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The Giant African Land Snail; a Delicacy in Africa, But a Pest Everywhere Else. A Review

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Abstract

A Giant African Land Snail (GALS) is the common name given to some species of molluscs in Africa, of which the three commonest species are *Lissachatina fulica*, *Achatina achatina* and *Archachatina marginata*. They are non-timber forest products that have been consumed as delicacy in Africa for millennia. About 200 years ago, *L. fulica* was introduced mostly by human agents into other tropical and sub-tropical countries, where it evolved into a pest, threatening biodiversity, agriculture and became an urban menace. It presented a public health concern because it harbours pathogens and parasites that made it a vector of many diseases. Attempts to control the snail using physical, chemical and biological methods has recorded meagre successes in most countries and often accompanied with greater biodiversity and public health concerns. We proposed an invasivore control after appropriate processing and cooking as an alternative method of control. Besides, bioactive substances with novel biotechnological applications have increasingly been detected in the snail. Hence, the aim of this study is to appraise GALS especially *L. fulica*, which is a delicacy in Africa, but an invasive pest in other parts of the world. We reviewed literature and presented the culinary and pharmacologic benefits among other uses, its nativity and global spread, nuisance and pest attributes and control measures of *L. fulica*.
Keywords: Achatinid snails; Biodiversity impacts; Food pathogens; GALS; Invasivore; Microbiome; Parasites; Pestiferous snail.

1. Introduction

A Giant African Land Snail (GALS) is the common name given to some species of molluscs (Gastropods) in Africa, of which the three commonest species are *Lissachatina fulica* (formerly *Achatina fulica*), *Achatina achatina* and *Archachatina marginata*. These species, which occur in the wild mostly as detritus feeders and herbivores, play a role in the sequestration of carbon, which is important in climate change mitigation and formation of compost. Land snails are in high demand in Africa because of their high nutritive, medicinal, cultural and economic values [1, 2]. Economically, they are commonly classified as non-timber forest products. These species are a delicacy and important source of protein to over one billion people in sub-Saharan Africa. GALS are also used for cosmetics, traditional medicine and objects of religious rituals/worship in Africa, Asia and some parts of South America [3, 4]. However, one of these species, *L. fulica*, has spread around the tropical and subtropical world mostly through human agents. It has become established and adapted as agricultural pest and vector of parasites and pathogens in several countries of the world.

In the early 1800s, *A. fulica* were collected from East Africa and introduced by humans throughout the tropics and subtropics, where they have become adapted, established and evolved or classified as pests [5, 6]. It has begun emerging sporadically even in temperate countries [2, 4]. *L. fulica* has been ranked among the world's 100 worst invasive alien species [7-9], while some authors rated it as the second worst invasive alien species [10, 11] and the most damaging pestiferous land snail in the world [12]. Outside their native African range, the snails have been a formidable threat to biodiversity because of their destruction of diverse plant species including crops, competition with native snails for food and habitats and potential to transmit pathogens and parasites.

Notwithstanding the nutritional benefits of consuming snails, their cultural, religious, medicinal, economic and educational values especially in Sub-Saharan Africa, one of these species, *L. fulica* is classified as pest in many countries, where they have become a threat to biodiversity and small-scale agriculture. Achatinid snails are vectors of pathogens and parasites and could therefore contribute to food related disease burdens even in their area of nativity in Africa and beyond [13]. Hence, the aim of this study is to appraise GALS especially *L. fulica*, which is a delicacy in Africa, but an invasive pest in other parts of the world. We reviewed literature and presented the culinary and pharmacologic benefits among other uses, its nativity and global spread, nuisance and pest attributes and control measures of *L. fulica*.

2. Ecology of Giant African Land Snail

The Giant Africa land snails are among the largest land snails in the world [14, 15]. *A. marginata* and *A. achatina* originated from West African coast, while *L. fulica* originated from East African coast. In their native range, the snails are commonly found in the forest floors, where they carry out degradation of waste biomass, thereby contributing to carbon fixation and recycling of nutrients. Their habitat ranges from riparian forests to the savannas. However, they are also found in diverse habitats such as mountains, woodlands, wetlands, dry lands, farms and home gardens [2, 3]. They are becoming adapted to disturbed ecosystems in suburban areas including farms and home gardens [10, 16].

These species of snails are mostly nocturnal, foraging for food mostly at nights [6, 17] and occasionally during the day [13]. They usually have a home range from where they forage and return [18]. Within their native range in Africa, Achatinid snails are mostly herbivores and detritivores, whereas in the countries *L fulica* have been introduced to, they seem to have evolved into a formidable pest [8, 9]. They have been reported to devour over 500 different plant species [4, 5, 19] including fruits, vegetables, food crops and tree crops [19, 20]. In order to meet their calcium requirement for shell growth, the snail consume building materials such as paints, plaster boards, stucco and concrete [18, 21].

GALS are part of the food web, primarily as commensals and decomposers, helping in the degradation of forest litter, which is important in nutrient cycling and carbon sequestration [13, 22]. They play host to guilds of microbial species in their gut that forms their microbiome, which facilitate the biodegradation of biomass with great efficiencies [3, 23]. GALS are also known to scavenge and forage on wastes including municipal solid wastes (MSW) and improperly treated human wastes [6, 18], which have also resulted in the infection and persistence of pathogens in the snail [24, 25].

Environmental factors particularly temperature and humidity affect the distribution of GALS in the wild [6, 9]. The snail is able to survive in a wide range of temperature from 0 – 45^{o}C [20], with optimal range of 22 - 32^{o}C [4]. They reproduce during the monsoon season, when the humidity is typically high [26]. There is ample evidence that climate change is affecting the distribution of the snail in the wild [9, 11, 27]. GALS have a robust adaptation mechanism against adverse weather conditions. For instance, during the periods of drought, they aestivate, whereas during winter, they hibernate [4, 18] and become metabolically inactive for months, only to resume metabolic activities when the conditions becomes favourable [2, 20].

Anthropogenic activities seem to be a major factor in the distribution of GALS. Humans purposely obtained *L. fulica* and introduced them in other tropical and sub-tropical countries. Human venture into the wild for timber and other forest products have affected the natural habitat of the snail. Agricultural practices including shifting cultivation, slash and burn agriculture, use of pesticides have been reported to affect Achatinid snail [1, 28]. Pollution including oil spills has impacted the population of the snail in the wild. Urbanization and infrastructural development such as roads, dams etc have encroached into the natural habitat of the snail [29, 30]. The presence of untreated human wastes and municipal solid wastes has attracted the snails to urban centres. *L. fulica* seems to have now adapted to human areas and have been found to be well established especially in coastal urban centres where they scavenge urban wastes [4-6, 31]. The snail is a delicacy in Africa, where they are typically harvested from the wild and consumed. Human activities have therefore affected the snail in different ways. In their native African range, their population is declining due to overharvesting and other human activities [1, 28], whereas in the countries that they were exported to, they have evolved to become a formidable pest [3, 5]. The reproductive ecology of the snail is dependent on weather conditions. The snail typically breeds during the wet season when the humidity is high [15], which often coincide with the availability of lush vegetation. The snails are hermaphrodite; hence, a single individual can reproduce and multiply into a new colony, which is quite rare though [20, 32]. But in most cases, it requires reciprocal copulation in order to produce viable eggs [18].

GALS can attain sexual maturity as from 6-12 months [4, 27] and can begin to lay eggs within 8 - 20 days after mating [18]. GALS can lay eggs several times within a year after a single mating. However, the different GALS species can lay different quantities of eggs. *L. fulica* is the most prolific followed by *A. achatina* whereas *A. marginata* is the least. While *A. marginata* lays about 30-40 eggs per clutch, *L fulica* can lay between 100 - 500 eggs per clutch several times in a year, which can reach up to 1800 eggs per annum depending on the weather conditions [4, 5]. The incubation period is also different among GALS, being 7-8 days in *L. fulica* [33] and 29 – 40 days in *A. marginata* [34]. GALS eggs have survivorship of 49- 90% [4, 27, 32] but hatchability differs among species; 86.56% for *A. marginata*, 75.12% for *L. fulica* and 65.38% for *A. achatina* [35]. GALS can generally live between 3 and 10 years [15, 27, 36].

3. Global Spread of African Giant Snail

The three common species of GALS originated from Africa, while *L. fulica* originated from East African coast, *A. marginata* and *A. achatina* originated from West African coast. These species have now been reported throughout the African continent [25, 37, 38]. These species were restricted to the African continent until about 200 years ago, when humans intentionally collected *L. fulica* from East Africa and introduced them into other countries and continents in the tropics and neotropics [3]. In 1800, *L. fulica* was exported to some Indian Island Nations (Seychelles, Madagascar, Mayotte, Mauritius, Comoros and Reunion), but were introduced from Mauritius to Kolkata, India, from where it spread locally [11] and to other Asian countries and the Pacific Islands [4, 5]. Molecular studies have supported this hypothesized pattern of migration of the snail. Between 1900 and 1945, *L. fulica* was spread mostly by humans to several countries in region including Sri Lanka, Taiwan, Nepal, Korea, Japan, Bangladesh, Bhutan etc [5, 8, 11]. For instance, Fontanilla, *et al.* [8] traced the origin of the snails circulating in the wild in various countries and continents to a common ancestor originating from East African coast. Ayyagari and Sreerama [39] carried out molecular studies on the snails circulating in Indian continent and linked them to ancestors from Mauritius, though, they also found other haplotypes in lesser frequencies, which suggest multiple introductions.

The introduction of *L. fulica* to the Americas was mediated by humans. The snail was first introduced from Japan into Hawaii in the Islands of Maui and Oahu in 1936 and became established in the wild in 1938 and spread to two other Islands (Hawaii and Kauai) before they were eradicated in 1958. The snail soon emerged from other locations in Hawaii in 1963 including Molokai, Lanai, Kalaupapa and Mauna Loa, which were also controlled [40]. The snail was first detected in South Florida in 1966, which was eradicated in 1975 [5, 8]. It re-emerged in 2011 and was then eradicated in 2021 [19, 20, 41] and re-emerged again in 2022 and 2023 [19, 41].

L. fulica was introduced in the Caribbean in the 1980s [9] and become established in Guadeloupe in 1984, Martinique in 1988, Barbados and St. Lucia in 2000 and Antigua in 2008 [5, 8]. The introduction of *L. fulica* from Indonesia to Brazil in 1980 paved the way for the snail in Latin America [5, 8, 42]. Initially, snail farming (escargot) was actively promoted in Brazil, but when the business collapsed, farmers dumped their products in public bins, along the roads and into the forest, which led to the establishment of the snail in the wild [5]. Within 10 years, the snail had spread and became stablished in other countries in the region including Columbia, Peru, Argentina, Venezuela, Paraguay, Ecuador, Cuba [8, 9, 42]. The nail has occasionally been reported in temperate countries, where they were not introduced including United Kingdom, France, Italy, Portugal, Malta, Greece, Spain and Cyprus [4, 8].

4. Giant African Land Snail as Delicacy among Other Uses

Achatinid snails are consumed by the people of Africa as alternative animal protein [1] with *Achatina achatina* the most preferable followed by *Archachatina marginata* whereas *A. fulica* is the least [43]. Snail meat popularly known as 'Congo meat' is quite tender, tasty and chewy with a characteristic mushroom-like flavour [44]. A snail meat is considered as highly nutritive because of their high protein content and essential amino acids such as arginine, phenylalanine, lysine, leucine and isoleucine [22, 45]. The protein content of snail meat is about 20% [22], which is considered higher than those of conventional protein sources including fish (18.0%), fowl (18.3%), cow (17.5%), pig (14.5%) and sheep (16.4%) [44]. Snail meat is low in fats and cholesterol [46, 47], and rich in vitamins especially vitamin B complex and C [25]. In addition, it is high in some minerals especially calcium, iron, potassium, magnesium, zinc, phosphorus, manganese and copper with low in sodium [25, 45, 47].

Meat and other products from GALS have been used for traditional African medicine for centuries. Owing to the nutritive properties of snail meat, it is generally believed that the consumption of snail meat can promote good health [47]. Hence, it is increasingly being used for the management of some chronic disease conditions such as asthma, stroke, diabetes mellitus, hypertension and other cardiovascular diseases [43, 45, 48]. Due to the high iron content of Achatinid snail, which ranged from 45-59mg/kg, it is used for the prevention and treatment of anaemia [25, 45, 49]. In addition, a snail meat is used to boost maternal health. Consumption of snail meat can reduce labour pain and promote delivery [49] and enhance the nutrition of lactating mothers [1, 45]. Tanyitiku, *et al.* [13], stated that the regular consumption of Achatinid snails can promote good health by boosting the immune system, which could prevent some chronic health conditions such as cardiovascular diseases, obesity, diabetes and some forms of cancers. It is also used for the treatment of whooping cough [45]. Some of these claims are beginning to be established scientifically. For instance, Tella [50] demonstrated the antihypertensive effect of the visceral fluid and tissue extract of the foot of *L. fulica*.

Other body parts of the Achatinid snail such as visceral fluid, mucus and shell have medicinal and biotechnological applications. For instance, the different body parts of Achatinid snail have been demonstrated to have wound healing properties including the milled shell [51], mucus [52, 53] and visceral fluid [45]. Listed several uses of the visceral fluid of Achatinid snails includingthe treatment of hypertension, anaemia, ulcer, asthma, kidney diseases, tuberculosis and constipation, reduction of haemorrhoid and improvement of eyesight and voice. Engmann, *et al.* [45] mentioned the application of snail visceral fluid in the stopping bleeding from cuts and healing amputated limbs, treatment of eye problems and rheumatism, and suppression of smallpox infection. Studies have demonstrated the antimicrobial properties of snail mucus [54]. Snail mucus has many potential biotechnological applications including for the manufacturing of adhesives, lubricants, drugs and cosmetics. Other bioactive substances with novel applications have been detected in Achatinid snails including Achatina cardioexcitatory peptide-1 [55], and Fulicin and fulyal [56] which have been demonstrated to have excitatory effect on the heart.

Snails are typically displayed for sale in open markets and along major highways (Figure 1) in many West African countries [24, 47, 57]. The snail value chain provides employment and means of livelihood for some rural women [57, 58]. Culturally, Achatinid snail are used as object of worship in Africa [49], Asia and among the Candomblé territories in Brazil [50, 59]. Owing to the importance of snail in the diet, health and traditions of Africans and the recent awareness about the health benefits of snails, there have been increasing demand for the snail, both locally and internationally. The snail has become a highly priced delicacy, which only rich people can afford [1]. The demand for the snail, among other factors have keep the snail population under control in the wild. Recent studies have shown that, the population of the snail is declining, hence the research focus especially in West Africa is on the domestication and cultivation of the snail [28].

5. Giant African Land Snail as Pest

Achatinid land snails including *L. fulica* are not considered as a pest in their area of nativity, but an asset [43]. Whereas outside their native range in the countries they have been introduced to, they seemed to have attained a pest status. The specific reasons for this behaviour are not fully understood, but it has been speculated that in their new habitats they lack their natural predators [40], they are not specific in their dietary requirements, hence they feed on broad range of plant species [10] and are not routinely consumed by humans [5]. Their high fecundity makes them to proliferate quickly to colonize new habitats. Their unique reproductive features include; being hermaphrodites (one individual is enough to start a new colony), can attain sexual maturity and lay eggs at 6-12 months, and can lay eggs multiple times up to 100 eggs/clutch cumulatively over 2500 eggs in one year after a single mating [4]. The snails are hardy, being able to tolerate adverse weather conditions [2, 20]. In recent times, the snails seem to have become adapted to disturbed ecosystems including farms, home gardens and peri-urban areas [10, 16]. It appears the ongoing climate change favour its invasiveness [9, 11, 27].

In the countries outside Africa, where the snails have been introduced to, they have been reported to devour diverse plant species including ornamental plants, medicinal plants and food crops [11]. They feed on over 500 different plant species [4, 27]. They seem to have preference for the succulent parts of plants such as tender shoots, leaves, flowers, fruits and buds [10, 11]. They have been reported to cause extensive damage in small farms, but not in large farms [5, 11]. The snail is known to be quite voracious consuming virtually all types of crops including tubers, fruit crop, vegetables, cereals and spices [11, 33]. Apart from agriculture, the snail is also a threat to wildlife biodiversity. These exotic snails have been reported to compete with native snails for food and habitats potentially leading to extinction of indigenous snail species [11, 27, 38]. They have been observed to attack other snails and slugs. Achatinid snails have been reported to pose significant economic and ecologic threat in places they have been introduced into [6, 7]. Apart from their direct damage to crops by their herbivorous feeding habits, the snail has been reported to act as vectors in the transmission of pathogens and parasites to plants and animals [10, 27]. *A fulica* have been reported to invade protected areas in several countries including the Amazon in Brazil [5], Paranense rainforest in Argentina [4] and elsewhere [10].

Apart from being adapted to disturbed ecosystems, *L. fulica* seem to be particularly attracted to suburban areas, where they forage untreated human wastes and municipal solid wastes [5, 18]. In urban areas they have been reported to feed on building materials as sources of calcium including stucco, plaster boards, paints [36]. As they forage the urban environment, they often leave behind trails of faeces and mucus along their paths on regular basis [5, 7]. Snails that crawls along the roads are often crushed by vehicles, potentially causing safety problems because of the mucus, which can cause vehicles to skid [5, 11] or the sharp edges of their shells can puncture vehicle tyres [36].

The ecology and feeding habits of land snails has made them to acquire guild of microbes that forms their microbiome [3, 23]. Snails are free-ranging, typically crawling in the soil, foraging on vegetation and organic wastes including manure, compost, untreated faeces and MSW, which have resulted in the ingestion, attachment and establishment of symbionts [25, 60, 61]. The population of microbes differs in the different anatomic sites of the snail, with the gut and foot/head having the highest population [25, 26, 61]. While most of these microbes have aided the snails in biodegradation of lignocellulosic material and nutrient recycling, others are human pathogens. Authors have detected diverse pathogens from Achatinid snails, some of which exhibited multidrug resistance including *E. coli*, *Aeromonas hydrophilia*, *Yersinia enterocolitica*, *Shigella*, *Salmonella*, *Vibrio*, *Pseudomonas*, *Micrococcus*, *Streptococcus*, *Staphylococcus*, *Proteus*, *Klebsiella*, *Listeria* etc [26, 62]. The presence of pathogens and parasites is one of the major challenges of consuming snail meat especially in the places introduced. But it should be noted that all living things have their unique microbiome including domesticated animals. Although, domesticated snails have been shown to harbour less pathogens, but no organism is free of microbes. Other snail species consumed in some Europeans including *Helix lucorum* and *Cornu aspersum* have been reported to contain pathogens, whose population are lower in domesticated than wild snails [63]. Cases of transmission of pathogens mostly occur when snails are either eaten raw or improperly processed/cooked [25, 26, 37].

The presence and/or association of Achatinid snails with the life cycle of different parasites is another major public health concern of the snails. This phenomenon is not however unique to Achatinid snail, but other molluscs including indigenous snail species in the United States and elsewhere [64]. Among the parasites that have been detected in Achatinid snail, the rat lungworm *Angiostrongylus cantonensis*, which causes eosinophilic meningoencephalitis, have been mostly reported [5, 11, 12, 27, 65]. Rat lung worm have also been detected in other snail species in Florida including *Bradybaena similaris* and *Zachrysia provisoria* [64]. Human cases of eosinophilic meningoencephalitis is uncommon. For instance, as one of the southern most states in the US, Florida is known for its humid subtropical climate, ideal for the proliferation of GALS. The state is highly populated with an estimated 140 million visitors in 2023 alone. Florida experiences sporadic emergence and re-emergence of GALS, which frequently leads to quarantine and warnings about its propensity to transmit rat lungworm disease. Interestingly, reports published in 2021 has shown that there has not been a single diagnosed human case in Florida [64]. However, in Brazil, human cases of eosinophilic meningitis were mostly reported among persons that consumed raw *L. fulica* [5, 65].

6. Control Measures

The control measures of Achatinid snails differs among countries based on their pest status. There are two general but opposite approaches i.e., as pest or non-pests. GALS are not regarded as pest in their native African range, where they are consumed as alternate source of proteins and especially used for the preparation of different types of soups. Increasing human demand for the snail has among other factors controlled the population of the snail in the wild. In many African countries, the population of the snails is declining in the wild, hence attention has now focused on their domestication and breeding. But countries beyond Africa, where the snails where introduced, they are regarded as pests, hence, their research focus is on the development of measures to eradicate the snails. But it has been observed that once the snail becomes established in a place, it can be complex, difficult, time consuming and expensive to control [4, 27]. Hence, once detected, recent approaches involve acting swiftly to eradicate the snail before they get established in the wild [27]. Different control measures have been tried in different countries with different levels of successes and challenges. Some countries such as Nepal have abandoned their control programs due to high cost. Resurgences have also been reported in some places where the snails have been eradicated [32]. The control measures of the pestiferous snail can be grouped into legislative, physical, chemical and biological or their combinations, since a single approach is seldom effective [5, 6, 27].

Legal instruments form the basis for the control of invasive species. Many countries where Achatinid snail were introduced,have now instituted legal frameworks for eradicating the snail such as laws, policies, national eradication programs and incentives [5]. For example, in 2005, Brazil enacted laws prohibiting the breeding and commercialization of *L. fulica*, served as the legal basis for the implementation of a national plan for the eradication of the snail [5]. Similarly, the US has regulations banning the importation of *L. fulica* without permits, including any materials that might potentially contain their eggs such as plants, soil, compost, building material or machinery [12]. The law gave legal support for the various control measures including quarantine, manual collection and physical destruction of snails and application of chemicals. But the case is different in Europe, where the European legislation which prohibit the breeding, marketing and releasing of invasive species did not consider *L. fulica* as an invasive alien species, hence, they are permitted in Europe [4].

Physical control measures involve trapping or handpicking of the snails and their eggs and destroying them by various means [4, 6, 9]. There are diverse methods for killing the snail including drowning [66], crushing with machineries or vehicles along the road [5], burial with or without chemical treatment [5]. Physical methods for the control of the snail have the advantage of not causing appreciable direct impact on non-target organisms. However, its efficiency can be limited especially if the snail has become established over a wide area [4]. Besides, being a hermaphrodite, a single missed snail or egg can potentially lead to the formation of a new colony.

Chemical controls are often considered when physical methods are unable to eradicate the snail or when their cost is high [4]. Several common chemicals have been used for the control of snails including wood ash, common salt, copper sulphate, calcium oxide, iron phosphate [38, 66, 67]. Different types of molluscicides have been used, of which the commonest is metaldehyde [66, 68]. Metaldehyde have been used for decades for the eradication of *L. fulica* with profound success in different countries including the US [5, 27]. However, the use of chemical agents for the control of snails has some environmental sustainability concerns. Chemicals can have effect on non-target organisms. For instance, chemicals such as common salt is not selective against *L. fulica*, it can also kill other organisms especially annelids. Metaldehyde have been reported to be toxic to humans [38], terrestrial mammals and birds [68] and many domestic animals including cattle, swine, goats, sheep, cats, horses and dogs [69, 70]. For instance, in Brazil, the indiscriminate application of metaldehyde caused the killing of some known natural predators of *L. fulica* such as skunks, bats, lizards, and rodents, which makes it more difficult to control the snail [5].

Various measures have been considered in different countries for the biological control of *L. fulica*, which have yielded various outcomes. Extracts from plant species that exhibited molluscicidal activities have been tried for the control of the snail including bulb powder of garlic (Allium sativum), water extract of chili pepper (Capsicum frutescens), oil expressed from Himalayan cedar (Cedrus deodara), the latex of Christ thorn (Euphorbia splendens) [38] and seeds of Thevetia peruviana Schumann [71]. Various attempts have been tried to use the juvenile snail as live feed for reared catfish or as alternative sources of protein and calcium in the formulation of feeds for domesticated animals especially pigs and poultry [66]. Other researchers have suggested the boosting of known natural enemies of the snail as a biological control agent, where available. However, biological control measures using *L. fulica* as feed could potentially transmit pathogens and reinforce their persistence in the wild.

Notwithstanding, the following predators of *A. flulica* have been suggested; rats, common mongoose, foxes, wild pigs, birds, monitor lizard, crustaceans and protozoans, millipedes and beetles, microbes, helminths and nematodes, and insects particularly ants and flies [66, 67, 72]. However, in few countries including USA (Hawaii) and India, some predatory snails and other organisms obtained locally and imported, where introduced to tackle *L. fulica* in the wild. Of which the following snails, which became established locally, were found to be most effective at controlling *L. fulica*; the oleacinid *Euglandina rosea* (rosy wolfsnail) from Florida, *Gonaxis quadrilateralis* and *G. kibweziensis* from Kenya, *Gullela wahIbergi* Krauss from South Africa and *Edentulina ovoidea* from Mayotte [40, 72]. The effectiveness of the predatory snails was marred by other challenges. Some of the predatory snails were only able to devour eggs, juveniles and medium-sized *L. fulica*, they attacked and caused the extinction of some native mollusc, and also exhibited other pestiferous tendencies [4, 72].

There is a growing awareness about invasivore approach for the control of problematic pests [73]. It is thought that the human consumption of pests can help to put their population under control. The www.invasivores.org has emerged as an advocacy group promoting awareness, research and development of recipes using invasive species as raw materials and networking with restaurants that advertise dishes prepared with invasive species. Meanwhile, the consumption of wild Achatinid snails have been an age-long practice in Africa, which has contributed to the decline in the population of the snail in the wild. In the countries where the snails have attained pest status, they could consider human consumption as alternative control measure, which have the added advantage of providing food, while saving on the costs and environmental challenges of other control measures. However, snails should not be consumed raw or partially cooked. The world should follow the techniques used by Africans for the preparation of land snail prior to consumption. It involved cleaning, removal of visceral mass and steaming before cooking in diverse ways such as boiling, frying, roasting or smoking [25, 60, 61]. It is believed that appropriate preparation and cooking can eliminated most of the pathogens and parasites in snail meat, making it safe for human consumption [19, 24, 63].

7. Conclusion

The GALS, including *A. marginata*, *A. Achatina* and *L. fulica* are the most popularly consumed in Africa from time immemorial. About 200 years ago, humans introduced *L. fulica* into other countries particularly in the tropics and neotropics, which has evolved to becoming a pest in these areas. Climate change and anthropogenic factors appears to have affected the snail differently. Being a scavenger, improper waste management has caused the snails to invade urban areas and becoming contaminated with human pathogens. While climate change seems to have contributed to the reduction of the snails in Africa, it appears to contribute to their expansion in other places. Habitat degradation and agriculture has contributed to the decline in Achatinid snails in Africa, but appears to increase its invasiveness elsewhere. Human consumption of the snail and the presence of its natural predators appears to have keep the population of the snail in Africa under control.

Scientific literature outside Africa, seems to regard all GALS as pests, instead of focusing only on *L. fulica* outside its native habitats. This difference in the way the snails are perceive also affected research priorities. While researchers in Africa are working on domesticating the snails in order to meet the shortfall from the wild, researchers outside the continent of Africa are working to control the snail. Several physical, chemical and biological methods have been developed and tried in the wild, with limited levels of successes accompanied by greater biodiversity and public health concerns. The introduction of *L. fulica* outside its native range and attempt to control them using other exotic and predatory snails appear ill-conceived and has led to biodiversity losses including causing the extinction of endemic snail species. Since most of the control methods have failed to eradicate *L. fulica* and the species among other GALS are a delicacy in Africa and certain tribes in Brazil, we proposed the invasivore control as an alternative approach for controlling the snails after proper processing and cooking. Hence, research efforts should instead focus on the breeding of clean snails in Africa devoid of human pathogens and parasites.

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We declare no conflict of interest

Authors’ Contributions

EIO conceived the study and wrote the first draft of the manuscript, PCA sourced for literature, OE reviewed the initial draft, while all authors reviewed and approved the final version.

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Figure-1. Achatinid snails displayed for sale along East-West Road, Mbiama, Rivers State, Nigeria