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WOMEN SHELLFISHERS AND FOOD SECURITY PROJECT

**PARTICIPATORY ASSESSMENT OF SHELLFISHERIES IN THE
ESTUARINE AND MANGROVE ECOSYSTEMS OF
BENIN**



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Cover photo: Oysters (left) on sticks and mangroves (right) in Lake Nokoué, Benin

Photo credit: Alphonse Adite

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TABLE OF CONTENTS

	<u>Page</u>
Detailed Partner Contact Information.....	ii
TABLE OF CONTENTS.....	iii
LIST OF TABLES.....	v
LIST OF FIGURES.....	vi
ACRONYMS.....	vii
Executive Summary.....	1
1. Introduction.....	4
1.1. Description of Benin Republic.....	4
1.2. Objective of the study.....	5
2. Methodology.....	6
2.1. Study sites.....	6
2.2. Field survey/data collection.....	7
2.3. Summarized background data.....	9
3. Status of Shellfisheries.....	10
3.1. Shellfish Exploitation.....	10
3.1.1. Estimated number of shellfishers.....	10
3.1.2. Insights on gender in shellfish exploitation.....	11
3.1.3. Shellfishing as primary occupation.....	12
3.1.4. The shellfish value chain.....	12
3.1.5. Species harvested.....	17
3.1.6. Harvesting methods.....	24
3.1.7. Harvest volumes and value.....	24
3.1.8. Seasonality of harvests.....	24
3.2. Mangrove Ecosystem.....	24
3.3. Governance/Management Regimes.....	25
3.4. Climate Risk Mitigation.....	27
4. Conclusion and Recommendations.....	28

References	30
Appendices	34
Appendix 1: Total number of communities/villages with shellfishing activities occurring in mangrove ecosystems of Benin.....	34
Appendix 2: Descriptive statistics of monthly sales of shellfish from coastal sites	35
Appendix 3: Methods of processing and use of shellfish.....	36
Appendix 4: Local organizations and research reports on shellfisheries and mangrove ecosystems in Benin.....	38
Appendix 5: Images from field visits.....	44
Appendix 6: Revised list of stakeholders.....	59

LIST OF TABLES

	<u>Page</u>
Table 1: Summarized data on survey respondents.....	9
Table 2: Estimated number of shellfishers in user communities. *	11
Table 3: Age structure of shellfishers (Respondents). *	11
Table 4: Habitats, harvesting methods, processing methods, and uses.....	14
Table 5: Common shellfish species exploited in each coastal ecosystem and their habitat.....	21
Table 6: Exhaustive common and uncommon exploited shellfish recorded by researchers.	22
Table 7: Role of mangroves in the value chain of the shellfisheries.....	25
Table 8: Status of the estuarine and mangrove ecosystem used for shellfisheries.....	27
Table 9: Total number of communities/villages with shellfishing activities occurring in mangrove ecosystems of Benin.....	34
Table 10: Monthly sales in US \$ of shellfish from three coastal sites.	35
Table 11: Analysis of variance (ANOVA) of monthly sales in US \$ of shellfishes from three coastal sites.....	35
Table 12: Methods of processing and use of shellfish.	36
Table 13: Local Organizations engaged in mangrove restoration and shellfisheries.	38
Table 14: List of published and unpublished research (Technical reports) on mangrove and shellfishes.	40

LIST OF FIGURES

Figure 1: Map showing the coastal waters (Southern Benin).....	7
Figure 2: Fisher (men & women) population including shellfishers in Benin.....	8
Figure 3: Importance of shellfisheries (% resource users).....	12
Figure 4: Rank of shellfish species harvested at the Benin coastal waters: Oysters and snails are the top shellfish exploited.....	17
Figure 5: Common exploited shellfish species in Benin coastal waters.....	20
Figure 6: Meeting at Degoue village (Coastal Lagoon).....	44
Figure 7: Meeting at Degoue village (Coastal Lagoon).....	45
Figure 8: AVLO Village.....	46
Figure 9: Mangrove at Avlo village (Coastal Lagoon).....	46
Figure 10: Mangrove at Avlo village (Coastal Lagoon).....	47
Figure 11: Discussion with the Chief of the Village AVLO.....	47
Figure 12: Discussion with the Chief of the Village AVLO.....	48
Figure 13: Discussion with the President of oyster exploitant of AVLO village.....	48
Figure 14: Mangrove at Avlékété Village (Coastal Lagoon).....	49
Figure 15: Mangrove at Djègbadji Village (Coastal Lagoon).....	49
Figure 16: Mangrove at Djègbadji Village (Coastal Lagoon).....	50
Figure 17: Oyster shell at Avlékété.....	50
Figure 18: Oyster market (Agatogbo village) at Lake Ahémé.....	51
Figure 19 Lake Nokoué.....	52
Figure 20: Acadja: park of branches installed in Lake Nokoué to attract fishes and produce oyster.....	53
Figure 21: Acadja fisheries (fish and oyster) in Lake Nokoué.....	54
Figure 22: Acadja fisheries (fish and oyster) in Lake Nokoué.....	55
Figure 23 Acadja fisheries (fish and oyster) in Lake Nokoué.....	56
Figure 24: Acadja fisheries (fish and oyster) in Lake Nokoué.....	57
Figure 25: Spat (small oysters) on sticks in Lake Nokoué.....	58

ACRONYMS

AFEHB	Benin women association of oyster operators
CCM	Centre for Coastal Management
CRC	Coastal Resources Center
INSAE	National Institution of Statistics and Economic Analysis
UCC	University of Cape Coast
URI	University of Rhode Island
USAID	United States Agency for International Development

Executive Summary

Basic Contextual Information	
Country	Benin
Total land area	114,763 km ²
Population	11.49 million (2018)
Percentage population living in/near the coast	17%
Gross Domestic Product (GDP)	10.35 billion USD (2018)
Human Development Index Rank	0.520 (163 out of 189)
Length of coastline	121 km
Fish consumption (as a percent of animal protein)	38 %
Anemia prevalence	62% for children under 5 56% among pregnant women 46.9% among women of reproductive age (15-49)
Estimated mangrove cover	6,600 ha
Estimated estuarine and mangrove ecosystem-based shellfish harvesters	710
Estimated women shellfish harvesters (percent)	669 (93 %)
Estimated direct household shellfish beneficiaries	5774
Estimated percentage of shellfish harvesters at all nodes of the value chain (vertical integration)	67%+
No. of coastal systems with mangrove-based shellfishing	3
Shellfish management regulations	Framework law n° 2014-19, August 7, 2014, on Fishing and Aquaculture in the Republic of Benin, Articles 8 and 12 favorable to enabling co-management approaches for fisheries.

Mangrove management regulations	
Coastal ecosystems with shellfisheries identified as Ramsar sites	Entire coast of Benin: Basse Vallée du Couffo, Lagune Côtière, Chenal Aho, Lac Ahémé (524,000 ha) Basse Vallée de l'Ouémé, Lagune de Porto-Novo, Lac Nokoué (652,760 ha) An estimated 6,600 ha of this are associated with shellfisheries

Source: Chuku et al. 2020, Global Mangrove Watch, Ramsar Sites Information Service (RSIS).

In the Benin coastal waters, namely Lake Nokoué, Porto-Novo Lagoon, Coastal Lagoon and Lake Ahémé covering about 11,768 Km² and belonging to Benin Ramsar sites, shellfisheries constitute an important component of mangrove fisheries and provide substantial revenues for grassroots, mainly women shellfishers. The current study was undertaken to assess and document shellfisheries and mangrove status. Surveys were conducted with the shellfishers in coastal villages. Other stakeholders such as researchers, government and NGOs were interviewed.

Shellfisheries involve mainly women aged 13-75 years. Shellfisheries in coastal areas include activities such as culture, harvesting, transportation, processing, retailing/marketing, and consumption. The most common shellfish exploited were *Crassostrea tulipa* (mangrove oyster), *Achatina achatina* (giant snail), *Tympanotonus fuscatus* (small gastropod), *Cardiosoma armatum* (Wetland crab), *Callinectes sp* (Lagoon crab) and *Penaeus sp* (Shrimp). Shellfish meats are sold fresh, fried, and smoked and monthly revenue from shellfishing ranged between \$74-\$480 (\$252±142).

Mangrove degradation and seasonal/periodic flooding were the main threat for the shellfisheries. Overall, the Benin fisheries law explicitly allows for co-management through delegation of authority including to fisher associations. Holistic and community-based approaches including ecological/biological research, law reinforcement, governance regimes, climatic factors, mangrove forest protection and restoration, ecosystem monitoring, shellfish farming improvement, and marketing are required for the sustainable exploitation of shellfishes.

To improve women's shellfisheries livelihoods and working conditions, and mangrove health in Benin, stakeholders articulated the following recommendations:

- Respect the various fisheries and environmental laws and regulations.
- Raise awareness on the policies available for mangrove protection.
- Protect the mangrove habitat.
- Promote environmental education.
- Sensitize fishermen on the roles of mangroves and the necessity to protect them.
- Provide capacity building for all stakeholders on sustainable use of mangrove ecosystems.
- Organize men and women shellfishers into associations.
- Regulate shellfish collection, including through co-management frameworks.

- Implement a shellfisheries inventory.
- Conduct research on shellfish habitat conservation.
- Implement ecological research.
- Research oyster mortality during flooding - depict the cause of mortalities during flooding.
- Develop and promote shellfish farming.
- Avoid fishing by fishermen in oyster culture areas.
- Modernize shellfishing techniques.
- Provide technical assistance and financial aid (training, materials, funds) to resource users and other stakeholders to facilitate improved and sustainable shellfisheries harvesting, processing, and sales.
- Train women (and men) shellfishers to adopt good practices to preserve the environment and their health.
- Develop shellfisheries value chains for the valorization of products to increase value added and income, especially for women. This can be achieved by training women in hygienic processing methods, improving the presentation of products, and seeking out markets for their sale.
- Promote shellfish sales in hotels and restaurants.
- Encourage shellfish consumption on a large scale.
- Promote other livelihood activities so that the oysters and mangroves will be restored.

1. Introduction

In the coastal zone of Benin, shellfishes are intensively exploited and provide sustainable financial resources for local coastal communities through collection of wild stocks and traditional shellfish farming. In artisanal/commercial fisheries, shellfish such as molluscs (oysters and snails) and crustaceans (shrimps and crabs) are massively harvested at the community level for food and sales and their shells are sold and used as ingredients for animal food industries (Adite et al, 2013). In terms of nutritional composition, shellfish contain about 80% water, 17.2% protein, and many vitamins such as A, D, E, B1, B2, B6, B12, C etc., and minerals. Consequently, shellfish meat stands as valuable food for human health. In aquaculture, most shellfish species are cultivated for food, provide financial resources for households, and are a low-cost investment compared to fish farming. Regarding ecological importance, shellfish such as *Crassostrea sp* are an indicator of environmental health that can signal the degree of contamination of aquatic ecosystems since they accumulate polluting substances. Also, shellfish such as oysters reduce ocean and coastal water acidification caused by the continuous absorption of anthropogenic carbon dioxide.

In Benin, the mangrove shellfishes, mainly oysters, crabs, and snails are highly exploited by coastal communities especially women. In general, oyster culture and shellfish collection are widespread in Benin brackish waters such as Lake Nokoué, Lake Ahémé, Porto-Novo Lagoon, and the Coastal Lagoon. According to Adite et al. (2013), traditional oyster farming in the Benin coastal waters generated an annual yield of 30 kg/m² with estimated mean yearly revenues of 160,000 FCFA (US\$330) per individual. Inland water fisheries statistics indicated that, in addition to the mangrove oyster, some shellfish such as shrimps, molluscs, gastropods, and crabs are exploited in the coastal waters by women shellfishers. Also, in Northern Benin, a freshwater shellfish, *Etheria elliptica* (Bivalvia: Etheriidae) is highly exploited in Pendjari River (Akele, 2015). There is a high potential for shellfish exploitation in the Benin aquatic ecosystems and particularly in the coastal waters. Yet, the shellfisheries are not documented, and the mangrove habitat is being degraded. Some efforts at conserving shellfishing livelihoods have been made through mangrove restoration actions of NGOs such as Eco Benin and Action Plus, but efforts are ad hoc. This survey undertaken as part of the Women Shellfishers and Food Security project, funded by USAID, aims at assessing and documenting shellfisheries in the coastal waters of Benin, including the demographic data on women shellfishers and the current status of mangrove ecosystems.

1.1. Description of Benin Republic

The Benin Republic (formerly Dahomey) is a country in West Africa located 9° 19' 18.20" N (Latitude) and 2° 18' 36.02" E (Longitude) and covers about 112,622 km². The altitude ranges between sea level in the south and 400-650 m in the northwest where the Atacora chain is the outstanding mountain (Adomou, 2005). The country is bordered by the Atlantic Ocean on the south, by Togo to the west, by Nigeria to the east and by Burkina Faso and Niger to the north. Benin's coastline measures about 121 km long.

The climate is hot and humid in the south and hot and dry in the north. Average annual temperatures vary from 26 to 28°C and may reach 35- 40°C in the northern region. The mean annual rainfall varies from 900 to 1300 mm. The south of Benin has two rainy and two dry seasons. The main dry season is from December to April, with a short cooler dry season from late July to early September. The north region has one dry season and one rainy season. In the north, the rain season lasts 7 months (on average) and covers the period April-October with the optimum around August/September. Geologically, the southern region comprises sedimentary rock whereas the northern part includes granito-gneissic rocks (Adomou, 2005). Willaine & Volkoff (1967) reported four types of soils that include ferralitic soils covered by semi-deciduous forest, ferruginous soils covered by dry forest, woodland, and savannah, vertisol soil covered by semi-deciduous forest, and hydromorphic soils covered by swamp and riparian forests. Hydrography includes running water such as the Ouémé river with Okpara stream, Zou stream, the Niger river with streams such as Alibori, Sota and Mekrou, Mono River, Couffo River etc. Coastal waters are Lake Nokoué, Coastal Lagoon, Lake Ahémé, and the Lagoon of Porto-Novo. Freshwater lakes are Toho-Todougba, Dati, Toho, Cele, Azili etc. Main activities in Benin are agriculture, animal rearing, fisheries, commerce etc. The official spoken language is French. Major local dialects number as many as 50. Fon, (part of the Gbe language group ranging from Ghana to Western Nigeria) and Yoruba are the most common in the southern areas subject of this study. In the south, Porto-Novo is the country's capital city and the largest city. The economic capital is Cotonou.

1.2. Objective of the study

The objective of the study is “to undertake a participatory assessment of the shellfisheries in mangrove ecosystems in *Benin* using local academic, government and shellfish community contacts.” This study complements a [Literature Review](#) covering shellfisheries in each of the 11 coastal West Africa countries from Senegal to Nigeria. The specific objectives are to:

- a. Identify types of mangrove/estuarine ecosystem-based shellfisheries, by species and location.
- b. Estimate catch per day/month/season, fishing calendar, seasonality of shellfisheries and harvesting methods, processing, and trading of shellfishes.
- c. Estimate revenue generated from mangrove/estuarine ecosystem-based shellfisheries.
- d. Determine the challenges and health-related conditions associated with the consumption of shellfishes.
- e. Assess mangrove exploitation, its uses, gender attributes in its harvest, condition, and protection status.
- f. Determine the governance/management regimes as applied to shellfisheries and mangrove systems.
- g. Determine the effect of climate risks on the livelihoods and food security of women who depend on coastal mangrove and estuarine systems.

2. Methodology

2.1. Study sites

Shellfisheries were assessed in the Benin coastal waters of Southern Benin such as Lake Nokoué and Porto-Novo lagoon, Coastal Lagoon and Lake Ahémé (Figure 1).

Lake Nokoué and Porto-Novo lagoon: Lake Nokoué and Porto-Novo lagoon are situated between 6°20' and 6°30'N, and between 2°20' and 2°35'E and cover about 150 km² (Lalèyè and Moreau, 2003) (Figure 1). As brackish water, Lake Nokoué receives salty water from the Atlantic Ocean on the South and the freshwater from the Ouémé River and Sô stream. Lake Nokoué is connected to the Lagoon of Porto-Novo through Totche canal. During the rainy season, Ouémé River and Sô stream flow into Lake Nokoué and the Porto-Novo lagoon (Texier, 1980), reducing salinities that varied between 0g/l and 40g/l (Sonon et al., 2021). Because of their proximity to Cotonou and Porto-Novo cities, the most densely populated cities, many anthropogenic disturbances have profoundly affected the ecology, hydrology, salinity, and the ichthyological diversity of Lake Nokoué and the Porto-Novo lagoon. Likewise, a couple of decades ago, Lake Nokoué was bordered by mangrove forests (*Avicennia*, *Rhizophora*) that provided the lake with nutrient enrichment, spawning areas, and buffer to shoreline erosion. However, these mangroves were destroyed by the increasing population of fishermen and this destruction has negatively impacted fish and shellfish populations. In addition, the prominence of water hyacinth (*Eichhornia crassipes*) led to the modification of water quality such as the reduction of dissolved oxygen ranging from 0 to 0.58 mg/l during high colonization of floating plants (Gnohossou, 2006). Fish are intensively exploited, and shellfisheries are present but moderate.

Coastal Lagoon: In Benin, the Coastal Lagoon comprises Ouidah lagoon and Grand Popo lagoon. The Coastal Lagoon is the only ecosystem where mangroves are still relatively well-structured. This coastal water covers about 3000 ha of mangrove associated with 6000 ha of swamps during flooding (Figure 1). As brackish water, the Coastal Lagoon receives salty water from the Atlantic Ocean and freshwater from the Mono River (527 km) that supports a hydroelectric dam (Adite et al., 2013). Annual salinities ranged between 0-35‰, depths varied between 0.5-4.47 m and transparencies between 3-150 cm, water temperatures between 25.3°C-35.2°C, pH between 5.5-8.7, and dissolved oxygen between 0.1-8.5 mg/l (Adite et al. 2013). Mangrove species such as *Rhizophora racemosa*, *Avicennia africana* and grasses (*Cyperus articulatus*, *Paspalum vaginatum*) were the dominant plant community. The fish fauna includes about 51 species dominated by families such as Eleotridae, Cichlidae, Mugilidae, Clupeidae, Gereidae, Claroteidae and shrimps (*Macrobrachium sp.*, *Penaeus sp*) crabs (*Callinectes sp*, *Cardiosoma sp.*) that are intensively exploited. Also, mangrove oysters (*Crassostrea sp.*) and other shellfishes (shrimps, crabs etc.) are permanently and intensively exploited. However, the hydroelectric dam greatly affects the hydrological regimes, the water quality, and the biological resources.

Lake Ahémé: The Lake covers about 80 km², but reaches 100 km² during the rainy season. Lake Ahémé is situated in Southwestern Benin between latitudes 6.20° and 6.40°N and between longitudes 1.55° and 2°E. This brackish water body receives freshwater from the Couffo stream and salt water from the Atlantic Ocean (Lalèyè et al., 2004). Lake Ahémé is linked southward to a coastal lagoon via the

10 km-long Aho Channel. In 2000, water temperature varied between 28°C - 31°C, pH between 6.65 – 10.51, dissolved oxygen between 3.66 mg/l – 8.16 mg/l and peak salinities varied from 21g/l to 31g/l. Mangrove species have been destroyed and are now limited to some plantations of *Rhizophora racemosa* and *Avicennia Africana* (Gnacadja, 2000). About 71 fish species dominated by cichlids, mullets etc. have been recorded in Lake Ahémé where fishing activity is very intense. Also, shellfish exploitation is present but moderate.

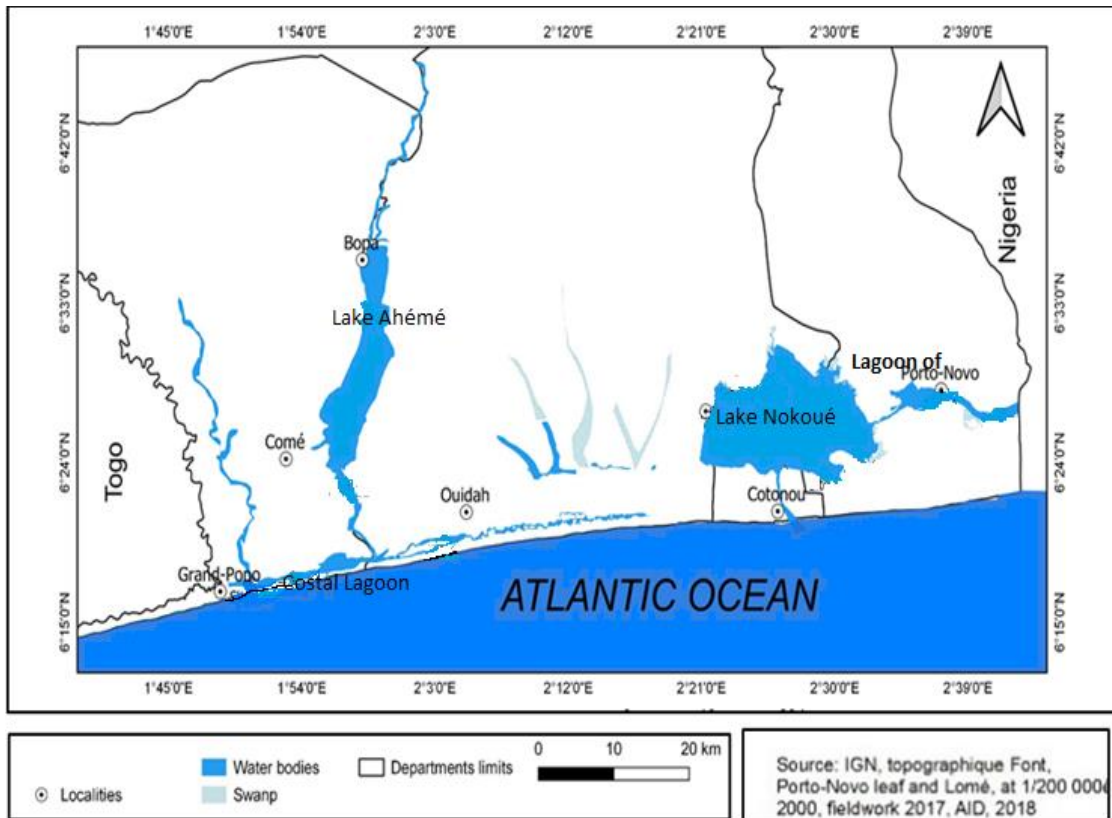


Figure 1: Map showing the coastal waters (Southern Benin).

2.2. Field survey/data collection

Combined methods including documentation, phone call, site visits and interviews were used to gather information on shellfisheries and mangrove status. Some institutions such as the Benin Department of Fisheries, the National Institution of Statistics and Economic Analysis (INSAE), the University Departments and Laboratories were visited to get available data for the survey. Published articles, technical research reports and the list of ongoing projects on mangrove restoration and shellfish were obtained from internet research and from personal contact with researchers and officials.

Phone calls were the primary means used to make some appointments and even to directly get some data from government, NGO, University, resource users, and other stakeholders. Identification of mangrove and shellfish sites, identification, and meeting with shellfishers and interviews were implemented through site visits. Photos of site visits are presented in Appendix 5. Interviews were

conducted with four categories of stakeholders that deal with mangroves, shellfishing, aquatic ecosystems, environmental management, and particularly with coastal waters:

- The resource users: this category of stakeholders includes men and women shellfishers involved in shellfishing activities (harvesting, culture, processing, transportation, marketing etc.).
- Government.
- Academic/Researchers (Universities, Research Institutes).
- NGOs.

Fifteen resource users were surveyed: five in Lake Nokoué and Porto-Novo Lagoon that comprises about 11,140 fishermen and shellfishers, five in Lake Ahémé comprising 5,226 fishermen and shellfishers and five in the Coastal Lagoon that harbors about 3,020 fishermen and shellfishers (Figure 2 and Appendix 1). The resource users were selected according to their experience in shellfisheries and their availability for the interview. Also, 11 individuals from NGOs (4), Government (2), and Academic/Researchers (5) were interviewed. Two different questionnaires were used: one for the resource users and one for NGO, Government and Academic/Researchers. Questionnaires include information on shellfisheries, mangrove, governance/management regimes and climate risk mitigation. The survey instrument is available in the regional summary report (Chuku et al, 2021). Collected data was recorded online and submitted to the project managers. Microsoft Excel software was used to compute percentages (%), means, and standard deviations (SD).

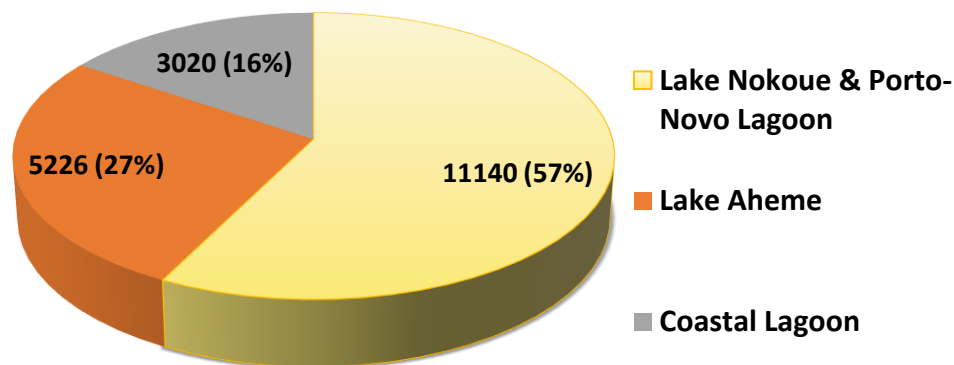


Figure 2: Fisher (men & women) population including shellfishers in Benin.

2.3. Summarized background data

The table below summarizes the basic demographic data for survey respondents.

Table 1: Summarized data on survey respondents.

Total Number of Participants			25
Resource Users	Total	15	
	Sex	Female	14
		Male	1
	Category	Harvester	80%
		Processor	100%
		Marketer	667%
		Consumer	100%
	Age Range	20-60 years	
	Women of Reproductive Age (15-49)	91%	
Average Household Size	8		
Non-Resource Users	Total	11	
	Sex	Female	1
		Male	10
	Category	Academia/Research	5
		Government	2
Private/NGO/CSO		4	

3. Status of Shellfisheries

3.1. Shellfish Exploitation

In Benin, because of the long coastal area that stretches over 150 km, there is a wealth of coastal fishery resources that plays an important role in socio-economic dynamics. Yet, because of the overexploitation of fisheries resources and the decline of fish stocks and catches, the exploitation of aquatic resources such as shellfish is increasing while associated habitats such as mangrove forests are being degraded. Indeed, despite their important ecological role as refuge, nursery and spawning grounds for fishes and shellfishes, and anti-erosive properties, rural populations are increasingly exploiting mangroves causing habitat fragmentation and degradation. To ensure rational management of shellfishes, it is necessary to assess the status and level of exploitation of the resources as well as their main habitat, the mangrove forest (Adite et al, 2013). In Benin, shellfish exploitations are mainly carried out in three aquatic ecosystems, namely:

- Lake Nokoué/Porto-Novo Lagoon.
- Coastal Lagoon.
- Lake Ahémé.

3.1.1. *Estimated number of shellfishers*

Information on the number of shellfish harvesters in Benin is largely not available. In this participatory assessment, the resource users indicated the number of shellfishers in their communities and/or harvesting areas. Conservative estimates are made with the assumption that each respondent represents exclusively one harvesting area/community to moderately compensate for the shellfish harvesting sites not visited, while averaging obvious duplications for communities with large numbers. The estimates provided in this report represent a combination of information gleaned from available literature sources deemed reasonable from the perspective of ground experience in the women-led shellfisheries sector as well as estimates from the participatory assessment conducted.

An estimated 710 persons, the majority of which are females, are engaged in shellfisheries livelihoods in Benin.

The estimated number of shellfishers recorded from the best guest of resource user interviewees are presented in Table 2. The data showed that the number of shellfishers varied from one water body to another. The estimated number varied from 22 - 40 shellfishers for Lake Ahémé, 35 - 60 shellfishers for Lake Nokoué, and 40 - 110 shellfishers for the Coastal Lagoon, indicating the prominence of shellfishers and shellfisheries in the Coastal Lagoon. It is important to note that the data in Table 2 is one gross estimation of the number of shellfishers. Because shellfisheries were overlooked by officials, statistics on shellfishers are scant. For example, the authors of this assessment were able to identify and collect contact information for more than 220 oyster shellfishers in Lake Nokoué alone.

Table 2: Estimated number of shellfishers in user communities. *

Ecosystem	Number			Sex					
				Male			Female		
	min	max	mean	min	max	mean	min	max	Mean
Lake Ahémé	22	40	29	5	12	9	10	28	20
Lake Nokoué/ Porto-Novo L.	35	60	46	25	35	29	10	35	18
Coastal Lagoon	40	110	74	10	15	12	30	100	64
Total per site	22	110	50	5	35	17	10	100	34
Total overall	97	210	149	40	61	50	50	164	102

* From respondents' estimation

An estimated 5,774 persons are direct household shellfisheries beneficiaries based on an average household size of 8.

The size of the survey households varied between 3 and 14 individuals with an average of about 8 individuals per household. Females dominated the households and averaged 5 individuals per household, while the mean number of males was 3 per household.

In general, the average age of shellfishers is 41.5 ± 9.3 years. The shellfishery is dominated by individuals between 30 and 50 years that constitute about 82% of the sample (Table 3). About 91% were 20-50. This is important to note because women 15-49 years are considered as women of reproductive age, an important target age group for health and nutrition initiatives. Due to the constraints of the shellfishery, older people (age > 60) are less involved. Respondents (interviewees) ages vary between 20 to 60 years-old, but they noted that, in general, the age of the shellfishers range from 13 to 60 years for men and 13 to 75 years for women. Interviews and personal observation also indicated that teenagers of 10 – 19 years are involved in shellfisheries.

Table 3: Age structure of shellfishers (Respondents). *

Sex	Age structure				
	20-30	30-40	40-50	50-60	Total
Female	9.09%	36.36%	45.46%	9.09%	100%
Male	0%	0%	100%	0%	100%
Male + Female	8.33%	33.33%	50.00%	8.33%	100%

*Based on respondent (resource users) ages

3.1.2. Insights on gender in shellfish exploitation

In the Benin coastal area, shellfishing is an activity practiced almost exclusively by women. The results of the shellfisheries survey (including oysters, snails, shrimps, and crabs) indicated that women

constitute approximately 93.33% (14/15) of the shellfishers, although estimates in Table 2 indicate two thirds women and one third men.

Regardless of the ecosystem, both men and women are involved in the exploitation of shellfish. According to respondents, all men shellfishers (100%) are involved in harvesting and helping women to harvest. Mostly, for oysters, men help women to collect shellfish on the bottom by diving. About 78.60% (11/14) of women are involved in harvesting and 100% of women are involved in processing. In general, for 83.33% of interviewees, the withdrawal of the men's support would not affect the harvesting. On the other hand, 16.37% of women think the opposite because they believe that they need the physical strength and endurance of men to increase their productivity.

3.1.3. Shellfishing as primary occupation

Even though shellfishing is practiced by some men, it is not their main activity. It is a secondary activity. For these men, the main activities are fishing and catching crabs. For 25% of women, shellfisheries are their main activity. The 75% remaining women shellfishers have for main activities mat making, catching crab, salt processing, fishing, coconut selling, soya cheese cooking, clothes selling, trading of firewood and goods, and sale of fishery products. For these women, shellfish harvesting is seasonal mainly for species such as oysters and shrimps. Indeed, shellfisheries is a secondary occupation for 60% of all the resource users interviewed while this activity is a primary occupation for only 27% of the resource users (Figure 3).

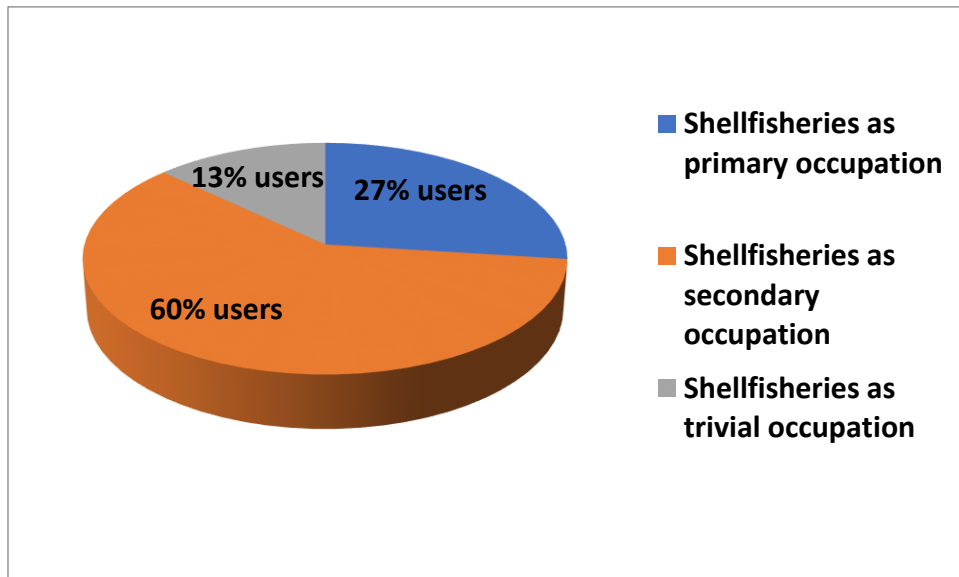


Figure 3: Importance of shellfisheries (% resource users).

3.1.4. The shellfish value chain

Shellfisheries at the coastal area include activities such as harvesting, culture, transportation, processing, retailing/marketing, and consumption. Harvesting is practiced by about 80% of the shellfishers (12/15 resource users) and 100% are processors, while 66.67% and 33.33% are involved in retailing/marketing and shellfish culture (farming), respectively. All respondents (100%) consume shellfish species including

oysters and 25% consume it either daily or monthly while 50% consume it at least once a week. Therefore, at least 67% of the resource user respondents in this study (of which 93% were women) engaged in harvesting, processing, trading and consumption. This indicates a very vertically integrated value chain with women harvesters dominant at every node and implies that value chain improvements at any node can directly benefit women harvesters and creates an opportunity to incentivize behavior change for sustainable resource management.

The main species harvested are oyster, snails, shrimps, and crabs that are consumed and/or sold by local communities. The shellfish are sold fresh, fried, or smoked and used as ingredients in the preparation of sauce and consumed with rice and corn meal. In addition, the small snails (gastropod) are also used as bait to catch fish and crabs. The shells of the oysters (source of calcium) are used as ingredients to prepare animal feed. Shells are also used to construct houses and to reshape roads. The shells of some species such as *Achatina sp.* are used as ingredients in traditional medicine. Table 4 summarizes habitats, harvesting methods, processing methods, and uses for species found in Benin's coastal water bodies. Appendix 3 includes a list of processing methods and use organized by the three coastal shellfisheries sites studied.

To promote and increase the consumption of shellfish species, the shellfishers propose the following measures:

- Introduce shellfish in hotels and restaurants to increase revenue and to improve the sales of the shellfish.
- Improve the marketing and sales of shellfish.
- Improve the processing of the shellfish to have access to other markets and to sell them at a good price.
- Increase awareness on the health benefits of shellfish among relevant stakeholders.
- Promote high consumption of shellfish.
- Implement research focusing on shellfish farming.
- Increase shellfish stocks by promoting shellfish farming and sustainably managed wild collection.

Regarding health-related precautions, 75% of respondents noted that shellfish require a good cleaning process before sales and consumption.

Table 4: Habitats, harvesting methods, processing methods, and uses.

Shellfish species	Specific habitat	Harvesting method	Use	Processing method	Other uses (Shell)
<i>Crassostrea tulipa</i> (oyster)	Mangrove roots and stems, rocky substratum Fringing lagoons and estuaries Low subtidal level attached to rocks, shells, or stones on muddy sand bottoms; Sandy-mud, Acadja	Cut from mangrove roots with a small knife, collected by hand at low tide on foot or from a small boat If the oysters are in the mud, men plunge in to get them and drop them into the nearby canoe In Acadja, by diving to harvest on the bottom	Consumption/sale (to prepare local "sauce called "Dja" and eat along with rice, or "Ablo")	Fried and smoked; After collection, put in salt water to prevent them from dying, opened with a knife, and meat removed. The meat is then washed with lemon and fried. May be put on a skewer.	Build house foundations Animal food ingredient Wound healing House and road construction Medicine (calcium) Fish food
<i>Achatina spp.</i> (giant land snail)	Aquatic vegetation area, Wetland	Collected in aquatic vegetation areas mainly at night Removed from the sandy-mud substratum of mangrove areas using gloves	Consumption/sale; To prepare local "sauce called "Dja" and eat along with rice, or "Ablo"	The animal is killed with hot water. The flesh is washed with clean water and lemon and then fried	Build house foundations Animal food ingredient Wound healing Traditional medicine ingredient
<i>Pachymelania fusca</i> (snail)	Sandy-mud substratum of the mangrove areas	Removed using gloves	Consumption/sale	Boiled and fried after cleaning with water and lemon	Reshape roads
<i>Pachymelania aurita</i> (snail)	Sandy-mud substratum of the mangroves area	Removed using gloves	Consumption/sale	Boiled and fried after cleaning with water and lemon	Reshape roads

<i>Tympanotonus fasciatus</i> (periwinkle)	Sandy-mud substratum of the mangroves area	Removed using gloves	Consumption/ sale	Boiled and fried after cleaning with water and lemon	Reshape roads Build houses Animal food ingredient
<i>Lanistes varicose</i> (snail)	Sandy-mud substratum, mangroves area, wetland	Removed from the sandy-mud substratum of the mangroves area using gloves	Consumption/ sale	Boiled and fried after cleaning with water and lemon	Reshape roads Animal food ingredient Build houses
<i>Neritina glabrata</i> (snail)					
<i>Senilia senilis</i> (cockle)					
<i>Penaeus</i> sp (shrimp)	Sandy-mud substratum, water column, mangrove	Collected with net (Shrimp nets)	Consumption/ sale	Fried and smoked	
<i>Squilla aculeata</i> (shrimp)	Substratum, water column, mangrove roots.	Fishing nets and traps.	Consumption/ sale	Boiled, smoked, fried	
<i>Holthuis penaeopsis atlantica</i> (shrimp)	Coastal water, lagoon, sandy and muddy				
<i>Panulirus regius</i> (lobster)	Substratum, water column, mangrove roots	Fishing nets and traps.	Consumption/ sale	Boiled, smoked, fried	
<i>Macrobrachium</i> sp. (shrimp)	Fresh water: part of the development is in brackish water.	Collected with nets Lay shrimp nets, then light lanterns at night to attract the shrimp in the half-light	Consumption/ sale	Smoked on the appropriate stoves using corn, palm, and coconut husks as fuel	

	Bottom sand or stones. sandy-mud substratum	where they are trapped by the nets. Lift the nets before sunrise			
<i>Callinectes sp</i> (lagoon crab)	Sandy-mud substratum, water column, mangrove	Harvested with traps Harvested with a special Crab net	Consumption/ sale	Fried and smoked	
<i>Cardisoma sp.</i> (wetland crab)	Mangrove, sandy-mud substratum riparian vegetation zone	Harvested with traps. Use baited crab swing to trap crabs. The crabs attracted by the bait are locked in the swing.	Consumption/ sale	Boiled, smoked, fried	
<i>Cronius ruber</i> (crab)	Riparian vegetation zone	Use baited crab swing to trap crabs.			
<i>Ocypoda cursor</i> (crab)	Riparian vegetation zone	Use baited crab swing to trap crabs.			
<i>Portunus validus</i> (crab)	Substratum, water column, mangrove roots	Fishing nets and traps.	Consumption/ sale	Boiled, smoked, fried	

3.1.5. Species harvested

In the coastal waters examined (Lake Nokoué/ Porto-Novo lagoon, Coastal Lagoon and Lake Ahémé), several shellfish species are exploited (Table 4). The most widespread and commonly exploited types of shellfish are oysters, snails, shrimps, and crabs in that order (Figure 4).

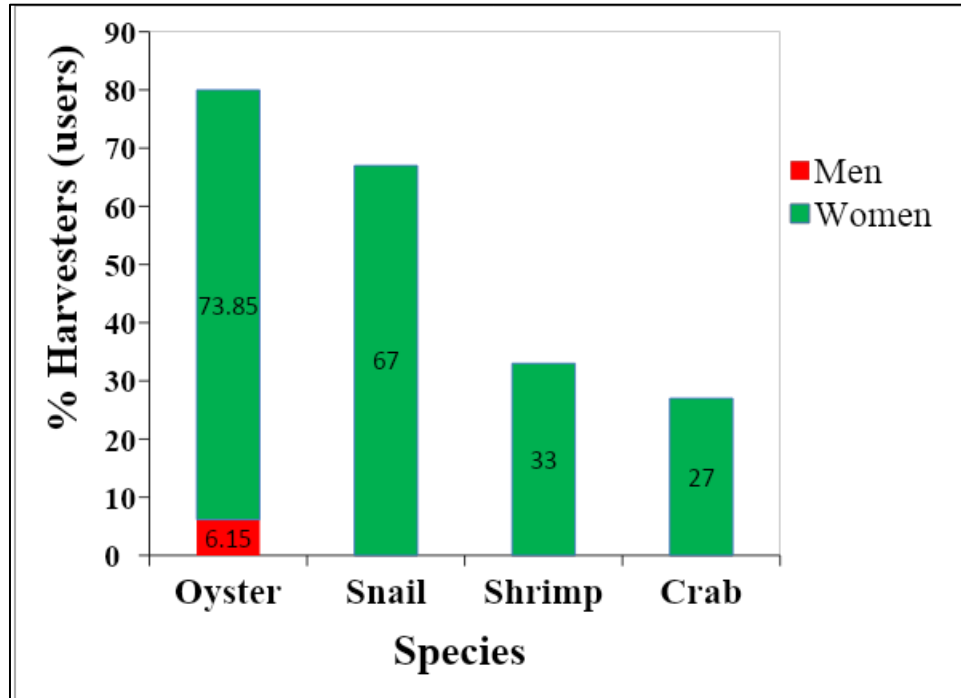


Figure 4: Rank of shellfish species harvested at the Benin coastal waters: Oysters and snails are the top shellfish exploited.

The specific species most exploited include the following list and as shown in Figure 5 (a-j):

- *Crassostrea tulipa* (mangrove oyster).
- *Achatina achatina* (giant air breathing land snail).
- *Tympanotonus fuscatus* (periwinkle).
- *Laniste varicus* (snail).
- *Penaeus sp* (shrimp).
- *Cardisoma armatum* (wetland crab).
- *Callinectes sp* (lagoon crab).



Figure 5a: *Tympanotonus fuscatus* (wlankoun/Ahovi).



Figure 5b: *Laniste varicus* (Gui).



Figure 5c: *Parachymelania fusca* (wlankoun).



Figure 5d: *Callinectes* sp (Asson; Lagoon crab).



Figure 5e: *Crassostrea tulipa* (Adakpin).



Figure 5f: *Cardisoma* sp (Agassa; wetland crab).



Figure 5g: *Achatina* sp (agbi).



Figure 5h: *Penaeus* sp.



Figure 5i: *Tarebia sp* (wlankoun/Ahovi).



Figure 5j: *Melanoide sp* (wlankoun/Ahovi).

Figure 5: Common exploited shellfish species in Benin coastal waters.

An exhaustive list of common and uncommon exploited shellfish recorded by researchers can be found in Table 6 below. The different habitats of key shellfish species harvested from each of the coastal sites studied are presented in Table 5. Shellfish species are mainly found in sandy-mud substratum, sandy substratum, water column, mangroves, mangroves roots and "Acadja..

Table 5: Common shellfish species exploited in each coastal ecosystem and their habitat.

Eco-systems	Shellfish (Common local name)	Shellfish (Common name English)	Shellfish (Scientific name)	Habitat
Lake Ahémé	Adakpin	Oyster	<i>Crassostrea tulipa</i>	Sandy-mud substratum, sandy substratum, mangrove roots
	Aguouin	Snail	<i>Achatina achatina</i>	Wetland
	Agassa	Crab	<i>Cardisoma sp</i>	Wetland
	Bobo	Periwinkle	<i>Tympanotomus fascatus</i>	Wetland
	Degon	Shrimp	<i>Penaeus sp</i>	Water column
	Asson	Lagoon crab	<i>Callinectes sp</i>	Sandy substratum, Water column
Lake Nokoué	Adakpin	Oyster	<i>Crassostrea tulipa</i>	“Acadja”, sandy substratum; sandy-mud substratum
	Aguouin	Snail	<i>Achatina achatina</i>	On the lakefront
	Agui	Periwinkle	<i>Tympanotonus fascatus</i>	Sandy substratum; sandy-mud substratum
	Degon	Shrimp	<i>Penaeus sp</i>	Water column
	Asson	Lagoon crab	<i>Callinectes sp</i>	Sandy substratum, Water column
Coastal Lagoon	Gui	Snail		sandy substratum; sandy-mud substratum
	Ahovi	Snail	<i>Achatina achatina</i>	Wet land, sandy-mud substratum of the mangroves area, sandy substratum
	Agassa	Crab	<i>Cardisoma armatum</i>	wetland
	Bobo	Periwinkle	<i>Tympanotonus fuscatus</i>	Wetland, sandy-mud substratum of the mangroves area, sandy substratum
	Degon	Shrimp	<i>Penaeus sp</i>	Water column
	Asson	Lagoon crab	<i>Callinectes sp</i>	Sandy substratum, Water column

Table 6: Exhaustive common and uncommon exploited shellfish recorded by researchers.

Shellfish (Scientific name)	Common name (local)	Common name (English)	Water body
<i>Crassostrea tulipa</i>	Adakpin	West African mangrove oyster	Lake Nokoué/Porto-Novo Lagoon; Coastal Lagoon; Lake Ahémé
<i>Achatina achatina</i>	Agui	Giant land snail	Lake Nokoué/Porto-Novo Lagoon; Coastal Lagoon; Lake Ahémé
<i>Achatina fulica</i>	Agui	Giant snail	Coastal Lagoon
<i>Tympanotonus fuscatus</i>	Wlankoun	periwinkle/ gastropod	Lake Nokoué/Porto-Novo Lagoon; Coastal Lagoon; Lake Ahémé
<i>Pachymelania fusca</i>	Ahovi	snail	Lake Nokoué/Porto-Novo Lagoon; Coastal Lagoon; Lake Ahémé
<i>Pachymelania aurita</i>	Ahovi	snail	Lake Nokoué/Porto-Novo Lagoon; Coastal Lagoon; Lake Ahémé
<i>Lanistes varicose</i>	Agui	snail	Lake Nokoué/Porto-Novo Lagoon; Coastal Lagoon; Lake Ahémé
<i>Penaeus (Melicertus) kerathurus</i>	Degon	Caramote prawn	Lake Nokoué/Porto-Novo Lagoon; Coastal Lagoon; Lake Ahémé
<i>Penaeus (Farfantepenaeus) notialis</i>	Degon	Pink shrimp	Lake Nokoué/Porto-Novo Lagoon; Coastal Lagoon; Lake Ahémé
<i>Penaeus monodon</i>	Degon	Blue tiger prawn	Lake Nokoué/Porto-Novo Lagoon; Coastal Lagoon; Lake Ahémé
<i>Callinectes amnicola</i>	Degon	Bigfisted swimcrab	Lake Nokoué/Porto-Novo Lagoon; Coastal Lagoon; Lake Ahémé
<i>Callinectes pallidus</i>	Asson	Gladiator swimcrab	Lake Nokoué/Porto-Novo Lagoon; Coastal Lagoon; Lake Ahémé
<i>Callinectes latimanus</i>	Asson	crabs	Lake Nokoué/Porto-Novo Lagoon; Coastal Lagoon; Lake Ahémé
<i>Holthuispenaeopsis atlantica</i>	Degon	Guinea shrimp	Lake Nokoué/Porto-Novo Lagoon

<i>Cardisoma armatum</i>	Agassa	crabs	Lake Nokoué/Porto-Novo Lagoon; Coastal Lagoon; Lake Ahémé
<i>Macrobrachium vollenhovenii</i>	Chacha	African River Prawn	Lake Nokoué/Porto-Novo Lagoon; Lake Ahémé
<i>Macrobrachium macrobrachion</i>	Chacha	Shrimps	Coastal Lagoon
<i>Macrobrachium felicinum</i>	Chacha	Niger River prawn	Lake Nokoué/Porto-Novo Lagoon;
<i>Macrobrachium raridens</i>	Chacha	Volta River Prawn	Lake Nokoué/Porto-Novo Lagoon
<i>Macrobrachium dux</i>	Chacha	Congo river prawn	Lake Nokoué/Porto-Novo Lagoon
<i>Neritina glabrata</i>	Agui	Mollusc	Lake Nokoué/Porto-Novo Lagoon;
<i>Cronius ruber</i>	Agassa	crabs	Lake Nokoué/Porto-Novo Lagoon
<i>Ocypoda cursor</i>	Agassa	crabs	Lake Nokoué/Porto-Novo Lagoon
<i>Portunus validus</i>	Asson-Yohounyo	Smooth swim crab	Lake Nokoué/Porto-Novo Lagoon
<i>Senilia senilis</i>	Mollusque	Bloody cockle	Coastal Lagoon
<i>Mactra sp</i>	Agui	Mollusc	Lake Ahémé
<i>Tagelus angulafus</i>	Agui	Mollusc	Lake Ahémé
<i>Tagelus angulafus</i>	Agui	Mollusc	Lake Ahémé

3.1.6. Harvesting methods

To harvest mangrove oysters, a knife is used to remove the oyster from the mangrove roots. When the habitat is sandy-mud substratum or sandy substratum the oysters are harvested by diving. Snails are picked up from the aquatic vegetation, crabs are harvested using appropriate crab gears and shrimps are collected with seine nets. Harvest methods by species are summarized in Table 4 above.

3.1.7. Harvest volumes and value

Regardless of the coastal water body, monthly income from shellfish sales ranged between US \$74 – \$480 (mean: US \$252±142). Monthly sales in the Coastal Lagoon, Lake Nokoué and Lake Ahémé were not significantly different ($F=1.837$; $P>0.05$) (see Appendix 2).

Shellfish products are sold at several levels. Twenty-five percent (25%) of operators claim to sell their products on local community markets and more remote and larger markets, 8.34% of operators sell their products to hotels/restaurants and traders, and 33.33% of shellfishers deliver their products to intermediaries.

3.1.8. Seasonality of harvests

Harvesting is mostly seasonal for oysters, shrimps, and crabs. Oysters are exploited seasonally from July to November or from mid-March to the end of September, with harvests done daily or weekly during the season. *Achatina achatina* and *Tympanotonus fusca* are harvested all months of the year.

3.2. Mangrove Ecosystem

In Benin, the coastal lagoon is the only coastal water where mangrove forest is well established and well-structured despite the ongoing degradation. In Lake Ahémé mangrove is reduced. It is almost absent in Lake Nokoué. About 50% of the respondents confirm that these mangrove forests are intensively exploited by both men and women. In general, mangrove is used for:

- Firewood.
- oyster harvesting.
- firewood for oyster processing.
- making traps for crabs.
- making fishing gear.
- mangroves are involved in the different stages of shellfish harvesting and exploitation.
- mangroves serve as nursery grounds for shellfish production .

About 85% of respondents believe that mangroves are highly degraded (low status) and very poorly protected.

Table 7: Role of mangroves in the value chain of the shellfisheries.

Value chain node	Role of mangroves
Harvesting	-Nursery and spawning grounds for shellfish -Shellfishes are attached to mangroves roots -A favorite habitat for most shellfish and increase shellfish stocks -Mangrove zones help increase production and therefore harvesting of shellfish
Transportation	-Boats are used and based in mangrove areas to load oysters
Processing	-In some villages used as firewood to cook shellfish
Retailing/marketing	-Increase shellfish productivity and stocks leading to an increase of sales
Consumption	-Healthy mangrove habitat increases the quantity of shellfish -Mangrove zones help increase consumption of shellfish products

Table 7 summarizes the roles of mangroves in the value chain of shellfisheries. The mangrove tree also provides a stock of medicinal plants used by communities and is a significant source of income for the women who farm the shellfish. Also, the mangrove habitat in Benin Ramsar reserves is used for nature conservation, tourism, and pastoralism (Ramsar N° 1017 & 1018). It is thought that eco-tourism might present a strategic option for developing diversified or alternative economic activities in the mangroves, based on conservation, restoration and valuing of natural and cultural aspects of the forests. The sustainability of these resources is critically dependent on the continuing health and functioning of the mangrove ecosystems.

3.3. Governance/Management Regimes

All stakeholders, namely shellfishers, researchers, NGOs and government are aware of regulations on fisheries and mangrove forests. Some of these regulations or laws are as follows:

- Framework law n ° 2014-19 of August 07, 2014, relating to Fishing and Aquaculture in the Republic of Benin.

Articles 8 and 12 of this fisheries law seem to provide a favorable legal basis for co-management approaches. Indeed, in Benin may be no legal barrier to delegating use rights to women's shellfishery associations (https://www.fsvps.gov.ru/fsvps-docs/ru/importExport/benin/files/vet_benin_2014-19.pdf). The French version of Articles 8 and 12 and an unofficial translation are as follows:

- « Article 8 : Le droit à la pêche appartient à l'État. Toutefois, l'État peut déléguer l'exercice de ce droit conformément aux dispositions de la présente loi-cadre et de ses textes d'application ». Translation: The right to fish belongs to the state. However, the State may delegate the exercise of this right in accordance with the provisions of this framework law and its implementing texts.
- « Article 12 : Sur certains plans d'eau, la gestion des ressources halieutiques et l'aménagement des pêcheries peuvent être confiés à des organes de gestion, comprenant notamment des représentants des pêcheurs, établis par le ministre en charge de la pêche. » Translation: On certain bodies of water, the management of fishery resources and the development of fisheries may be entrusted to management bodies, including in particular representatives of fishermen, established by the Minister in charge of fisheries.
- Law n ° 98-030 on the framework law on the environment in the Republic of Benin.
- Law n ° 2002-16 of October 18, 2004, on the wildlife regime in the Republic of Benin.
- Law No. 87-014 regulating the protection of nature and the practice of hunting in the People's Republic of Benin.
- Law No. 2018-10 of April 16, 2018, on the protection, development, and enhancement of the coastal zone in the Republic of Benin. These regulations and laws include:
 - Ban of cutting of mangroves roots.
 - Ban of small/unapproved mesh net to catch fish.
 - Prohibition of use of fertilizer or toxic chemicals near lagoons.
 - Ban of construction of Acadja in Lake Ahémé and in the Coastal Lagoon.

In addition, communities have developed traditional practices to protect mangroves and shellfishes. These practices are:

- A woman who has given birth should not go to the lagoon for 3 months.
- A woman who has recently given birth or in her menstruation should not go to the lagoon during that period.
- Prohibition of washing of dishes and clothes in lagoons.
- No fishing and collection of oysters on Saturday and Sunday.
- Prohibition to harvest oysters or fishing one day (“Mignonhi” day) per week.
- Fishing in sacred sites prohibited.

To be efficient in the protection of mangrove ecosystems and in the promotion of shellfisheries, the communities have organized themselves into associations. Two associations, “Otchanmi” (women oyster harvester) and AFEHB (Benin women association of oyster operators) were created. However, these associations are still informal because they are not registered.

Given the importance of these aquatic ecosystems and their level of exploitation, the entire coast of Benin is now covered by designation, and subsequent expansion, of two contiguous Ramsar sites. These sites are also covered by other protection agreements as identified in Table 8.

Table 8: Status of the estuarine and mangrove ecosystem used for shellfisheries.

Water body	Protection status
Lake Nokoué and Porto-Novo lagoon	RAMSAR Convention 1018 on wetlands
	International Trade in Endangered Species of Wild Fauna and Flora CITES convention
	UN Convention on the Law of the Sea
Lake Ahémé and Coastal lagoon	RAMSAR Convention 1017 on wetlands
	International Trade in Endangered Species of Wild Fauna and Flora CITES convention
	UN Convention on the Law of the Sea

Regarding management, some mangrove restoration activities have been implemented by local NGOs such as “ECO BENIN” and “Action Plus” who have been involved in mangrove plantation at the Coastal Lagoon, and by various other initiatives identified in Appendix 4. So far, nothing has been done to improve shellfisheries, except a couple of scientific investigations on oyster’s community structure, trophic ecology, and farming. Appendix 4 also presents a list of published and unpublished research (Technical reports) on mangrove and shellfishes.

3.4. Climate Risk Mitigation

All the resource users interviewed indicated that the main climatic factor threatening their activity is flooding. In particular, mass mortality of oysters is due to flooding. For 75% of resource users, oyster farming and mangroves do not affect the climate and they do not see the relationship between mangroves and climate. However, 25% believe that a well-structured mangrove forest can be favorable for rain and confirmed that mangroves regulate the temperature of the village. This category believes that mangrove cutting does affect climate. Researchers, Government and NGOs recognize that the exploitation of natural aquatic resources is influenced by climatic conditions. The main factors that are responsible for the seasonal exploitation of shellfishes are:

- Flooding.
- sea level rise.
- Rainfall.
- Drought.

Mangroves also influence the climate if there are massive cuttings. The overexploitation of the mangrove ecosystem and especially utilization of the mangrove as firewood can affect carbon sequestration by mangrove trees.

4. Conclusion and Recommendations

The current assessment of Benin's coastal water shellfisheries and mangrove habitat provides valuable information on shellfish richness, exploitation, major threats, and management perspectives. Overall, shellfisheries in the coastal ecosystems involve mainly women aged 13 - 75 years. These shellfisheries include activities such as traditional shellfish farming, harvesting, transportation, processing and marketing. The most widespread exploited shellfish species recorded in the Benin coastal waters is the mangrove oyster (*Crassostrea tulipa*), the wetland crab (*Cardisoma armatum*), the lagoon crab (*Callinectes sp*), the giant snail (*Achatina achatina*), a small gastropod (*Tympanotonus fuscatus*), and shrimp (*Penaeus sp*). Mangrove forests, bottom sand-mud substratum, "Acadja," and the water column constitute the major habitat of shellfishes. In addition to nutritional/health importance, shellfisheries provide substantial income for communities. Shellfish meats are sold fresh, fried, and smoked mainly in local markets. However, shellfisheries are threatened by mangrove destruction and climate change impacts such as flooding. An integrated approach to shellfisheries management including mangrove forest protection and restoration, ecological/biological studies, law enforcement, shellfish farming, marketing, financial and technical assistance, and ecosystem follow-up monitoring are required for the sustainable exploitation of shellfishes. Benin's entire coast has been identified as wetlands of international importance for conservation and sustainable use under the Ramsar Convention. Benin's fisheries law provides the legal framework for participatory fisheries management with the possibility of authorities delegated to fisher associations. Two nascent women's shellfish associations are present. To improve women's shellfisheries livelihoods and working conditions, and mangrove health in Benin, stakeholders articulated the following recommendations:

- Respect the various fisheries and environmental laws and regulations.
- Raise awareness on the policies available for mangrove protection.
- Protect the mangrove habitat.
- Promote environmental education.
- Sensitize fishermen on the roles of mangroves and the necessity to protect them.
- Provide capacity building for all stakeholders on sustainable use of mangrove ecosystems.
- Organize men and women shellfishers into associations.
- Regulate shellfish collection, including through co-management frameworks.
- Implement a shellfisheries inventory.
- Conduct research on shellfish habitat conservation.
- Implement ecological research.
- Research oyster mortality during flooding - depict the cause of mortalities during flooding.

- Develop and promote shellfish farming.
- Avoid fishing by fishermen in oyster culture areas.
- Modernize shellfishing techniques.
- Provide technical assistance and financial aid (training, materials, funds) to resource users and other stakeholders to facilitate improved and sustainable shellfisheries harvesting, processing, and sales.
- Train women (and men) shellfishers to adopt good practices to preserve the environment and their health.
- Develop shellfisheries value chains for the valorization of products to increase value added and income, especially for women. This can be achieved by training women in hygienic processing methods, improving the presentation of products, and seeking out markets for their sale.
- Promote shellfish sales in hotels and restaurants.
- Encourage shellfish consumption on a large scale.
- Promote other livelihood activities so that the oysters and mangroves will be restored.

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Appendices

Appendix 1: Total number of communities/villages with shellfishing activities occurring in mangrove ecosystems of Benin

Table 9: Total number of communities/villages with shellfishing activities occurring in mangrove ecosystems of Benin.

	Name of community/estuary (water body)	Males		Females	
		Number*	Age range (years)**	Number*	Age range (years)**
1	City of Sô-Ava	186	12-65	3	15-60
2	Village of Ganvié I	513	09-70	2	12-65
3	Village of Ganvié II	474	10-68	12	14-70
4	Village of Houedo- Aguekon	1014	10-70	24	15-65
5	Village of Dékanmè	199	10-70	5	12-65
6	Village of Vekky	2325	09-75	95	12-70
7	City and villages of Cotonou	2228	11-65	1811	13-65
8	City and villages of Ouidah	1224	18-65	776	12-70
9	City of Kpomassè				
10	Village of Agbanto- Sègbohoulè	1201	10-70	276	11-70
11	Village of Nazoumè- Tokpadomè	898	09-75	110	10-70
12	City of Comé	356	19-65	46	12-65
13	Village of Agatogbo-Akodeha	1540	10-75	212	12-70
14	City of Grand-Popo	210	08-75	23	12-60
15	Village of Avloh-Gbéhoué	573	10-75	214	10-75
16	City of Bopa	324	13-75	9	12-65
17	Village of Kpossotomè	242	10-70	12	11-70
18	City and villages of Porto- Novo	208	13-75	6	14-65
19	City and villages of Aguégoués	2007	09-75	28	10-70
	Totals	15722	09-75	3664	10-75

*Source: Database of Benin Department of Fisheries

**From the current survey

Appendix 2: Descriptive statistics of monthly sales of shellfish from coastal sites

Table 10: Monthly sales in US \$ of shellfish from three coastal sites.

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Coastal lagoon	5	289,20	154,464	69,079	97,41	480,99	120	480
Lake Nokoué	5	308,00	134,052	59,950	141,55	474,45	80	420
Lake Ahémé	5	158,80	109,987	49,188	22,23	295,37	74	350
Total	15	252,00	141,859	36,628	173,44	330,56	74	480

Table 11: Analysis of variance (ANOVA) of monthly sales in US \$ of shellfishes from three coastal sites.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	66030,400	2	33015,200	1,837	,201
Within Groups	215705,600	12	17975,467		
Total	281736,000	14			

Appendix 3: Methods of processing and use of shellfish

Table 12: Methods of processing and use of shellfish.

Ecosystem	Shellfish	Uses	Method of processing	Uses of shells
Lake Ahémé	<i>Crassostrea tulipa</i>	Consumption and sale	<ul style="list-style-type: none"> - Shells are opened, Flesh is taken off from the shells Meat is cleaned with water - Sale of the fresh meat or cooked and sold. - Boil and fry the meat 	<ul style="list-style-type: none"> - Animal feed ingredient - Building of houses Manufacturing of the powder - Reshape roads
	<i>Achatina achatina</i>	Consumption and sale	<ul style="list-style-type: none"> - The whole snail is boiled with the shell, - Flesh is taken off from the shell - Meat is cleaned with water and lemon or with water, salt, and vinegar, fresh meat is cooked, fried, and sold. 	<ul style="list-style-type: none"> - Traditional medicine ingredients - Reshape roads
	<i>Cardiosoma sp</i>	Consumption and sale	<ul style="list-style-type: none"> - The whole snail is boiled with the shell, - Flesh is taken off from the shell - Meat is cleaned with water and lemon, fresh meat is cooked, fried and sold. 	-
	<i>Tympanotomus</i>	Consumption and sale	<ul style="list-style-type: none"> - The whole snail is boiled with the shell, - Flesh is taken off from the shell - Meat is cleaned with water and lemon or with water. Salt and vinegar, fresh meat is cooked, fried, and sold. 	<ul style="list-style-type: none"> - Traditional medicine ingredients - Reshape roads

Coastal Lagoon	<i>Crassostrea tulipa</i>	Consumption and sale	After harvesting, oyster is put in the shade The valves are opened, the flesh taken off from the valves and cleaned with water	Animal feed ingredient Build houses Make powder for medicine Reshape roads
	<i>Tympanotonos fuscatus</i>	Sale	- The whole snail is boiled with the shell, - Flesh is taken off from the shell - Meat is cleaned with water and lemon or with water, salt, and vinegar, fresh meat is cooked, fried and sold.	Reshape roads
	<i>Cardiosoma armatum</i>	Consumption and sale	The crab is boiled with the shell, The meat is taken off from the shell Meat is cleaned, cooked, fried, and sold.	-
	<i>Tympanotonos fuscatus</i>	Sale	The snail is boiled, and the flesh is taken off from the shell Meat is cleaned with water and lemon, fresh meat is cooked, fried, and sold	Reshape roads
Lake Nokoué	<i>Crasstossera tulipa</i>	Consumption and sale	After cooking, the flesh is removed and washed several times with drinking water. The oysters are fried or not and sold or eaten	Animal feed ingredient Build houses Make powder Reshape roads
	<i>Achatina achatina</i>	Consumption and sale	The animal is killed with hot water. The flesh is washed with clean water and lemon, then fried	- Traditional medicine ingredients - Reshape roads
	<i>Tympanatonus fuscatus</i>	Used as bait	The shell is detached, and the flesh removed	Traditional medicine ingredients Reshape roads

Appendix 4: Local organizations and research reports on shellfisheries and mangrove ecosystems in Benin

Table 13: Local Organizations engaged in mangrove restoration and shellfisheries.

N°	NGO or UN Agency Name	Address (e-mail, telephone)	Goals	Mangrove Activities	Shellfish Activities	Aquatic Ecosystems
1	ECO-BENIN	Mob. / Whatsapp : +22995285220 Email : contact@ecobenin.org / Skype: gautier.amoussou	Promotion of Ecotourism, local development, Environment protection	Mangroves Restoration Program and ecotourism in Mono Province at Grand-Popo City		Coastal lagoon and Mono River at “Bouche du Roy”
2	Fondation GoodPlanet	Fondation GoodPlanet Longchamp 1, Carrefour de Longchamp 75116 PARIS. Phone : 01 48 42 01 01	To sensibilize for environmental issues, environmental protection, biodiversity conservation.	Mangrove Restoration project in Bénin		Fondation GoodPlanet is active at Lake Ahémé in the Mono Province; at Aho Chenal, at the coastal lagoon, village Avlékété, from Ouidah City to Cotonou City
3	Cybelle Planète	Téléphone: 07 68 09 83 72 Adresse postale Cybelle Planète, 4 Plan des Castors, 34750 Villeneuve-lès-Maguelone, France	Sensibilize on ecological issues through participative approaches of management; biological diversity (plants, forest, animal, human culture), foster eco volontariat, Protection of marine fauna in Mediterranean	Mangrove plantation and environmental education in Bénin		Mangrove plantation in lake Ahémé and in Avlo village
4	UNDP BENIN		Encourage grassroots and local community for sustainable development; improve revenues through oyster collection and production; salt production, agriculture, animal rearing.	Protection and plantation of mangroves species	UNDP have given micro-crédits to women leaving at the coastal lagoons for	Coastal lagoon in Benin

					small scale activities	
5	FAO - Bénin	FAO - Benin Avenue Jean Paul II - Lot 549 - parcelle H - quartier Zongho Ehuzu COTONOU Mailing Address: P.O. Box 1369, Cotonou +229-21-21314245 Fax. +229-21-21313649 FAO-BJ@fao.org	Revenue generating activities, Environment protection and management, Capacity building	Mangrove restoration project at Ramsar site 1017 in Bénin: Plantation of about 150 hectares of Acacia, Eucalyptus and Mangrove at Lake Ahémé and at the Coastal lagoons with the assistance of FAO		Local communities of Lake Ahémé and Coastal lagoon: Kpomassè City, Bopa City and Come City. The project also includes the coastal lagoon of d'Abomey- Calavi City, Ouidah City and Grand-popo City
6	Benin Environment & Education Society	Benin Environment and Education Society (BEES ONG) Address: 03 BP 779 Jéricho, Cotonou, Bénin Tel : +229 20 060783 Mobile : +229 97 167 835 E-mail : bees@bees-ong.org / bees@hotmail.fr , Web : www.bees-ong.org	Promote sustainable development through the conservation of biodiversity	Plantation and protection of Mangrove in Bénin		Benin wetlands
7	EcoEcolo	Adresse : 05 BP 9139 Cotonou, Akpakpa Téléphone : +22997449101 ecoecolo2009@gmail.com	-Socio-economic development of rural communities, -environment protection -ecosystem restoration	Mangrove Restoration in Bénin		
8	ACTION PLUS	BP 287 Ouidah, République du Bénin info@ongactionplus.org	Management of domestic wastes, Mangrove restoration, Socio-economic development of grassroots.	Plantation of Mangrove at the coastal lagoon of Bénin		Coastal lagoons

9	CEPRAEDES	08 BP 0234 Cotonou +229 61288917 amenblessa@gmail.com	“Environment Protection & Sustainable Development	Mangrove protection and restoration	Assistance in Oyster culture and oyster Food Technology	Lake Nokoué, Lake Ahémé and Coastal lagoons
10	Cercle pour la Sauvegarde des Ressources Naturelles (ONG Ce.Sa.Re.N)	cesarenong@yahoo.fr 02 BP 268 Cotonou +229 95425047	Environment Protection & Biological Resources Conservation	Project on Conservation and sustainable management of mangrove forests in Bénin		Coastal waters of Benin
11	PROTOS-BENIN	http://www.protos.org/ N° 501 Rue 12.164, Cocotiers/Haie Vive 08 BP 1178 Tri Postal, Cotonou, Benin info.benin@protos.org +229 21 30 41 28	Facilitating sustainable Development, Equitable water management	-Water management, - Will start soon a mangrove restoration activity		Coastal waters

Table 14: List of published and unpublished research (Technical reports) on mangrove and shellfishes.

N°	Topic	Title	Authors	Publication date
1		The history of the mangrove vegetation in Bénin during the Holocene: A palynological study	M.G. Tossou, A. Akoègninou, A. Ballouche, M.A. Sowunmi, K. Akpagana	2021
2		Local uses of mangroves and perceived impacts of their degradation in Grand-Popo municipality, a hotspot of mangroves in Benin, West Africa	Sètondé Constant Gnansounou, Mireille Toyi, Kolawolé Valère Salako, Doré Oscar Ahossou, Tèwogbade Jean Didier Akpona, Rodrigue Castro Gbedomon, Achille Ephrem Assogbadjo, Romain Glèlè Kakaï	2021

3		Food technology of the mangrove oyster, <i>Crassostrea tulipa</i> () of the coastal waters in Benin (West Africa)	Amen Pamela T. Adite	2021
4		The contribution of communication in the development and sustainable exploitation of mangrove oysters of the Benin coastal waters	Perpetue Mahouclo Adite	2021
5		Fuelwood consumption and supply strategies in mangrove forests - Insights from RAMSAR sites in Benin	Jean Adanguidi, Elie Antoine Padonou, Afio Zannou, Sidol B.E. Houngbo, Idelphonse O. Saliou, Symphorien Agbahoungba	2020
6		Mangroves Under Demographic Pressure and Salt Production Threats in the Municipality of Ouidah (Benin)	Sehouevi M. D. Agoungbome, Estelle Gbenontin, and Moussa Thiam	2020
7		Preliminary study on the occurrence of micro-plastic in the diet of the mangrove oyster, <i>Crassostrea tulipa</i> (Lamarck, 1891) of the coastal lagoon of Southern Benin.	Adite Alphonse. & Agomma Tokpanou Judicaël	2020
8		Socio-economic and cultural values of two species of crabs (<i>Cardisoma armatum</i> Herklots and <i>Callinectes amnicola</i> Rochebrune) in Southern Benin, Africa: Management of post-harvest losses and exoskeletons	Toussaint Mikpon, Durand Dah-Nouvlessounon, Nadège Adoukè Agbodjato, Halfane Lehmane, Olaréwadjou Amogou, Christine N'Tcha, Wassiyath Mousse, Haziz Sina, Hyacinthe Ahissou, Adolphe Adjanohoun and Lamine Baba-Moussa	2020
9		Évolution actuelle des écosystèmes de mangrove dans le littoral béninois	OREKAN O. A. Vincent, PLAGBETO Hermann. A., EDEA Emile, SOSSOU Mariano D.	2019
10		Mangroves in Benin, West Africa: threats, uses and conservation opportunities	Oscar Teka, Laurent G. Houessou, Bruno A. Djossa, Yvonne Bachmann, Madjidou Oumorou, Brice Sinsin	2019

11		Population structure and exploitation of the mangrove oyster <i>Crassostrea tulipa</i> (Lamarck, 1891) spats at the coastal lagoon (South-Benin)	Adite Alphonse, Bonou Basile, Hinvi Mishael	2019
12		Population structure of the mangrove oyster, <i>Crassostrea tulipa</i> (Lamarck, 1891) of Lake Nokoué and Lake Ahémé (South-Benin)	Mensenh Theophile, Loko chancel, Adite Alphonse	2018
13		Sizes at first sexual maturity and capture and demographic parameters of crabs <i>Callinectes amnicola</i> and <i>Cardisoma armatum</i> in the complex Nokoué Lake Porto-Novo lagoon in South Benin	Appolinaire Goussanou, Gabriel Assouan Bonou, Antoine Chikou, Guy Apollinaire Mensah and Issaka Youssao Abdou Karim	2018
14		Exploitation de l'huître des Mangroves <i>Crassostrea gasar</i> (Adanson, 1757) dans le Lac Nokoué Au Bénin.	Hyppolite Agadjihouede, David Géraud Akele, Armel Ulrich Mahounan Gougbedji, Philippe Adédjobi Laleye	2017
15		Ethnobotanical Survey of Mangrove Plant Species Used as Medicine from Ouidah to Grand-Popo Districts, Southern Benin	Hubert O. Dossou-Yovo, Fifanou G Vodouhè and Brice Sinsin	2017
16		Population dynamics of freshwater oyster <i>Etheria elliptica</i> (Bivalvia: Etheriidae) in the Pendjari River (Benin-Western Africa)	G.D. Akélé, H. Agadjihouédé , G.A. Mensah, P.A. Lalèyè	2015
17		Domestication de <i>Portunus validus</i> et <i>Callinectes amnicola</i> au Bénin	Hinvi Lambert Cloud, Sohou Zacharie, Agadjihouede Hyppolite, Laleye Philippe and Sinsin Brice	2014
18		Carbon Budget as a Tool for Assessing Mangrove Forests Degradation in the Western, Coastal Wetlands Complex (Ramsar Site 1017) of Southern Benin, West Africa	Gordon N. Ajonina, Expedit Evariste Ago, Gautier Amoussou, Eugene Diyouke Mibog, Is Deen Akambi, and Eunice Dossa	2014

19	Shell-fisheries	The oyster farming in the coastal ecosystem of the Southern Benin (West Africa) : Environment, growth, and contribution to sustainable coastal fisheries management.	Adite, A., Abou, Y., Sossoukpê, E. and Fiogbé, E. D.	2013
20		Feeding ecology of the mangrove oyster, <i>Crassostrea gasar</i> (Dautzenberg, 1891) in traditional farming at the coastal zone of Benin, West Africa.	Alphonse Adite, Stanislas P. Sonon, Ghelus L. Gbedjissi	2013
21		Meristic and morphological characterization of the freshwater prawn, <i>Macrobrachium macrobrachion</i> (Herklots, 1851) from the Mono River – Coastal Lagoon system, Southern Benin (West Africa) : Implications for species conservation	Alphonse Adite, Youssouf Abou, Edmond Sossoukpe, M. H. A. Gildas Gbaguidi and Emile D. Fiogbe	2013
22	Mangrove	Fish Assemblages in the Degraded Mangrove Ecosystems of the Coastal Zone, Benin, West Africa: Implications for Ecosystem Restoration and Resources Conservation.	Alphonse Adite, Ibrahim Imorou Toko, Adam Gbankoto	2013
23		Drivers causing decline of mangrove in West-Central Africa: a review	<ul style="list-style-type: none"> • Njisuh Z. Feka • Gordon Ajonina 	2011
24		Sedimentologic study of mangrove milieu in Bénin (West-Africa)	M. Gaillard, M. Gaillard, J. Lang, J. Lucas	1982

Appendix 5: Images from field visits



Figure 6: Meeting at Degoue village (Coastal Lagoon).



Figure 7: Meeting at Degoue village (Coastal Lagoon).



Figure 8: AVLO Village.



Figure 9: Mangrove at Avlo village (Coastal Lagoon).



Figure 10: Mangrove at Avlo village (Coastal Lagoon).



Figure 11: Discussion with the Chief of the Village AVLO.



Figure 12: Discussion with the Chief of the Village AVLO.



Figure 13: Discussion with the President of oyster exploitant of AVLO village.



Figure 14: Mangrove at Avlékété Village (Coastal Lagoon).



Figure 15: Mangrove at Djègbadji Village (Coastal Lagoon).



Figure 16: Mangrove at Djègbadji Village (Coastal Lagoon).



Figure 17: Oyster shell at Avlékété.



Figure 18: Oyster market (Agatogbo village) at Lake Ahémé.



Figure 19: Lake Nokoué.



Figure 20: Acadja: park of branches installed in Lake Nokoué to attract fishes and produce oyster.



Figure 21: Acadja fisheries (fish and oyster) in Lake Nokoué.



Figure 22: Acadja fisheries (fish and oyster) in Lake Nokoué.



Figure 23 Acadja fisheries (fish and oyster) in Lake Nokoué.



Figure 24: Acadja fisheries (fish and oyster) in Lake Nokoué.



Figure 25: Spat (small oysters) on sticks in Lake Nokoué.

Appendix 6: Revised list of stakeholders
(Excel file)