mean 3.50 ± 0.32 and 4.21 ± 0.2 respectively per month per household, while the price per m^3 of wood was constant across sites. However, price varied accordingly with the wood harvesting calendar (Fig. 4) at a mean price of US$30 (see *iv* in Appendix 2). This price is anecdotal information from the field. The wood is used for a variety of purposes in the study sites: construction, bed-making, cooking utensils, charcoal production, fish traps, and others. However, the study assessments were limited to fish smoking, cooking, and construction of fish-smoking rafts. There is variation in diameter class distribution of mangrove wood exploited across all study sites (Fig. 5).

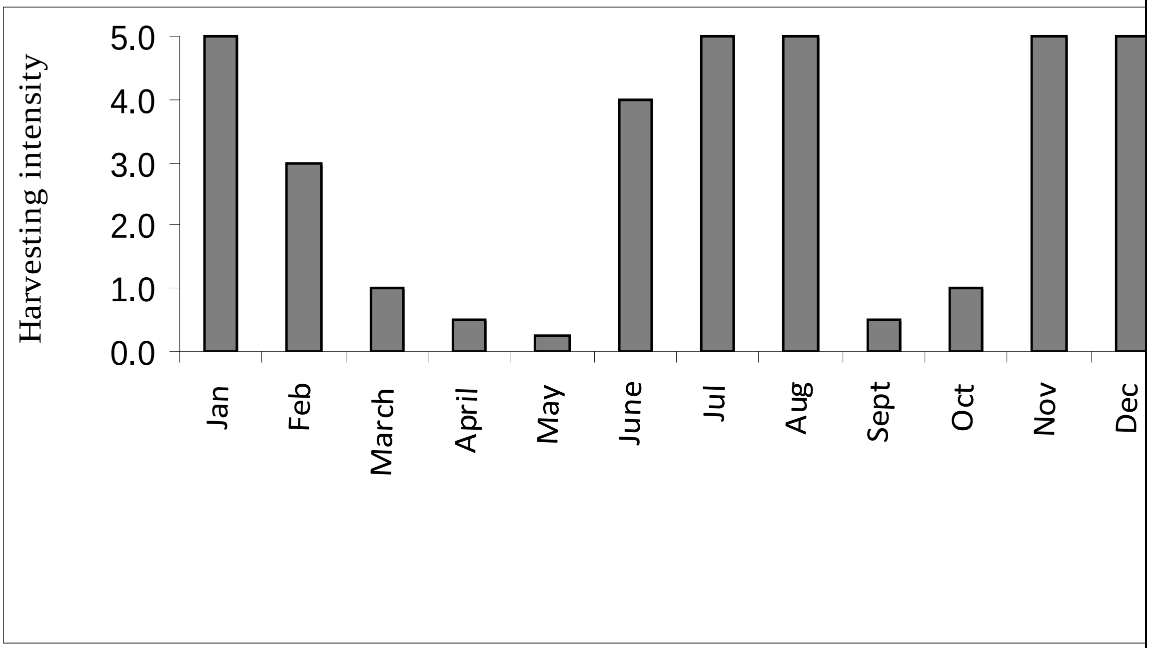

Fig. 4. ***Seasonal calendar for mangrove wood harvest in the Douala-Edea Wildlife Reserve, Littoral Province, Cameroon (Harvest intensity weighted on 5-point scale: 1= very low, 2= low, 3= medium 4= high and 5 = peak)***

We estimated that 42,839 m^3 of mangrove wood was extracted annually in study localities, with the harvested wood being used for almost identical purposes, although the quantities allotted per use-type varied across sites (Table 1). About 42,453 $m^3$of extracted wood was used for fish smoking and/or cooking. Determining the quantity of wood used for cooking alone was difficult because of the dual responsibilities of women who simultaneously cooked under the TSS while smoking fish. Moreover, sometimes charcoal from the process was used for other purposes. However, we evaluated that very little wood (0.003%) and (0.05%) is used annually for cooking and constructing fish smoking rafts, respectively. In addition, the construction wood was mixed with poles from terrestrial forests, but we did not quantify this. Most of the women acknowledged using wood from the terrestrial forest, not as an alternative fuel source, but as a necessity for the first day of fish smoking. This phase of smoking needs to be fast, hence fast-burning wood is required to minimize fish spoilage. Unfortunately, we could not determine this quantity of forest wood during this study.

Fish smokehouse performances with respect to wood and energy conservation

The comparative characteristics of the TSS and ISS are summarized in (Table 2). The TSS had a mean wood consumption of 1.4±0.6 m^3 and a mean smoking time of 21.02±0.65 hours, while the ISS showed mean fuel consumption of 0.91±0.16 m^3 and a mean smoking time of 7.48±0.45 hours, respectively (see *v* in 2). This indicated a high significant difference between the ISS and TSS with respect to time ($F_{1, 10}$ = 1751.862; p<0.001) and quantities of wood used between systems ($F_{1, 10}$= 29.881; p<0.001). Based on fuel-wood consumption and energy conversions, the ISS conserves about 50% of wood relative to the TSS and is 70% more efficient than the TSS per complete fish-smoking session. With respect to the quality of fish, commercial fish dealers and fish smokers found no difference in taste, color, and appearance of fish smoked in the two systems. However, there seemed to be varying opinions on the potential adoption of the Eeyd/CWCS ISS across sites (Fig. 6). Furthermore, some of the fish smokers highlighted health problems resulting from the persistent use of the TSS. Some of these problems are related to respiratory system, fatigue, and sight. Reports from the district health unit indicate that fire disasters, skin burns, and stillbirths are caused by the persistent use of TSS.

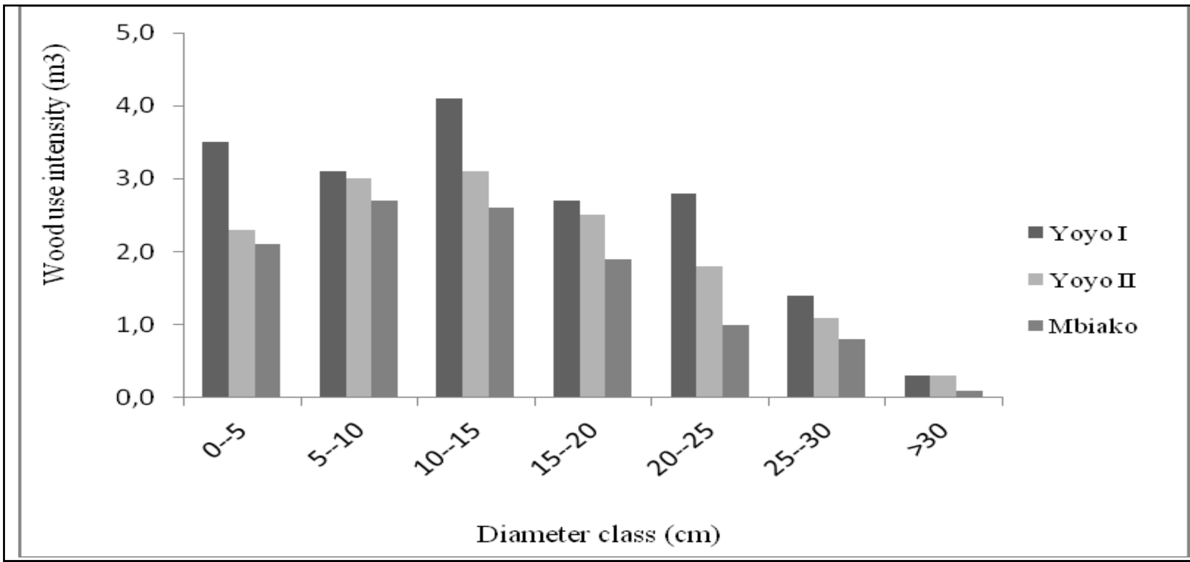

Fig. 5. **Diameter class distribution for mangrove wood exploited and used in the Douala-Edea Wildlife Reserve, Littoral Province, Cameroon. (Derived from 10 randomly selected wood piles per village [Yoyo I: n=396, mean=39.41, SD=25.95; Yoyo II: n=308, mean=30.82, SD=19.32; Mbiako: n=358, mean=35.80, SD=18.29])**

Discussion

Mangrove wood harvesting patterns, use and impacts

It is well documented that mangrove wood is an important source of energy and livelihood for coastal communities of West-Central Africa and beyond [4, 21]. Despite these values, there is growing scientific consensus that mangrove wood exploitation even on small scale has negative impacts on the population ecology of this system [19]. It is difficult to ascertain from this study if the current wood harvest levels are affecting the population ecology of mangroves because no forest assessments were carried out in this study. However, it is unequivocal that exploitation of wood from mangrove forests for use as fuel is a significant factor contributing to deforestation and degradation of mangroves and other forest types [1, 2, 15, 42]. Actions that potentially lead to mangrove forest deforestation and degradation, generally within isolated coastal communities that most often have little or no alternative sources of income, are highly driven by locally specific economic incentives [4].

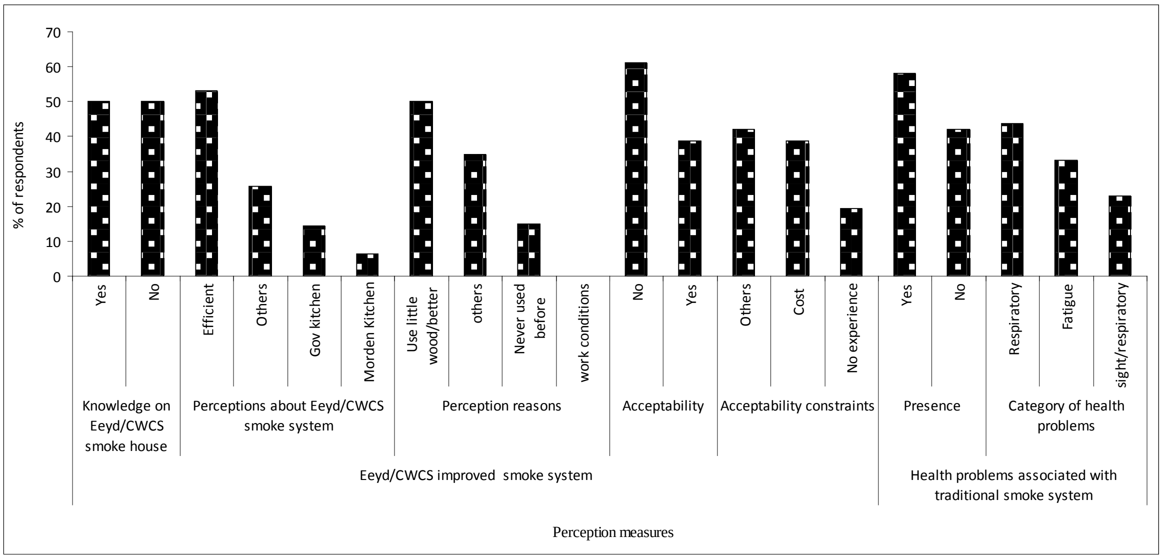

Fig. 6. Community perception of the characteristics of improved and traditional smoke systems in the three study villages in Douala-Edea, Cameroon (Base on 62 respondents (Yoyo I, 23; Yoyo II, 20; Mbiako, 19))

Correlating TSS wood consumption with mangrove forest deforestation and degradation is difficult because other factors such as the abandoning of wood in the forest following speculative harvests also adds to wood off-take from mangrove stands in this part of Cameroon [16]. In addition, the financial impetus because of high demand during the peak fish season (Fig. 4) is also an important intensifier of harvesting patterns. All these factors result in excessive exploitation, which may cause degradation of mangrove forests. Elsewhere, differential levels of wood exploitation have contributed to modification of forest population ecology [17]. Nevertheless, this study adds that high fuel-wood consumption levels in the DEWR region could be attributed to the poor efficiency in wood use by TSS. This is because the ISS was assessed to be 70% more efficient than the former.

The harvested wood is used for the same purposes in all studied villages, because of the remote location and common wood use activities in all three areas. However, fuel-wood purchase patterns and intensities varied because of village location and the intensity of economic activity—mainly fishing and fish-smoking. Hence, Yoyo I with the highest wood extraction quantities (Table 1) reportedly has the highest fish landings [36]. A population census carried out in the three villages by CWCS in 2000 showed that more than 70% of the active population, which is less than 15 years of age was involved in full-time fisheries-related activities. Mangrove wood and fisheries resource use characteristics and resource depletion are summarized in Fig. 7. All fish catch is smoked by over 90% of respondents in the three villages. Fish-smoking and cooking account for over 90% of mangrove wood use, which is preferred by more than 90% of the respondents for availability and characteristics, such as fish coloration, fire burning under both dry and wet conditions, and its high calorific value (Fig. 7). Wood is harvested directly from the mangrove forest by about 50% of the respondents although there seemed to be no perception of depletion of mangrove wood resources as expressed by 75% of the respondents.

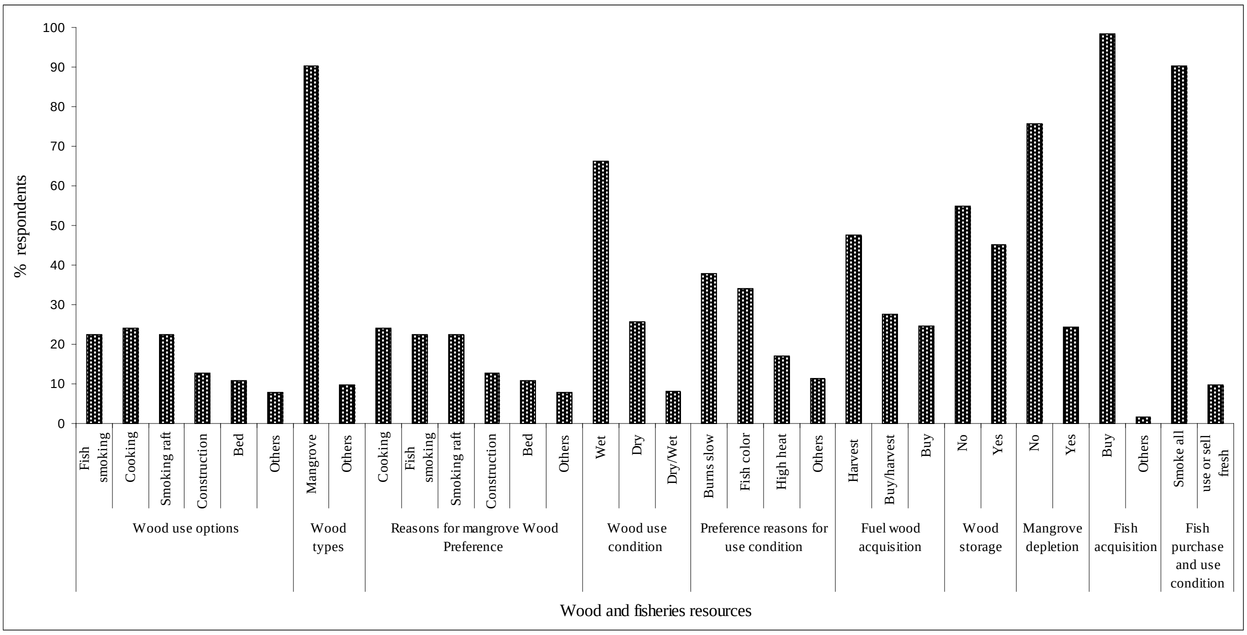

Fig. 7. Community mangrove wood and fisheries resource use characteristics and perception of mangrove degradation in the three study villages in Douala-Edea, Cameroon (Based on 62 respondents (Yoyo I 23; Yoyo II, 20; Mbiako, 19))

Although mangrove wood is economically important to tropical coastal communities [4, 13], it is highly controlled by an unorganized informal sector in Cameroon [15], which may account for the uncontrolled wood exploitation patterns observed (Personal observation). The management of mangrove forests falls under Cameroon's 1994 Forestry, Wildlife, and Fisheries Legislation. This regulation allows for the exercise of customary rights by local people for their subsistence; however, the current harvest practices in the DEWR are not limited to subsistence use [27]. The immediate consequence of this "*overuse*" of wood is the off-take of 0.60% of the 16,000 ha of mangrove stands of the DEWR per year. This is unsustainable, considering the population size of 1,774 for the three villages [36], relative to the population size of Cameroon, with a deforestation rate of about 1% per year [33]. Previous studies in the same villages indicated a deforestation rate of 0.33% per year [26]. The higher value in this study may be the result of an increased number of traditional fish-smoking systems, from 172 to 249, since 1998-2004 in the study sites. A key factor for this change is the increasing intensity of economic activities (fishing and fish-smoking). Similarly, about 1000 ha of mangrove forests are cleared annually from the Douala Estuary, situated within Cameroon's economic capital [15]. Although this study indicates that the rate of mangrove wood harvesting is relatively high, the overall intensity of the harvest rate in the entire reserve is underestimated because of the limited sample size and time of the study. Other impacts in the mangrove systems as a result of the studied excessive wood extraction can include disturbance of ecological processes and loss of vulnerable genetic material and mangrove productivity in an ecosystem where physiology and development is still poorly understood [1].

Performance of fish-smoking systems and prospects for mangrove conservation

Our results demonstrate that current levels of demand and supply for wood from mangrove stands in the study sites has adverse effects on the sustainability of this system. Reducing wood consumption is a logical approach to downsizing wood use quantities, and ISS can be used in achieving this aim [29]. The performance of the ISS model assessed herein has the potential of meeting this objective because it reduced both wood consumption and fish-smoking time relative to the TSS. The main reason for longer fish-smoking time and high fuel-wood consumption by the TSS is associated with its design. Its unconfined boundaries (Fig. 3) favor heat and energy loss, hence making it inefficient in the utilization of energy and smoke generated from the burning of wood. This inefficiency is also associated with the multi-functions women and children execute during the fish-smoking process. The ISS model as presented in this study could perform better if its independent sub-units (Fig. 2b) were integrated. This segmentation limits heat and smoke dissipation over small areas, hence reducing its efficiency with respect to fuel-wood consumption per unit area. Reducing the segmentation may further reduce the additional cost of construction materials and further reduce the quantities of wood consumed.

However, while this ISS can be instrumental in alleviating excessive fuel consumption patterns, the ISS has to be made more adaptable and cost effective by taking into consideration local customs and traditions [28]. The Eeyd/CWCS model is built from burnt bricks, which are very expensive and not readily available to fish-smoker households of the DEWR: a complete ISS costs about US$2,000 [44], hence its introduction as it stands in the region may be difficult if the issue of cost is not addressed. This may explain the diverse perceptions about the ISS system in these localities (Fig. 6). The respondents seem to be adequately aware of ISS because about 50% acknowledged its efficiency especially in terms of wood use although 15% have never used it before (Fig. 6). However, 61% were not ready to accept it largely because of cost (39%) and other considerations (42%), and were ready to continue using the traditional systems despite the presence of many health constraints such as respiratory problems (44%), fatigue (33%), and others acknowledged by 58% of the respondents.

Implications for conservation

The use of low fuel economy systems for fish-smoking enhances the quantity of wood consumption, hence perpetuating excessive fuel-wood use from mangrove forests in the DEWR. With an understanding of fuel-wood consumption levels of TSS, it is possible to start working toward the eventual phasing out of TSS. The introduction of ISS might reduce wood consumption and hence sustain the ecosystem. The effective replacement of the TSS with the Eyed/CWCS ISS means that about 70% of energy, i.e., 0.50 m^3 of wood, would not be used during each complete fish-smoking session. This means that a single TSS theoretically burns about 256 m^3/yr while a single, ISS consumes about 157 m^3/yr.—i.e., 60% less than the former. When extrapolated to the 259 fish-smoking systems in all study sites, TSS take-off is about 63,980 m^3, i.e., about 160 ha of annual mangroves. The annual avoided deforestation from ISS use can be projected to about 25,714 m^3–i.e., about 65ha (41%) of forests can be conserved annually in the study sites from the adoption of this smoke system. Similar experiments are on the way in Cambodia by Development and Appropriate Technology (DATe), a Non-Governmental Organization (NGO) that has developed a simple, but effective way of smoking fish and reducing mangrove wood use (Quatro, A., pers-com, 2007 See *vi* in Appendix 2). This indicates that for the potential use of ISS systems as a strategy for conserving mangrove ecosystems, particularly in developing countries, holds great promise. Moreover, the introduction of ISS has contributed to reducing fuel-wood consumption and improving working conditions for local communities in India [45]. The adoption of ISS will reduce US$2,772 of expenditure, largely in money gained from not purchasing the extra wood that the system can save. The latter also saves about 180 work days per year for those involved . Acquiring these valuables will significantly enhance the social well being of the women and children in this area and contribute towards poverty alleviation. It is possible that this time saved will encourage women and children to process more fish, but this is unlikely due to the seasonality of fish production in the region [36, 42].

Beyond the benefits of avoided fuel-wood use and the consequent mangrove forest conservation, the use of the ISS also represents an opportunity for reducing greenhouse gas (GHG) emissions by reducing extra biomass consumption. The Eyed/CWCS initiative is thus a strategy where local actions can contribute to both national mangrove conservation and global mitigation of climate change. The scales of such local actions can be up-scaled among other coastal communities in West-Central Africa where more than 8 million people depend on fishing and/or fish smoking as a means of livelihood sustenance [46]. Furthermore, adoption of the ISS by fish smokers in this region will reduce poverty and reduce the vulnerability of coastal communities to the impacts of coastal storms and surges, since larger stands of mangrove forests will be sustained over longer periods.

Conclusion

Given the current economic situation of Cameroon and most countries in coastal West-Central Africa, it will be difficult to suppress mangrove wood harvesting for fish-smoking, because it is an important livelihood activity in the region. The insights into mangrove wood harvest levels, price/m^3, and uses depicted in this study are important variables that can be useful for the sustainable management of mangrove ecosystems in the DEWR (and possibly beyond). In addition to sustaining mangrove stands, the advantages of developing and using Eeyed/CWCS or any other ISS model in the region include alleviating the sufferings of women and children involved in the fish-smoking exercise. However, its successful introduction and adoption depend on persuading the potential users of the ISS to accept this new technology. The methodological approach needs to be concise and very thoughtful, with a clear explanation of its aims and objectives to its potential users. For this reason, the successful introduction of the Eyed/CWCS model requires further community awareness and training programs on the objectives and advantages of this model as well as further research on adapting the present model to local realities. Some attention can be directed towards teaching fish-smokers how to construct and effectively use the Eyed/CWCS ISS.

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Appendix 1. Data computations

Volume of wood log = $\frac{\pi D2}{4} * hf$ (m^3) ………………………………………………………… (1)

Where:
D = log diameter
l = log length
f = log form factor (0.6 from Ajonina and Usongo 2001) [26]
π = 22/7

Wood piling coefficient, p = $\frac{\sum_{l=1}^{n} \frac{\pi}{4} D_n^2 lf}{abc}$ ………………………………………………………….(2)

Where:
p = actual volume of all logs in the pile/Volume of pile (this includes actual volume + air spaces within the pile)
a = pile width (m) b = pile length (m) c = pile height (m)
n = number of wood logs per pile or set,
a piling coefficient of 0.5 was obtained

Volume per hectare (m^3/ha), V_{stand} = $\frac{\sum_{l=1}^{n} \frac{\pi}{4} D_n^2 Hf}{A}$ ……………………………………………(3)

Where:
D= tree diameter, H = stand mean height, f = tree mean form coefficient A= forest stand area in hectares and n = number of trees in the forest stand
h = tree height and f = tree form coefficient (f = 0.6 from Ajonina and Usongo 2001)
Main assumptions in the efficiency calculation process:
For clarity (as direct values should not be used in equations) we can rewrite the formula as follows:
Efficiency = E_s = $\frac{\text{Useful energy}}{\text{Energy input from wood}}$ = $(MC_{fish\ weight\ loss\ fraction} . W_{fresh\ fish} . E_{fish}) / (W_{wood} . Cal_{wood})$
……………………………………………………………………………………………………… (4)

Where:
$MC_{fish\ weight\ loss\ fraction}$ = fish weight loss fraction (0.64) after smoking (final moisture content of 36%)
$W_{fresh\ fish}$ = weight of fresh fish (680 kg) kept constant in all systems
E_{fish} = energy required to evaporate water from fish using drying systems, about 5800kJ/kg [40]
W_{wood} = wood weight in kg (1m^3= 624 kg (Fresh weight) for *R. racemosa* measured from the field
Cal_{wood} = calorific value of wood (calorific value of *R. racemosa* = 16.9MJ/kg [41]
Relative efficiency (R_e) = E_{rel} = E_{TS}/E_{IS}…………………………………………………(5)
Where:
E_{TS} = mean energy consumed by TSS
E_{IS} = mean energy consumed by ISS
Extrapolations to standing volume to deduce current wood off-take rates because of fuel wood consumption by both systems, and avoided off-take due to improved efficiency of ISSs were done using the following formulae:
E_{annual}= 365.F.N. E_{av}-……………………………………………………………………………(6)
D_{ha} = E_{annual}/V_{stand}……………………………………………………………………………(7)
Where:
E_{annual} = Total wood consumed by a system per year
F = 0.8 (Correction factor being effective number of fish smoking days to be same as fishing effort = effective number of fishing days in the region 292 [42] /365 days in a year)
E_{av} = Average wood consumption (m^3)
N = number of fish smoking rafts in the area (in this experimental case, N=1)).This was used for the different extrapolations.
$D_{ha\ =}$ Deforestation rate or avoided deforestation rate (ha/yr, kg/yr),
$V_{stand\ =}$ standing volume or biomass in m^3/ha (403m^3/ha [39])

Appendix 2. Foot notes

[i] Kuetè Fidèle was the Conservator of the DEWR at the time of this study. He is currently the Conservator of the Campo Ma'an Reserve

[ii] At the time of this study there were 249 TSS with ten households having two fish-smoking systems from all study sites. In order to avoid redundancy only one questionnaire was administered per household. Our sample size was guided by the 20% of population size criteria according to Cochran [37]

[iii] Marketed smoked fish in Cameroon has moisture content in the range of (30-40) original moisture content See FAO [29]

[iv] At the time of this study in 2004 1US$=500FCFA

[v] For the TSS we smoked 680kg of fish and extrapolated accordingly, the ISS values to equate the former (See Appendix 3)

[vi] Alfredo Quatro is the Executive Director of Mangrove Action Project, Port Angeles WA, USA

Appendix 3. Physical attributes of TSS and Equivalent ISS ratios, as used in this study

Village	Tss size (m^2)	ISS unit sizes (m^2)	Equivalent ISS size rations
Yoyo I	20.10	3.36	6.0
	16.80	3.36	5.0
Yoyo II	21.12	3.36	6.3
	18.48	3.36	5.5
Mbiako	20.16	3.36	6.0
	21.01	3.36	6.3