



Crocodile Farming—A Tool for Sustainable Development in Coastal Communities: A Case Study of Emede and Esanma Captive Breeding Sites, Delta State, Nigeria

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Abstract

This study investigates the benefits of crocodile farming and ranching in Emede and Esanma Kingdoms, Delta State, Nigeria. A mixed-method approach was used, combining survey, key informant interview, and questionnaire methods. The results show that crocodile farming provides employment opportunities, income generation, and conservation benefits for the local communities. A total of 27 crocodiles were bred in captivity, with 16 Nile Crocodiles and 11 Dwarf crocodiles. The study also reveals that the communities are aware of the crocodile farms and have benefited from them. However, the chi-square analysis suggests that the variables are likely independent, indicating no significant difference between the observed and expected data. The study concludes that crocodile farming and ranching can be a sustainable and profitable venture for coastal communities, with potential economic and conservation benefits.

Subject Areas

Aquaculture, Fisheries & Fish Science

Keywords

Crocodile Farming, Sustainable Benefits, Coastal Communities, Conservation, Economic Benefits

1. Introduction

The Sustainable Development Goals (SDGs) as enumerated by the United Nations have aligned itself with several needs of man in all ecosystems such that no stone

is left unturned [1]. The SDG 1, 2, 14 and 15 which aimed at reducing poverty in rural areas, eradicating hunger, protection of life below water including her resources and life on land respectively, tend to cater for the coastal communities [2] [3].

The crocodile being a wetland megafauna and keystone species [4], is ecologically and economically asset in satisfying man's needs due to its protein (meat) for consumption, skins for leather products and teeth for jewelry [5].

A crocodile farm is a place where crocodiles are bred and raised for commercial purposes. Crocodiles on farms are typically kept in artificial enclosures, are provided with veterinary care and artificial food, and are protected from predators. Crocodile farms are often used for the production of skins, meat, oil, and claws [6]. Crocodiles are fed a diet of fish and other meat, and are cared for by trained handlers. They are usually slaughtered when they reach a certain size or age, and their skins and meat are then processed for sale. Crocodile farming is seen as a way to help conserve wild crocodile populations, as it reduces the demand for wild-caught crocodiles. Crocodile farming is a highly regulated industry, with strict guidelines in place for the health and welfare of the animals. In some countries, crocodile farming is considered a sustainable alternative to wild harvesting, as it can help to reduce pressure on wild populations [7]. The idea of keeping crocodiles in captivity for breeding purposes is not a new one, and dates back to the early 20th century. Many of these farms were tourist attractions where wild crocodiles and alligators were kept for display. However, as our understanding of the animals' needs has improved, crocodile farming has evolved to become a more sustainable industry that focuses on breeding and husbandry [6] [8].

The crocodilian farming industry has emerged as a significant livestock sector, with diverse farming systems encompassing closed-cycle captive breeding, ranching, and hybrid models [9]. These ancient reptiles, belonging to the order Crocodylia, comprise 24 species with distinct anatomical, physiological, and behavioral characteristics. The majority of farmed crocodilians belong to the Crocodile (*Crocodylus porosus* and *Crocodylus niloticus*) and Alligator (*Alligator mississippiensis* and *Caiman crocodilus*) families.

The methods of crocodile farming, varies depending on the region and the species of crocodile being farmed. The methods include intensive, semi-intensive, and extensive farming. Intensive farming involves keeping the crocodiles in high-density pens and providing them with a controlled diet. Semi-intensive farming involves lower densities of crocodiles and a less controlled diet, while extensive farming involves free-range or semi-wild conditions with minimal human intervention. The choice of methods depends on factors such as the availability of land, labor, capital, and the market for crocodile products. Two types of crocodile farming are in practice: Open and Closed Cycle [10]-[12]. The open cycle system of crocodile farming creates rooms for healthy and viable species that can be returned to the wild under favorable conditions [11] [12]. It is a technique used to monitor crocodile population in the wild and it is a conservation management

technique [13] [14]. But the closed cycle system of crocodile farming is more concerned on the products from the species such as meats, skins, and teeth for commercial usage [11] [12]. It is not a conservative approach as it does not cater for the preservation of native species of crocodiles [15] [16]. It is also very costly to fund from hatchlings to maturity [17]. Crocodile farming seems to affirm the notion that crocodiles are sentient beings such that the skins are used in fashion and leather industry as luxury items which in turn negate conservation strategies

Globally, approximately 5000 crocodilian farms operate, ranging from village-level enterprises to sophisticated facilities prioritizing animal care [9]. As with traditional livestock, consumers expect farmed crocodilians to be treated humanely and have a good quality of life. In response, the industry has developed an International Standard for Crocodilian Farming, emphasizing animal welfare outcomes and continuous improvement [9]. This standard adheres to international guidelines and includes mandatory requirements from breeding to slaughter. Notably, it advocates for an outcome-based approach, incorporating animal-based measures to reflect genuine welfare advancements [18] [19]. Although progress has been made in crocodilian husbandry, a validated animal welfare assessment protocol remains elusive [16] [20]. This knowledge gap is not unique to crocodilians, as studies on other reptile species also highlight the need for standardized welfare assessment methods [21].

While crocodile farming has many benefits, it is not without its challenges. Crocodile farming is a profitable business venture though it requires a large amount of initial investment [8]. Some of the reasons for engaging in this popular investment includes: production of meats for proteins, production of hides and leathers from the skin for shoes, bags and other leather products, production of jewelries from crocodile teeth, manufacture and prescription of orthodox and traditional medicine from crocodile body parts and for tourism [22]. It involves techniques such as housing facility with adequate temperatures, maintaining high water quality, appropriate cover, high standard of food quality and hygiene [23]-[25]. Other factors to consider in crocodile farming includes: housing enclosure size, fence materials and design, physical construction, gates, pool design and construction, landscape design, staff and general public safety, water quality and general maintenance, nesting, incubation, hatching and grow-out [26].

One of the main concerns is animal welfare. There is a common belief that crocodiles raised on farms are not given the proper space or care, and that they suffer as a result. Also, the high demand for crocodile skins and meat can lead to over-exploitation of wild populations, despite efforts to regulate the industry. There is also concern that crocodile farming could lead to disease outbreaks, as the animals are kept in close quarters. Despite these challenges, crocodile farming is seen as a way to provide a sustainable source of income for many communities around the world [7].

Effective crocodile farming involves a number of key practices. such as: a good understanding of crocodile biology, including their breeding and reproductive

cycles., the use of appropriate husbandry techniques, such as providing a suitable diet and adequate housing, effective management of disease and parasites is critical to maintaining a healthy and productive crocodile farm and finally, a good understanding of the market for crocodile products, and to have a plan for marketing and selling the products [27].

Crocodile Species are raised either by ranching or in captivity. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is an international treaty that regulates trade in endangered species of animals and plants. Two legal bases under CITES allow for ranching, or the breeding of animals for the purpose of conservation and trade. First, any party to the treaty can pursue ranching as a management option for Appendix II species, which are not considered to be threatened with extinction, as long as the ranching plan is in accordance with the provisions of Article IV of the treaty. Second, species listed in Appendix I, which are threatened with extinction, can be transferred (CITES, Article I, Paragraph I) [28] [29]. A comprehensive list is contained in [30] as shown (**Table 1**) below:

Table 1. Current use programs for crocodilians [26]. C = captive breeding; R = ranching; W = wild harvest.

Species	Use	Country
<i>Alligator mississippiensis</i>	C, R, W	USA
<i>Alligator sinensis</i>	C	China
<i>Caiman crocodiles</i>	W	Nicaragua, Guyana
<i>Caiman crocodiles</i>	C	Columbia
<i>Caiman crocodiles</i>	C, R	Brazil
<i>Caiman crocodiles</i>	R, W	Venezuela
<i>Caiman latirostris</i>	R	Argentina
<i>Caiman yacare</i>	R	Argentina
<i>Caiman yacare</i>	C, W, R	Bolivia
<i>Caiman yacare</i>	C, R	Brazil
<i>Caiman yacare</i>	W	Paraguay
<i>Melanosuchus niger</i>	W	Brazil
<i>Crocodylus acutus</i>	C	Honduras, Colombia
<i>Crocodylus acutus</i>	R, C	Cuba
<i>Crocodylus johnstoni</i>	C, R, W	Australia
<i>Crocodylus moreletii</i>	C, R	Mexico
<i>Crocodylus niloticus</i>	C, R	Zimbabwe, Kenya, Namibia
<i>Crocodylus niloticus</i>	C, R, W	Madagascar
<i>Crocodylus niloticus</i>	R, W	Tanzania, Mozambique
<i>Crocodylus niloticus</i>	R	Botswana, Malawi, Zambia, Uganda, Ethiopia, Swaziland

Continued

<i>Crocodylus niloticus</i>	R	Egypt
<i>Crocodylus niloticus</i>	C	Mauritius, South Africa, Tunisia
<i>Crocodylus suchus</i>	C	Senegal, Mali
<i>Crocodylus novaeguineae</i>	R, W	Papua New Guinea, Indonesia
<i>Crocodylus porosus</i>	C	China, Singapore, Vietnam, Thailand, Philippines
<i>Crocodylus porosus</i>	C, R, W	Australia, Indonesia, Papua New Guinea
<i>Crocodylus porosus</i>	C, R, W	Malaysia
<i>Crocodylus rhombifer</i>	C	Cuba
<i>Crocodylus siamensis</i>	C	Thailand, Cambodia, Vietnam, China

Ranching of crocodiles in some African countries has always been done in parallel with captive breeding such that the hatchlings from wild eggs are separated from the ones gotten from captive breeding [29]. Captive breeding of endangered species for re-introduction into the wild, is a specialized area of conservation that made use of farming technology but has different objectives. It is essential if there are no wild species of commercial value, or if the wild species are being utilized to their highest extent [28].

The practice of crocodile (*Crocodylus niloticus*) farming in southern Africa spans over two and a half decades. This industry's development was facilitated by a 1963 regulatory framework in Zimbabwe, which allowed licensed operators to collect and incubate wild crocodile eggs in controlled environments [8]. Statistics have shown that Zimbabwe is the second largest exporter of crocodile products [31] though threatened by dwindling economy as a country at a time, but her trade rose to over 100,000 skins annually which makes their reptile industry to employ hundreds of people [31] [32] has also shown in **Table 2** that over 2 million crocodile skins are traded annually.

Table 2. Estimated number of crocodylian skins supplied to the industry by method of production, 1977-99.

Year	Wild	Ranched	Captive-bred	Total
1977	306,337	1258	0	307,595
1978	400,917	175	0	401,092
1979	380,405	991	0	381,396
1980	1,117,219	1039	0	1,118,258
1981	945,000	3029	567	948,596
1982	830,045	3165	177	833,387
1983	861,954	6424	172	868,550

Continued

1984	846,951	11,565	632	859,148
1985	1,260,776	17,729	1384	1,279,889
1986	858,312	20,383	3287	881,982
1987	618,603	32,562	6964	658,129
1988	975,774	55,000	8995	1,039,769
1989	527,573	118,854	49,604	696,031
1990	452,486	135,751	112,488	700,725
1991	304,563	164,648	149,946	619,157
1992	259,562	194,389	250,913	704,864
1993	240,029	213,635	576,384	1,030,048
1994	270,174	251,849	599,189	1,121,212
1995	224,483	228,930	846,584	1,299,997
1996	180,855	231,168	690,815	1,102,838
1997	202,809	252,394	534,734	989,937
1998	120,011	236,216	722,978	1,079,205
1999	93,151	255,945	856,143	1,205,239

Source [33]: CITES trade data, supplemented by information provided by the CSG.

There is a complex relationship between crocodile farming and sustainable development as it helps to provide jobs and income for local people, as well as to generate revenue for the government through taxes and fees. This can lead to improvements in education, health care, and infrastructure in rural areas [28].

There are a number of ways to promote the sustainability of crocodile farming. One way is through the development of standards and certification programs. These programs can help to ensure that farms operate in an environmentally and socially responsible manner. It can also be done through the promotion of best practices, such as waste management and the use of sustainable feed sources as well as engaging with local communities to ensure that they are consulted and compensated for any negative impacts of the farms. Furthermore, research and education are key to ensuring that crocodile farming is sustainable in the long term [34].

The coastal communities where crocodile farming is practiced in the Niger Delta, Nigeria, is Emede and Esanma in Delta State. The aim of this research paper is to analyze the crocodile farming in the area and evaluate their contribution to sustainable development in a developing nation like Nigeria.

2. Materials and Methods

Production sites.

2.1. Farm 1

Emede is an Isoko town in Isoko South Local Government Area, Delta State. It

has a coordinate of 5.234424°N and 6.105125°E with a geographical boundary of 668 km². The crocodile farm at Emede Captive Breeding Site is that of a medium sized floored enclosure of about 2.44 - 3.66 meters in length, 1.52 - 2.74 meters in width and 1.22 - 1.83 meters in depth containing little volume of water which do not submerged the species of crocodiles in it as shown in **Figure 2** and **Figure 3**. The crocodile farm is located at outskirts of Emede town.

2.2. Farm 2

Esanma is a village in Bomadi, Delta State. It has a coordinate latitude of 5.1733°N, Longitude: 6.0947°E with a geographical area of 217 km² and elevation of 3 meters. It is a village populated with people as they live and work there [35]. The crocodile farm at Esanma captive breeding site is a very small enclosure housing with two adult and 2 Small dwarf crocodiles in dry floored cave of 2.13 - 3.05 metres in length, 1.83 - 2.44 meters in breadth and 2.74 - 3.66 meters deep with forested particles and muddy soil as shown in **Figure 4**. The crocodile farm is located behind residential uncompleted building within Esanma village (See **Figure 1**).

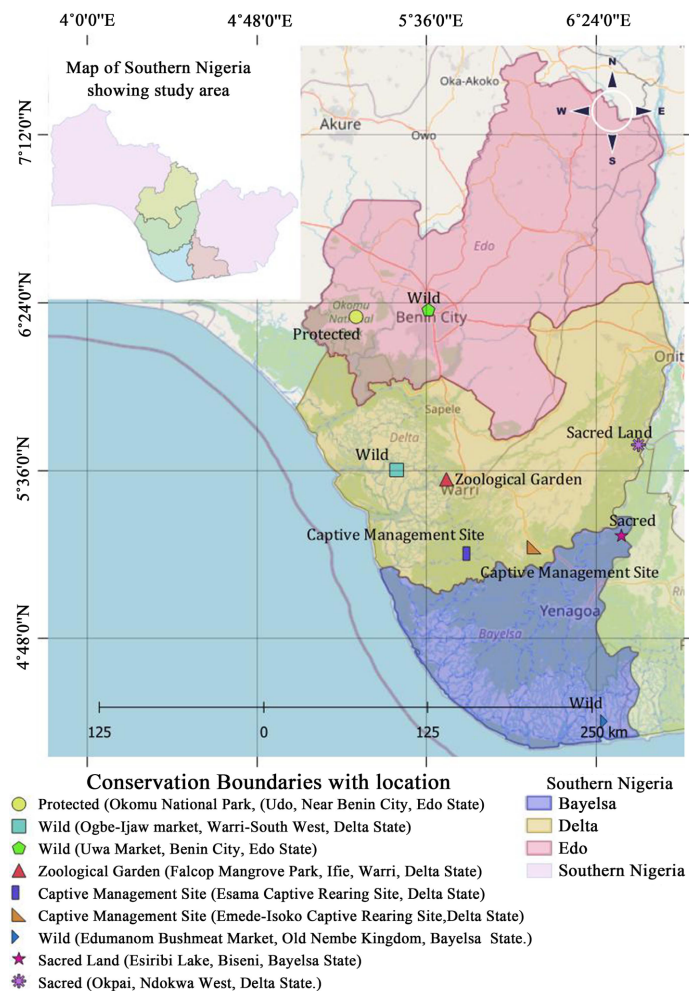


Figure 1. Map of Study Area (Emede and Esanma), Delta State, Nigeria. Method of Data Collection is a subheading.

The method adopted involves:

Survey method: Observing and recording the numbers of crocodile present in the captive site, noting the species.

Key Informant Interview: which involved recorded oral interview, was carried out to inquire the source where the crocodiles were gotten, gender of crocodiles in captivity, method of harvest, feeding regime and feed sources.

Questionnaires: Data were collected from the two crocodile farming locations and the households in the vicinities through a 6-item Questionnaire centered on community involvement, tourism and conservation, education, revenue generation and mitigation of environmental pollution. 120 households from all the households in Emede Kingdom and 105 households from all the households in Esanma Kingdom.

Statistical Tool used:

A Pearson Chi square of independence was the statistical tool used to analyze the data collected as observed data from which the selected frequencies were extracted from using number of rows (6) each for both (Emede and Esanma) and number of columns (4) each for YES/NO column.

The Pearson Chi square of independence is used because the two crocodile farms (Emede and Esanma Captive Breeding Site) are compared in terms of the relationship between them (**Figures 2-4**).



Figure 2. Nile Crocodile (*Crocodylus niloticus*) at Emede Crocodile Farm in 2022.



Figure 3. The crocodiles in enclosures at Emede Captive Breeding Site in 2022.



Figure 4. Dwarf Crocodile (*Osteolaemus tetraspis*) at Esanma Crocodile Farm.

3. Results and Discussion

A total of 27 crocodiles were bred in captivity with 16 Nile Crocodiles, 7 Dwarf crocodiles in Emede captive rearing site and 4 Dwarf crocodiles from Esanma Captive Rearing Site as shown in **Table 3** below.

Table 3. Number of crocodiles bred in captivity.

Species	Emede Captive breeding Site	Esanma Captive breeding Site
Nile Crocodile	16	0
Dwarf Crocodile	7	4
	23	4

Result from Focus Discussion:

The Crocodiles bred in captivity were captured and harvested from various sources such as ponds, river banks, forest floor and swamps as shown in **Table 4** below

Table 4. Sources where crocodiles were harvested.

Sources	Emede Captive breeding Site	Esanma Captive breeding Site	Total
Pond	5	4	9
River Bank	5	0	5
Swamp	3	0	3
Forest Floor	10	0	10
Total			27

Figure 5 shows the gender of crocodiles bred in captivity. 5 Male crocodile (3 Niles and 2 dwarfs) in Emede Captive Breeding Site and 2 male dwarf crocodiles at Esanma captive breeding site. 18 female crocodiles (13 Niles and 5 dwarfs) in

Emede Captive Breeding Site while 2 dwarf female crocodiles in Esanma captive breeding site.

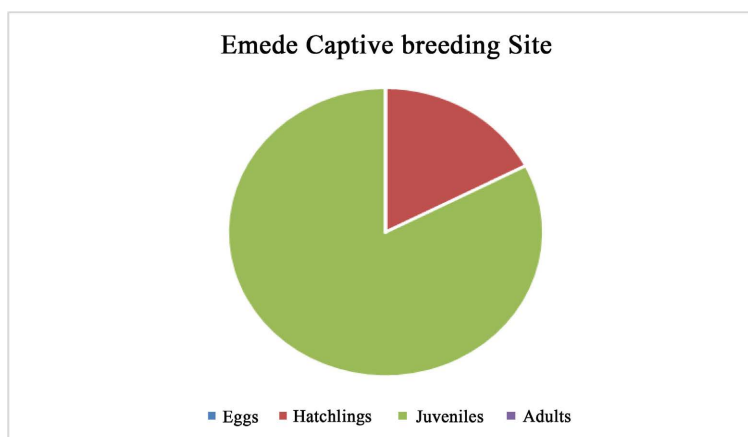


Figure 5. Gender of crocodiles species bred in captivity.

The crocodiles were harvested as hatchlings, 4 at Emede Captive Breeding Site and 0 at Esanma captive breeding site and as juveniles, 19 at Emede Captive Breeding Site and 4 at Esanma captive breeding site as shown in **Figure 6** below.

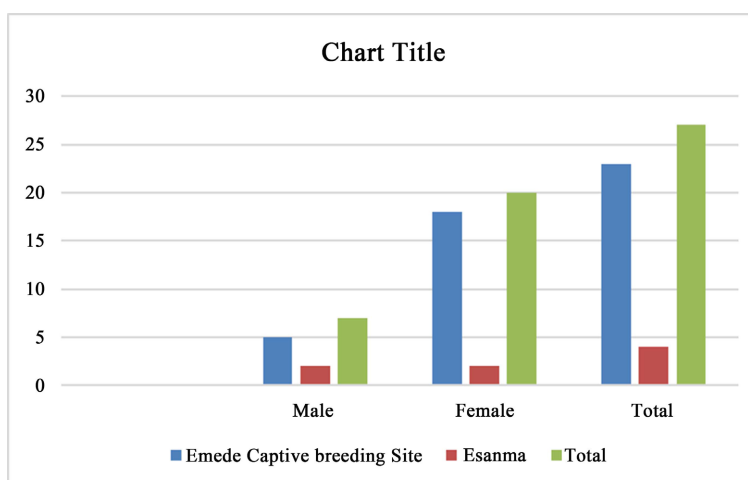


Figure 6. Growth Nature of crocodiles harvested for breeding in captivity.

Table 5. Polar questions on the role of crocodile farms in coastal community studied.

S/N	ITEMS	Emede Crocodile Farm		Esanma Crocodile Farm	
		YES.	NO	YES.	NO
1.	Do you have workers that work with you on your crocodile farm on daily basis?	75	45	60	45
2.	Do students or outsiders visit your crocodile farm occasionally?	50	70	55	60
3.	Do you make money from your crocodile farm by selling matured ones?	80	40	58	57

Continued

4.	Is your community aware that you have a crocodile farm?	60	60	70	45
5.	Does your community people benefit from your crocodile farm in one way or the other?	90	30	40	75
6.	Do other animals like lizards visit the crocodile farm?	65	55	68	47

From **Table 5**, out of the 120 households that responded to the questionnaire at Emede, 75 have worked or visited the crocodile farm, 45 have never worked nor visited the farm. In the same vein, from the 105 household in Esanma Kingdom, 60 respondents have worked or visited the crocodile farm while 45 respondents have not been there before.

At Emede Crocodile Farm, 50 respondents out of 120 have visited the farm for one studying or tourism purpose while 70 respondents on the hand have not visited for tourism or conservation studies. In the same vein, 55 respondents have visited the Esanma Crocodile Farm for conservation study purpose as against 60 respondents who has not done that. 80 respondents affirmed that farmers do sell of matured crocodile but 40 respondents disagree to that in Emede Crocodile Farm. Also, 58 respondents affirmed the sales of matured crocodile as opposed by 57 other respondents in Esanma Kingdom. Both respondents (60) equally that the community of Emede is aware of the crocodile farm. But in Esanma Kingdom, 70 respondents are aware of the Crocodile Farm in the village while 45 respondents are ignorant of what is happening about crocodile farm. The respondents, 90 from Emede affirmed that the community has benefitted in one way or the other from the small crocodile farm while 30 respondents were of contrary opinion. The same is applicable to Esanma as a lower percentage (40 respondents) that the community has benefitted as against 75 who have contrary views. 65 respondents affirmed that other animals like lizards and frogs visit the farm but 55 other respondents disagree to the answers in Emede Kingdom. As far Esanma Kingdom, 68 respondents affirmed that smaller reptiles and amphibians visited the enclosed farm while 47 respondents had a different opinion. These views were the opinions of households in the areas where the small crocodile farm is located.

The chi-square results of the above statistics are 58.549 and the critical value of 76.778 with the degree of freedom being 33. This implies that the observed data does not significantly differ from the expected data, and the variables are likely independent as it relates to both Emede Crocodile Farm and Esanma Crocodile Farm.

4. Discussion

From our studies, many of the crocodiles were harvested from ponds and forest floor at the juvenile stage. Researchers have shown that most crocodiles bred in captivity are from two sources (wild-caught crocodiles and captive bred crocodiles)

[36] [37]. The crocodiles bred in captivity are harvested from the wild population in their native range [38] [39]. The length of crocodile observed in Emede and Esanma captive rearing site were between 2 feet and 4 feet long. The length of crocodile bred in captivity varies depending on the species and specific breeding program. The two main factors that determine the length of crocodiles in captivity includes the available space and quality of environment [37] [40]. The feeding diet fed to crocodiles bred in Emede and Esanma captive rearing site were lizards, rats, fishes/fish by-products, frogs/toads, meats and insects (cockroaches and grasshoppers) in different proportions. This was applicable in [5] and [41], where poultry intestine was added to lizard meat and frog/toad meat. In Nigeria, the nutritional requirements for captive crocodiles are generally based on the recommendations of the American Association of Zoological Veterinarians (AAZV). The AAZV recommends a diet that consists of 40% - 60% protein, 20% - 40% fat, and less than 10% fiber. It is also recommended that the diet be supplemented with vitamins and minerals, as well as calcium, to ensure the health and well-being of the crocodiles. Some farms and ranches in Nigeria may also provide live prey, such as chickens or fish, to meet the dietary needs of their captive crocodiles [42] [43]. Captive crocodiles are usually fed with diets comprising fish, meat, eggs, and sometimes fruits. The exact diets vary depending on the size, age, species and activity level (WAZA and IUCN). The growing crocodiles eat more frequently and active than adult crocodiles [44] [45]. But in general, a balanced diet for captive crocodiles consists of 50% - 60% proteins, 25% - 35% fats, and 10% - 13% carbohydrates [46] [47].

Sustainable benefits of Crocodiles farms in Coastal communities

Our observations and intimate visit to these small enclosures of Crocodile revealed that the tendencies for a Subsistence Agriculture than a Commercial form, though students and community members have access to the crocodile enclosures at any time. The crocodiles are getting matured by the day hence, many sales have not been made especially in Esanma Captive Rearing site where only Dwarf crocodile species are present. From our analysis of the crocodile farm and the benefits derived from it follows thus, it has been determined that the farm is beneficial to coastal communities, especially Emede Kingdom Individual Laborers, Daily care, feeding, health care, incubation, incubation, larval growth and development are carried out in crocodile farms. The farmer works every day or sometimes hires helpers to work with him. According to [48], A Crocodile Farmer is a person who raises and takes care of many crocodiles to sell them for profit. They work in the farming and business industries. A Crocodile Farmer's main job is to: Take care of crocodile homes (enclosures), Learn new ways to breed crocodiles, Keep the environment clean and safe, make sure crocodiles are healthy and well-fed, talk to people who want to buy crocodiles, Do office work and marketing.

The Emede crocodile farm has some benefits for the local community, including providing limited employment opportunities. However, the farm is not currently engaged in commercially viable activities. Tourism is a significant contributor to

the local economy, offering jobs for young people in tour guiding, food sales, and local product marketing. Additionally, the farm provides employment opportunities and a market for local products, including dead livestock. The local products from the farm sold to tourists generate income for the community. It is essential to engage in multiple activities that benefit the local community, providing training, employment, and market opportunities. Integrating various activities, such as wildlife management and tourism, can maximize benefits for the community [49]. Crocodile farming and ranching have several economic advantages. They encourage the protection of endangered species and support wetland conservation [50]. In Africa Country like Zambia, the wildlife ranching industry, which includes crocodile farming, generates around \$15.7 million annually and provides jobs for many people [51]. These ranches also produce a significant amount of meat, benefiting local communities and staff [51]. The economic returns from wildlife ranching are substantial, making a strong case for government support [51]. In Sao Paulo, crocodile farming has been found to be economically viable with a high potential for returns [52]. Additionally, crocodile farming can provide economic benefits by producing valuable hides and meat without harming wild populations [8]. Collecting alligator eggs early in commercial facilities can lead to faster growth, benefiting producers economically [53].

Some of the gap in knowledge that this paper seems to address includes: Nutritional requirements, there is limited knowledge about specific feeding allocation for crocodile in captivity, particularly in Nigeria [42] [54]. Optimal diet variations: Many crocodile farms in Africa are used to giving only one type of feed to animals in captivity probably because of availability but in this research work, diversity of feed was observed [36]. Another gap in knowledge is that of Economic viability where the benefits of crocodile farming is stressed but the profitability of small scale farming in Nigeria is still an issue [52] [51] and Conservation impact.

5. Conclusion

The research highlights the benefits of crocodile farming and ranching for coastal communities, including employment opportunities, income generation, and conservation of endangered species. However, the Emede crocodile farm is not yet commercially viable, and its main contribution is providing limited employment opportunities. Integrating wildlife management and tourism can maximize benefits for the community. The research also shows that crocodile farming can be economically viable, providing valuable products like meat and hides while supporting wetland conservation. The study suggests that crocodile farming and ranching can be a sustainable and profitable venture for coastal communities, with potential economic and conservation benefits.

Conflicts of Interest

The authors declare no conflicts of interest.

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