Available online at http://ajol.info/index.php/ijbcs

Int. J. Biol. Chem. Sci. 9(1): 246-258, February 2015

ISSN 1997-342X (Online), ISSN 1991-8631 (Print)

International Journal of Biological and Chemical Sciences

*Original Paper* http://indexmedicus.afro.who.int

# Traditional exploitation of edible freshwater oyster *Etheria elliptica* (Lamarck, 1807) in Pendjari River (Benin-West Africa): assessment of income, human pressure and options for management

Giraud David AKELE[1*], Simon AHOUANSOU MONTCHO[1], Antoine CHIKOU[1], Guy Apollinaire MENSAH[2] and Philippe Adédjobi LALEYE[1]

[1] *Laboratoire d'Hydrobiologie et d'Aquaculture, Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, 01 BP 526 Cotonou, Bénin.*

[2] *Institut National des Recherches Agricoles du Bénin (INRAB), CRA-Agonkanmey ; 01 BP. 884 Cotonou, Bénin.*

[*] *Corresponding author, E-mail:akeldav@yahoo.fr*

## ABSTRACT

Freshwater oyster *Etheria elliptica* (Mollusca: Bivalvia) was harvested in Pendjari River as important source of protein and income. The river crosses the Pendjari Biosphere Reserve, a protected area in Northern Benin. The freshwater oyster is harvested outside and within the protected area with increasing human pressure. The current study aims at assessing fishery production, human impact on wild stocks and suggests sustainable management options. Individual semi-structured interviews and monitoring of oyster collection were used to collect data on harvesters' socio-economic characteristics, biomass production and seasonal income in 2008 and 2009. Mean shell size and weight as well as size frequency distribution were analyzed in relation to harvesting pressure. Oyster harvesting is the main traditional activity of Berba women in dry season, at low water level period. The oyster collectors used artisanal tools such as chisel-like metal, stone-hammer, rope, metal pan and pot. Biomass production, oysters mean size and weight decreased from protected sites to unprotected zones revealing negative anthropogenic pressure on oyster natural stocks. Size frequency distribution displayed an important proportion of smaller individuals in open access sites whilst larger size oysters were more encountered in protected zones. Therefore, exploitation appeared likely as a potential threat for oyster bed. Moreover, the oyster collectors not only exploited individuals without observing a minimum limit size, but they also targeted each year the same sites regardless rotation planning. Finally, oyster`s shell, a main substrate for larval settlement and bed restoration, were left on riverbanks after exploitation, reducing stocks reconstitution potential. Appropriate measures were suggested to Reserve staff for sustainable management.



**Keywords:** Freshwater mollusk, harvesting activities, human pressure, fisheries management.

## INTRODUCTION

Worldwide, mollusks bivalves group include many edible species of great commercial interest such as mussels and oysters (Gosling, 2003).The world market for bivalves has critically increased in the last three decades as highlighted by export trends since the seventies (124 300 tonnes in 1976 and 459 300 tonnes in 2005) (Lovatelli et al., 2008). Such increase was mainly due to



DOI : http://dx.doi.org/10.4314/ijbcs.v9i1.22

mussels with 257 300 tonnes in 2005 (Lovatelli et al., 2008). However, production increase was mainly provided by mussel aquaculture since natural stocks have faced overexploitation. Moreover, freshwater mussels (Mollusca: Bivalvia: Unionoida) were stressed to be threatened worldwide mainly due to overfishing (Anthony and Downing, 2001; Strayer, 2006).

In the tropics, oysters are found in rivers and coastal areas and supported many small artisanal fisheries (Haupt et al., 2010; Van Damme, 2011; Ikpi and Offem, 2012). Wild oysters are commonly harvested by local residents especially women as main traditional activity. Oyster exploitation provides protein and improves income of local communities (Bogan, 2008; Haupt et al., 2010; Ikpi and Offem, 2012). However, small artisanal fisheries, especially in Africa, were considerably unregulated and were declining due to overexploitation (de Bruyn et al., 2009; Haupt et al., 2010). For instance, in South Africa, de Bruyn et al. (2009) reported steady decrease in biomass of oyster *Striostrea margaritacea* between 1935 and 1955 due to lack of sound regulations. Wild stocks decline led to adverse socio-economic consequences for poor people, especially for women, owing to significant decrease of both low-cost protein and income (Narvarte et al., 2007; Ikpi and Offem, 2012).

*Etheria elliptica* (Lamarck, 1807) (Mollusca: Bivalvia: Etheriidae) is the only freshwater oyster occurring in many lakes and rivers through Africa (Graf and Cummings, 2006; Van Damme, 2011). The oyster was mostly harvested by growing indigenous populations along artisanal fisheries in Africa (Van Damme, 2011; Ikpi and Offem, 2012). In West Africa, the traditional exploitation of freshwater oyster has been described in many small fisheries mostly in Ghana (Ampofo-Yeboah, 2000) and in Nigeria (Ikpi and Offem, 2012). Besides, species oysterbed decline was pointed out in Burkina Faso (West Africa) resulting from excessive gathering by riverine population of Volta Basin (CNRST, 1992). Although African small fisheries were assumed to be facing unsustainability and overexploitation (poor and growing local population; unregulated exploitation, high demands for limited resources) (Narvarte et al., 2007), substantial information on human pressure on freshwater oyster are still lacking. The abundant literature available on species mainly focused on systematic and spatial distribution (Graf and Cummings, 2006; Van Bocxlaer and Van Damme, 2007). Information on bivalve exploitation remains limited to harvesting activities description and harvesters socio-economic traits (Ampofo-Yeboah, 2000; Ikpi and Offem, 2012). However, understanding how human pressure and harvesting technique affect stocks is of great importance not only to settle sustainable management measures but also for sensitization and environmental education activities targeting residents' dwellers (Hartill et al., 2005). In fine, this also contributes to secure their livelihood.

The freshwater oyster *E. elliptica* was harvested by residents in Pendjari River for livelihoods. The river crosses the Pendjari Biosphere Reserve (PBR), a protected area (Benin-West Africa) on two-third of its course (Agbossou and Okounde, 2001). In open access sites, heavy and unregulated exploitation is leading to stocks collapse; therefore, exploitation pressure is increasing on oysterbed within the Reserve where collection was under control (Kiansi, 2011). Indeed, within the context of ongoing co-management between local population and the Reserve managers, access was given to surrounding people to collect some reserve resources such as medicinal plants, straw and halieutic resources, as they contribute to anti-poaching activities and biodiversity conservation. Overall, oysters appeared to be the main resource requested by poor and growing local residents after fish species (Kiansi, 2011). This leads to increasing pressure on the oyster stocks within the reserve. Therefore, an establishment of sustainable management strategy for oyster wild stocks is one of the priorities of the PBR managers. This work aims at analyzing 1) the socio-economic characteristics of harvesters (sex, age, ethnic group, profession, income of exploitation), 2) the impact of harvesting pressure on natural stocks and the implication for co-management success and the sustainable use of this resource.

## MATERIALS AND METHODS

### Study area and species

The study was carried out along the Pendjari River in Northern Benin (West Africa) (10°24 N, 1°21E). The river crosses the Pendjari Biosphere Reserve for 200 km out of 380 km of its course and is a natural border between Burkina Faso and Benin (Agbossou and Okounde, 2001). The Pendjari River has a tropical hydrological regime with a low water season between December and June and a flood season from September to October. The Pendjari River is located in Sudanian climatic zone with one rainy season (April/May to October) and one dry season (November to March). Mean rainfall reached annually 1000 mm with 60% falling between July and September Daily temperature varies between 11 °C (at night in December) up to 40 °C (at noon in April) in the area (Sinsin et al., 2002).The riverbed is characterized by different types of sediments serving as substrates for sessile mollusks bivalves such as freshwater oyster *E. elliptica*.

The Pendjari Biosphere Reserve covers an area of 4666.4 $km^2$ and is composed of Pendjari National Park (2660.4 $km^2$) which represents the core integrally protected area where human activities are prohibited, the Konkombri hunting zone (251 $km^2$) and the hunting zone of Pendjari (1750 $km^2$); the latter hosts oyster harvesting activities.

### Sampling and data collection

#### *Socio-demographic traits of oyster harvesters*

Prior to data collection, the number of harvesting groups actively collecting oyster within the Reserve was recorded from reserve managers. Similar data were collected from key persons about harvesters operating in open access land. Overall, 90 harvesters living in surrounding villages (Daga, Porga 6, Porga7, Pouri, Setchendinga) were recorded. Distributed in five harvesting groups, they were active in different sections of the river: open access (Borne 0-5) and protected zones (Borne 18-28 and Borne 30-40), during 2008 and 2009 harvesting seasons. In Tampanga, 60 oyster collectors exclusively active in open access site were registered. As the latter were far from the Pendjari Biosphere Reserve, their collection activities remained limited to Tampanga accessible sites (Figure 1). Finally, 150 active harvesters were recorded among riverine communities. Respondents were chosen for this survey based on their level of involvement in and dependency on oyster harvesting (active every year), harvesting sites location (open access and protected zones), harvesting activity importance in dry season or time allocated (main activity in dry season) and agreement to take part in the research. Individual semi-structured interviews were used to collect socio-demographic data (sex, age, sociolinguistic group and occupation) of harvesters along the river. Overall, 120 harvesters out of 150 were involved in data collection.

#### *Oyster fishery production and income estimation*

To assess harvesting output, oyster exploitation was monitored during 2008 and 2009 harvesting seasons (December to July) in different stations. Oyster fishery production was analyzed by oyster biomass estimation. Biomass (kg) per collector and per site was estimated after weighting individual production in the field both in open access and protected zones. Biomass measuring tool was a metal pan containing 30 kg of living oysters. Total production per collector was obtained by multiplying the total numbers of pans collected by each harvester at the end of the season by 30 kg.

Living oysters were processed, sun-dried and sold in market with a small unit bowl containing about 1.5 kg of dried oysters and costing 2 500 FCFA. The collector income varies depending on duration of a harvesting trip (one or two weeks) and sites. The mean income per collector was estimated per different sites considering the market price of dried oysters sold with smaller unit bowl. The seasonal income of the collector was estimated taking into account the number of trips per season.

***Assessing human impact***

Oyster exploitation took place in the river both outside and within the protected area. In the current study, we monitored two open access sites (Tampanga and Borne 0-5) and two protected sites (Borne 18-28 and Borne 30-40) (Figure 1). Human impact was expressed through three harvesting pressure criteria summarized in Table 1. Three human pressure degree were defined as following: Tampanga (high human pressure), Borne 0-5 (medium human pressure) and Borne 18-28 and Borne 30-40 (low human pressure).

Values of parameters such as mean shell size and weight of oyster and size distribution frequency were estimated and compared among sites in relation to human pressure degree**.** Shell size (height or anterior posterior length) was measured with a caliper to 0.1 mm. Shell sizes were measured both for living individuals and relict shells from recent collection. Total weight of living oysters was measured to 0.1 g in different stations.

**Data analysis**

Frequency and percentages were used to analyze socio-demographic backgrounds of respondents among sites. The Kruskall-Wallis non parametric test (H) was used to compare, among all sampling sites, oyster biomass, income, oysters mean size and weight as data were not normally distributed (Dagnelie, 1984). Shell size frequency distributions were compared among sites using G-test (G).

## RESULTS

**Socio demographic traits of oyster collectors**

The socio-demographic traits of the oyster harvesters in the study area included their age, gender, ethnic group and occupation. Overall, interviews were conducted with 120 collectors of oyster *E. elliptica* both in open access sites (35 collectors at Tampanga and 20 collectors at Borne 0-5) and within the protected area (51 collectors at Borne 18-28 and 14 collectors at Borne 30-40). Oyster exploitation is dominated by women (93% of interviewees). Men mostly helped women to locate oysters stock in profound parts of the river. Age of harvesters ranged from 17 to 85 years with an average attaining 50 years. Most oyster collectors in open access zone were younger (mean age: 43 years). In opposite, old harvesters (mean age: 53 years and 75% of them aged over 40 years) were mostly encountered in the protected sites. Berba tribe women dominated (94%) oyster exploitation with few Mina (3%) and Kakamba (3%) people. Oyster *E. elliptica* was locally called "Kourou" by Berba people, Adja" by Mina and "Teounkoro" by Kakamba. Harvesters practiced mainly agriculture in rainy season whereas exploitation is the major occupation in dry season.

**Artisanal oyster harvesting and actual management strategies**

Overall, oyster was harvested yearly in dry season by native population mainly Berba women. In open access land, exploitation started at low level of the water period (November/December) and ended at the onset of rainy season in June/July. In contrast, exploitation within protected area started later, after the game hunting activities to avoid hunting accident and ended at the onset of rainy season. Thus, the duration of exploitation decreased from open access sites (6 months at Tampanga) to protected zone (about two months from May/June to July) with identical collection method. Oyster harvesting technique is traditional and artisanal. In shallow zones, women wade through the river and locate oyster clumps with their feet. As sessile organism, oyster lived attached to hard substrates (rocks, dead woods) or in colonies in the river bottom. Thus, artisanal tools such as chisel-like metal (locally called «Koutourou») and a stone/hammer (called «wangui») were used respectively to pry oysters and break large oyster colonies. Oysters were stocked in metal pan attached with a rope to women chest. Afterwards, the harvested oysters were stocked in heaps on riverbanks and were boiled in metal pot to remove easily the meat from shell. Fuel wood was cut from gallery forests surrounding the river. Oyster meat was later sun dried and conserved with ash.

Overall, oyster harvesting suffered of lack of rotation system in all stations. Interviews followed by observations of licenses issued for the exploitation at protected sites revealed that collection occurred each year mainly in the same sites. Moreover, there was neither indicated minimum size, nor limited landing biomass for harvesters. Furthermore, empty shells were left on river banks and in mounds, albeit they could be returned back to river to serve as substrates for larval settlement. Indeed, apart from a minor use as supplemental food for ostrich reared in Dassari (30 km away from Porga), oyster shells were useless for local population.

**Biomass production and income**

Mean biomass for all sites and seasons accounted for 247.6 ± 130.4 kg/collector (Mean ± SD). Biomass per collector was significantly different among sites ($H = 62.677$, $N = 140$, $p < 0.01$). Lower biomasses were recorded in open access sites with 118.9 ± 78.1 kg/collector and 199.3 ± 90.5 kg/collector respectively at Tampanga and at Borne 0-5 whereas higher values were estimated at protected sites (310.5 ± 122.5 kg/collector and 320.3 ± 72.3 kg/collector respectively at Borne 18-28 and at Borne 30-40) (Figure 2).

Overall, mean seasonal revenue per collector was estimated to 23 615 ± 14 335 FCFA covering a trip (5 to 15 days). The Kruskal-Wallis test ($H = 71.044$, $N = 140$, $p < 0.01$) showed significant difference among sites. Although, a limited harvesting period, seasonal revenues per collector in protected zone were almost two-fold ones in open access zones (Table 2).

**Shell size, total weight and size frequency distribution**

Overall, 674 shells were measured. Shell size ranged between 7.2 mm and 154 mm with mean size of 60.6 ± 19.4 mm. Significant differences were found in mean size among the 4 sites ($H = 158.6342$, $N = 674$, $p < 0.01$). Mean size increased from open access sites (49.5 ± 14.7 mm (N = 176) and 57.34 ± 16 mm (N = 254) respectively at Tampanga and at Borne 0-5) to protected zones (70.73 ± 17 mm (N = 138) and 73.93 ± 22.87 mm (N = 106) respectively at Borne 18-28 and in Borne 30-40).

Overall, 491 living oysters were weighted on exploitation sites. Individual weight ranged from 4 g to 240 g with 64.5 ± 42.8 g mean weight. Significant differences in mean weight were found among sites ($H=168.472$, $N=491$, $p < 0.01$). Mean weights were lower in accessible sites (36.4 ± 20.2 g and 59.2 ± 36.6 g respectively at Tampanga and at Borne 0-5). Protected sites recorded greater mean weight values with 79.9 ± 40.9 g and 81.9 ± 49.4 g respectively at Borne 18-28 and at Borne 30-40 (Figure 3).

Both oyster size and weight showed an increase with the decrease of harvesting pressure degree.

Size class distribution (Figure 4) of harvested *E. elliptica* individuals was drawn both in open access sites (Tampanga and Borne 0-5) and protected sites (Borne 18-28 and core area). Significant differences in size class distribution were found among the four sites ($G = 86.099$, $df = 3$, $p < 0.01$). Shell class 41-80 mm held the highest proportion of harvested specimens for all stations. Larger size classes (81-120 mm and 121-160 mm) were more abundant in protected sites with 24.2% and 38.7% respectively at Borne 18-28 and in core area. Larger specimens accounted for 9.2% and 11.2% respectively in Tampanga and Borne 0-5. Conversely, Tampanga in unprotected zone recorded the highest proportion (24.1%) of small oysters (0-40 mm shell class) among sites.

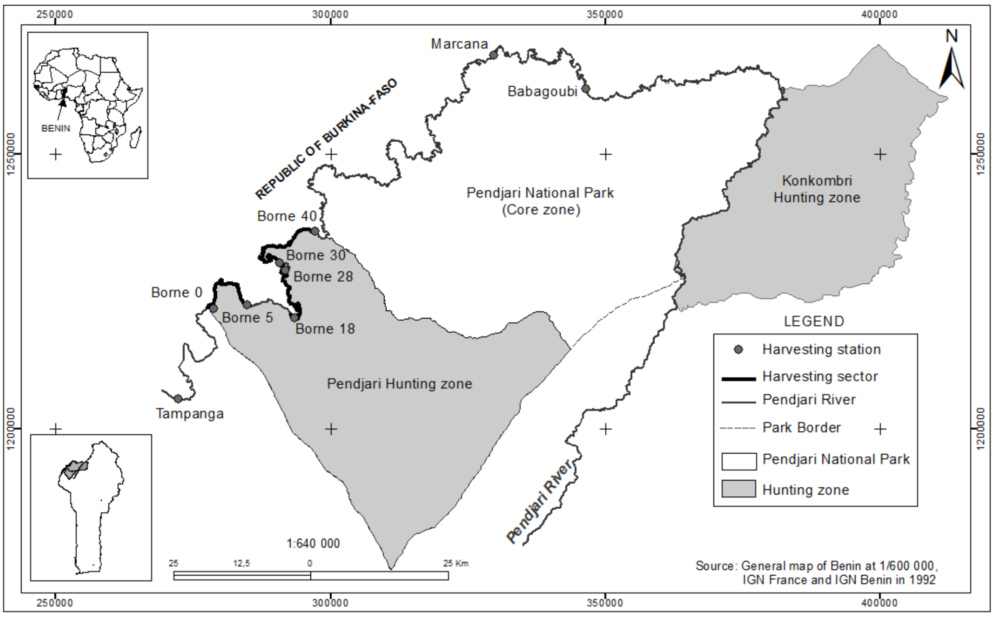


**Figure 1:** Oyster collection sites distributed along the Pendjari River located inside and outside the Pendjari Biosphere Reserve (Benin-West Africa).

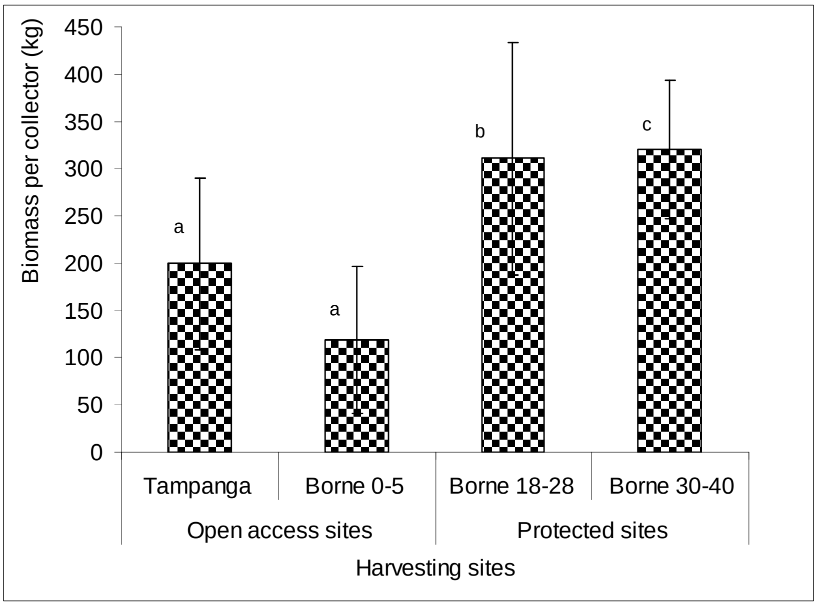


**Figure 2:** Oyster biomass (Mean ± Standard Deviation) per collector and per site during 2008 and 2009 harvesting seasons. (Kruskal-Wallis test, $p < 0.01$; Sites with different superscripts differ significantly).

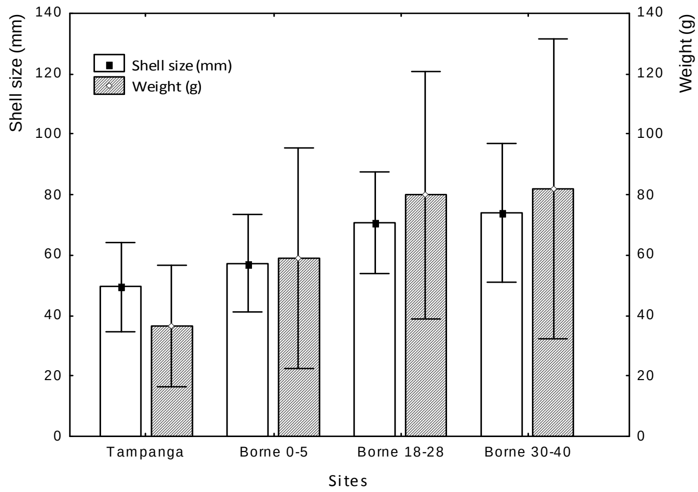


**Figure 3:** Shell size (Mean ± SD) and oyster weight (Mean ± SD) of sampled oysters during 2008 and 2008 harvested seasons.

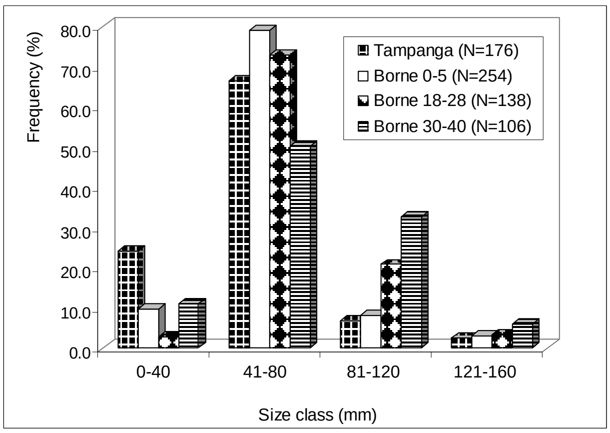


**Figure 4:** Size frequency distributions of oyster *E. elliptica* collected in the Pendjari River both from open access sites (Tampanga) and protected sites located within the Pendjari Biosphere Reserve.

**Table 1:** Characteristics of sampling sites in relation to human pressure degree on wild oysters.

| Sampling sites | Existence of regulation | Number of harvesters | Annual harvesting duration (month) | Harvesting pressure level |
|---|---|---|---|---|
| Tampanga | No regulation | Unlimited | 6 – 7 | High |
| Borne 0-5 | No regulation | Close riverine only | 5 | Medium |
| Borne 18-28 | Closed period<br>License required | Limited | 2 | Low |
| Borne 30-40 | Closed period<br>License required | Limited | 2 | Low |

**Table 2:** Mean income per collector (per trip) and per season during 2008 -2009 exploitation period in open access and protected sites (1dollar US = 507 FCFA).

| | Harvesting sites | Mean income/collector/ trip (FCFA) (*) | Seasonal income per collector (FCFA) (*) |
|---|---|---|---|
| Open access sites | Tampanga | 14 186 [a] | 44 000 [a] |
| | Borne 0-5 | 12 063 [a] | 41 200 [a] |
| Protected sites | Borne 18-28 | 32 000 [b] | 76 500 [b] |
| | Borne 30-40 | 32 500 [b] | 77 000 [b] |

(*) Significant difference ($p < 0.01$) Values with common superscript do not differ significantly

## DISCUSSION

### Oyster harvesting and its socio-economic importance

Worldwide, oysters serve as supplemental food source (Gosling, 2003). The freshwater oyster *E. elliptica* was gathered as important source of food and income for poor people livelihood through oyster shellfisheries in Africa (Van Damme, 2011; Ikpi and Offem, 2012).

Traditional oyster harvesting in the Pendjari River constitutes a cornerstone in socioeconomic life of local populations. Exploitation provides low-cost protein and generates useful income especially to women. Moreover, importance of oyster as main animal protein source was emphasized since most of fish production of river was exported to Burkina Faso where it generates more revenue to fishermen. Along the Pendjari River, characteristics of oyster harvesters are in accordance with past surveys. Thus, harvesters are mainly farmers in rainy season and exploitation occurred in dry season as reported in past studies in Ghana (West Africa) (Ampofo-Yeboah, 2000). In Africa, previous studies stated that exploitation was traditional women activity through many small fisheries while men were occupied by fish capture (Ampofo-Yeboah, 2000; Glaubrecht, 2010). In our study area, men were involved in fish capture, hunting activities; Non timber forests Products collection. Some men were recruited as forests guard by the Pendjari Biosphere Reserve staff (Vodouhè et al., 2009). Then, low implication of men in exploitation could be seen as a factor limiting pressure on oyster beds.

Age of collectors could likely influence the pressure on oysterbeds. In Senegal, mangrove oyster harvesting appeared to be difficult owing to the time spent away household. Therefore, exploitation is devoted to old people, especially to women without domestic and marital duties (Cormier-Salem, 1987). Similar trend was recorded in our study especially, concerning exploitation activities within protected area. In this zone, long time spent in forest (at least two weeks), facing extreme daily temperature variations from 11 °C at night to 40 °C during the day (Sinsin et al., 2002) and stress linked to presence of wild animals (lion, elephant, buffalos etc.) limited younger women participation. These women were more active in open access zone. In opposite, oysters were collected both by young and old women in White Volta (Ghana) (Ampofo-Yeboah, 2000). Furthermore, as traditional activity, oyster harvesting was generally limited to certain ethnic groups (Bay, 2000; Ampofo-Yeboah, 2000). In White Volta (northern Ghana), *E. elliptica* was collected by seven tribes (Dagombas, Gonjas, Konkombas, Mos, Dagartis, Ewe and Hausa) whereas Berba ethnic group people mostly dominated exploitation in the Pendjari river. In our study area, Berba is most the dominant ethnic group populating the villages surrounding the Pendjari River. Thus, dominance of Berba women on oyster harvesting could be seen as an advantage for setting appropriate strategies for oysters' management. Indeed, it seems likely easier to convince limited number of ethnic groups for conservation goals (Vodouhè et al., 2009).

Oyster exploitation contributes greatly to household income of collectors. In the study area, price of sun-dried oysters varied between 1 600 FCFA/kg and 2 000 FCFA/kg over year. Oyster price is about 4 times more expensive than the cost of dried freshwater oyster *E. elliptica* in Ghana (270 - 450 FCFA/kg) (Ampofo-Yeboah, 2000). In contrast, mangrove oyster was sold 2 000 FCFA/kg in Senegal (Bay, 2000) and is almost similar to our results. Estimated revenue per collector was twice higher in protected zone (32 000 – 32 500 FCFA) after a collecting trip of two weeks. This indicates the importance of protected zone for harvesters and pointed out stocks decrease in open access sites. Seasonal revenue per collector varied between 44 000 FCFA and 77 000 FCFA depending on number of trips and exploitation zone. Higher seasonal incomes were obtained in protected zones. Our findings were in accordance with the ones of Bay (2000) who reported 50 000 FCFA/collector for a season of five months while Cormier-Salem (1987) observed higher annual income (109 000 FCFA/collector) in Senegal. Although most part of production served as domestic consumption, revenue from oyster sale appeared to be greatly important for poor population with low annual income (72 000 FCFA), especially for women (Projet Alafia, 2009).

**Human pressure impact**

Throughout the world, unregulated harvesting of bivalves was known to affect adversely wild stocks (Haupt et al., 2010; Gosling, 2003). In Burkina Faso (West Africa), decline due to overexploitation of mollusk species including *E. elliptica* was reported (CNRST, 1992). In the current study, survey sites were chosen depending on human pressure degree on oyster stocks from open access zone to protected zone. Human pressure impact was characterized with mean shell size, mean oyster weight and oyster size frequency distribution and significant variations were proved among exploitation sites. Overall, previous studies assumed that oyster mean shell size decline was an indicator of stocks decline and overfishing (Rius et al., 2006; Haupt et al., 2010). For instance, Ajana (1980) reported size range decrease of mangrove oyster *Crassostrea gasar* from 60-70 mm to 45-55 mm in 1977 due to over exploitation in coastal fisheries in Nigeria. Our study underlined a decrease of mean size and weight of oysters from protected zones to open access zones. This indicates the negative impact of unregulated exploitation on bivalves stocks. This finding is supported by Haupt et al. (2010) in South Africa who reported that size of oyster specimens of protected zones was higher than ones of unregulated zones in relation to human pressure degree. Likewise, Rius et al. (2006) reported similar trend for mussels which size was smaller in open access zones than in protected sites. In the Pendjari River, oyster shells reaching a maximum shell height of 126 mm was observed in completely protected core zone where clandestine exploitation occurred. Consequently, the lower mean size (60.6 mm) of harvested oysters could be likely attributed to overfishing.

Although the variations among sites, size frequency distribution indicated higher proportion of smaller oyster individuals in open access sites, it was hypothesized that in absence of selection, indiscriminate harvesting occurred. Therefore, size frequency revealed the natural population structure (Hartill et al., 2005). Consequently, the dominance of smaller individuals in open access sites evidenced existing threats on oyster beds (Rius et al., 2006). Indeed, owing to annual heavy exploitation, harvesters did not enable juveniles to grow enough before exploitation occurred. Likewise, collection of smaller oysters in the Pendjari River was fostered by lack of defined minimum size such as the first maturity size (Hartill et al., 2005; Rius et al., 2006; Haupt et al., 2010). Our outcomes brought evidence of human pressure on oyster beds in the Pendjari River. Consequently, appropriate management strategies were required to overcome threats on freshwater *E. elliptica* in the river.

**Current management strategies of oyster fishery**

In the study area, management strategies remain limited to closed season in protected zone mainly due to wild stocks protection and hunting activities. Field monitoring of oyster exploitation and harvesting pressure assessment pointed out three (3) main types of threats on wild stocks: 1) exhaustive harvesting with negative implication for oyster beds, 2) lack of minimum size and 3) absence of rotational system.

Exhaustive harvesting occurred when harvesters collected all available oysters stocks encountered in sites before they moved to untapped streams (Rius et al., 2006). Such harvesting technique was assumed to decimate oysters' populations and caused stocks decline (Anthony and Downing, 2001; Rius et al., 2006). In the study area, Berba women mainly exert high pressure. Exhaustive harvesting leads to negative effects on natural population recovery because almost all colonies are removed. Indeed, presence of colonies or conspecific living oysters was required to trigger larvae settlement due to pheromone secretion (Tamburri et al., 2008). Consequently, management strategies should indicate a remaining oyster density per site to guarantee oyster stock reconstitution especially in protected zone.

In absence of minimum limit size, exploitation targets all sizes especially immature oysters and affects natural population to self-recruit. This likely leads to overexploitation (Hartill et al., 2005; Strayer, 2006). Past studies have demonstrated that size limit was established as useful tool for harvest regulations (Strayer, 2006) mainly in cases where management data were not available (Hartill et al., 2005). The freshwater oyster *E. elliptica* reached maturity size in range of 57-65 mm in the Pendjari River (personal communication). Therefore, a minimum limit size of 65 mm should be fostered in harvesting stations especially in open access zone where immature individuals were mostly gathered. Furthermore, past experiences stated that minimum size was easy to implement as rationale was easily accepted by collectors (Hartill et al., 2005; Carranza et al., 2009).

Rotational strategies lead to production increase since the stocks were left with fallow years for recovery whereas absence of rotation caused stock decline (de Bruyn et al., 2009). Rotating fishing areas have been demonstrated to be a sustainable tool to manage sessile and sedentary invertebrates stocks (de Bruyn et al., 2009). In the Pendjari River, collection occurred each year in the same sites because river banks «belong» to different communities living along the river. The staff of Pendjari Biosphere Reserve should establish rotational period among harvesting sites in accordance with harvesters and their collectivities as land-owner. Oyster-based research should investigate species growth performance to establish a rotational period, which in turn could ensure stocks conservation and increase oyster production for dwellers welfare.

**Implication for sustainable use strategies**

Despite the lack of management strategies underlined above, closed harvesting season (December-April) in protected zones as well as the obligate license remained useful management strategies (Strayer, 2006; Haupt et al., 2010). However, current management strategies should be enforced. In addition, community-based management approach of exploited oyster populations is considered as one of the most promising ways to link sustainability and economic growth (Carranza et al., 2009). Furthermore, empty oyster shells should be returned back to the river after exploitation. It was demonstrated that conspecific shells were preferred substrates for larval settlement and stocks recovery (Tamburri et al., 2008). Currently, empty shells were almost useless for local people and were left on riverbanks. In the Pendjari River, oyster specimens reach sexual maturity at 65 mm (personal communication). Therefore, a minimum harvesting size should be enforced mainly in open access sites where estimated mean sizes remained notably lower (49.5 mm at Tampanga and 57.34 mm at Borne 0-5). Conversely, oysters collected in protected zones were mostly larger than recommended limit size. In this respect, implementation efforts of minimum limit size should target open access zones.

## Conclusion

This study exhibited the income provided by freshwater oyster exploitation and revealed effect of human harvesting pressure on oyster wild stocks in the Pendjari River. Mean shell size and weight of oysters as well as size frequency distribution displayed the effect of human pressure degree on wild oysters stocks. Likewise, the traditional harvesting technique has potential threats for wild stocks. Sound sustainable strategies should be implemented to guarantee oyster stocks restoration and conservation. As the main proportion of harvesters collect oysters inside and outside the Reserve, regulation could be also implemented in accessible zones. Community-based strategies should be useful for oyster beds sustainable management. Future research works were necessary to collect scientific species-based data for stocks conservation.

## ACKNOWLEDGMENTS

We wish to thank BIOTA West Africa program for funding this research work. We also thank Pendjari oysters' collectors for their participation to the research work. Many thanks to our field guide, Dominique Sambieni for production data collection. We thank all anonymous reviewers for their valuable contribution.

## REFERENCES

Agbossou E, Okounde J. 2001. Réalisation des études hydrologiques et d'aménagement de la Réserve de Biosphère du complexe de la Pendjari. Rapport d'étude, Tome 1 et tome 2. CENAGREF, Cotonou, Bénin, p. 42.

Ajana AM. 1980. Fishery of the mangrove oyster, *Crassostrea gasar*, Adanson (1757) in the Lagos area, Nigeria. *Aquaculture*, **21**: 129-137.

Ampofo-Yeboah A. 2000. Aspects of the fishery, ecology and biology of the freshwater oyster (*Etheria sp*. Lamarck, 1807) in northern Ghana. Master of Philosophy degree in Zoology University of Cape Coast, p. 42.

Anthony J, Downing J. 2001. Exploitation trajectory of a declining fauna: a century of freshwater mussel fisheries in North America. *Can. J. Fish. Aquat. Sci.*, **58**(10): 2071-2090.

Bay T. 2000. Contribution à l'évaluation du stock d'huîtres de palétuviers (*Crassostrea gasar* Adanson) dans le Parc National du Delta du Saloum (Sénégal). Gembloux : Travail de fin d'études. Faculté Universitaire des Sciences Agronomiques de Gembloux, p. 75.

Bogan AE. 2008. Global diversity of freshwater bivalves (Mollusca:

Bivalvia) in freshwater. *Hydrobiologia*, **595**: 139–147.

de Bruyn PA, Moloney CL, Schleyer MH. 2009. Application of age-structured production models to assess oyster *Striostrea margaritacea* populations managed by rotational harvesting in KwaZulu-Natal, South Africa. *ICES J. Mar. Sci.*, **66**: 408–419.

Carranza A, Defeo O, Beck M. 2009. Diversity, conservation status and threats to native oysters (Ostreidae) around the Atlantic and Caribbean coasts of South America. *Aquatic Conserv: Mar. Freshw. Ecosyst*, **19**: 344–353.

CNRST. 1992. L'huître des rivières : distribution, rôle dans l'alimentation et la pharmacopée locale au Burkina Faso.- Ouagadougou. *Science et Technique, sér. Sci. Nat*, **20**(1): 5-16.

Cormier-Salem MC. 1987. La cueillette des huitres en Casamance. Place de cette pratique dans le système d'exploitation Diola. Document scientifique du Centre de recherche océanographiques de Dakar-Tiaroye 106, p. 104.

Dagnelie P. 1984. *Théorie et Méthodes Statistiques. Applications Agronomi-ques*. Tome II. Les Presses Agronomiques de Gembloux : Gembloux ; 463.

Glaubrecht M. 2010. The enigmatic *Cleopatra broecki* Putzeys, 1899 of the Congo River system in Africa – re-transfer from Potadomoides Leloup, 1953 (Caenogastropoda, Cerithioidea, Paludomidae). *Zoosyst. Evol.*, **86**(2): 283–293.

Graf DL, Cummings KS. 2006. Palaeoheterodont diversity (Mollusca:Trigonoida: Unionoida): what we know and what we wish we knew about freshwater mussel evolution. *Zool. J. Linn. Soc.*, **148**: 343-394.

Gosling E. 2003. *Bivalve Molluscs*: *Biology, Ecology and Culture.* Blackwell Science: UK; 456.

Hartill BW, Cryer M, Morrison MA. 2005. Estimates of biomass, sustainable yield, and harvest: neither necessary nor sufficient for the management of non-commercial urban intertidal shellfish fisheries. *Fish. Res.*, **71**: 209–222.

Haupt TM, Griffiths CL, Robinson TB, Tonin AFG, de Bruyn PA. 2010. The History and status of oyster exploitation and culture in South Africa. *J. Shellfish Res.*, **29**(1): 151–159.

Ikpi GU, Offem BO. 2012. Fishery and the Tourism Potential of Agbokum Waterfalls, Nigeria. *J. Water Resourc. Prot.*, **4**(9): 733-745.

Kiansi Y. 2011. Cogestion de la Réserve de Biosphère de la Pendjari : Approche concertée pour la conservation de la biodiversité et le développement économique local. Thèse de doctorat de l`Université d`Abomey-Calavi, p. 274.

Lovatelli A, Vannuccini S, McLeod D. 2008. Current status of world bivalve aquaculture and trade. En A. Lovatelli, A. Farias e I. Uriarte (eds). Estado actual del cultivo y manejo de moluscos bivalvos y su proyeccion futura: factores que afectan su sustentabilidad en America Latina. Taller TecnicoRegional de la FAO. 20–24 de agosto de 2007, Puerto Montt, Chile. *FAO Actas de Pesca y Acuicultura*, *Roma*, **12**: 45–59.

Narvarte M, Gonzalez R, Filippo P. 2007. Artisanal mollusk fisheries in San Matıas Gulf (Patagonia, Argentina): An appraisal of the factors contributing to unsustainability. *Fish. Res.*, **87**: 68–76.

Projet Alafia, 2009. Coton biologique et équitable dans la réserve de biosphère de la Pendjari, Benin. Rapport Annuel 2009, p. 10.

Rius M, Kaehler S, McQuaid CD. 2006. The relationship between human exploitation pressure and condition of mussel populations along the south coast of South Africa. *S. Afr. J. Sci.*, **102**: 130-136.

Sinsin B, Tehou AC, Daouda I, Saidou A. 2002. Abundance and species richness of larger mammals in Pendjari National Park in Benin. *Mammalia*, **66**(3): 369–380.

Strayer DL. 2006. Challenges for freshwater invertebrate conservation. *J. N. Am. Benthol. Soc.*, **25**(2): 271-287.

Tamburri MN, Luckenbach MW, Breitburg D, Bonniwell S. 2008. Settlement of *Crassostrea ariakensis* larvae: effects of substrate, biofilms, sediment and adult chemical cues. *J. Shellfish Res.*, **27**(3): 601-608.

Van Bocxlaer B, Van Damme D. 2007. Palaeobiology and evolution of the Late Cenozoic freshwater molluscs of the Turkana Basin: Iridinidae Swainson, 1840 and Etheriidae Deshayes, 1830 (Bivalvia: Etherioidea). *J. Syst. Palaeontol.*, **7**(2): 129–161.

Van Damme D. 2011. *Etheria elliptica*. In *IUCN 2012*. IUCN Red List of Threatened Species. Version 2012.2. <www.iucnredlist.org>. Downloaded on 21 March 2013.

Vodouhè GF, Coulibaly O, Greene C, Sinsin B. 2009. Estimating Local Values of Non-Timber Forest Products to Pendjari Biosphere Reserve Dwellers in Benin. *Econ. Bot.*, **63**(4): 397–412.