REVIEW ARTICLE

Crayfish production potential in Africa: A Review

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ABSTRACT

Globally, the consumption of crayfish as food and utilization as ornamental species is increasing rapidly in most countries implying that its farming is gaining significant importance in the aquaculture sector with a considerable interest in the production for commercial purpose. In order for this to happen, it is vital to understand the morphological and genetic characteristics of crayfish species which would assist in selection and propagation of the desirable species for specific breeding objectives. The objective of this review was to highlight the morphological and genetic characteristics, the growth and reproduction, feeding and nutrition, economic significance and challenges and opportunities in crayfish production. In order to review the crayfish potential production in Africa, we used published statistical data and information from literature and compared all the information obtained to the rest of the world. An analysis of the existing information indicated that during the early stages of post hatch, a high mortality rate can result due to poor nutrition which is linked with low survivability. The breed is another important factor that influence productivity and profitability of crayfish farming. Crayfish exhibit detectable differences in breeding patterns which is highly influenced by the climatic, health and nutritional environments. Other factors that impact the crayfish sector include climate change, poor water quality, deteriorating habitat, overfishing and diseases such as crayfish plaque. There are various options in the management and conservation strategies applicable to crayfish production and include reintroduction, restocking and habitat restoration. The importance of crayfish as a species cannot be overstated as it has contributed food and incomes to households. It is cheap to start and operate, scalable and climate friendly approach to enhancing food and nutrition security in poor households. This review paper is therefore an attempt to gather together information relating to crayfish production which can trigger interest in using the species as a source of nutrients and incomes mainly in Africa where it has not attracted much interest.

Key Words: Crayfish, genetic variation, growth, nutrition, Morphology

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1.0 Introduction

Crayfish is one of the largest freshwater crustacean species (Weya et al., 2017), with a significant contribution to global aquaculture. According to FAO (2012), crayfish contribute the highest aquaculture production among the crustacean species. Crayfish have been regarded as keystone species (Parkyn et al., 1997) that can be chosen to aid the sustenance of endangered freshwater ecosystems (Richman et al., 2015). Currently, crayfish are divided into 4 superfamilies, 5 families, 44 genera, and 653 species based on a study by Bracken-Grissom et al. (2014), and many of them are found in Australia and North America (Holdich 2002). However, the study by Crandall and Buhay (2008) concludes that there are 640 species of freshwater crayfish that are distributed naturally all over the world's continents except Antarctica and mainland Africa.

According to many research reports, nine crayfish species were introduced into Africa (Madzivanzira et al., 2020). These were the noble crayfish *Astacus astacus* (identified by Linnaeus 1758), smooth marron *Cherax cainii* (identified by Austin and Ryan 2002), yabby Cherax destructor (identified by Clark 1936), Australian redclaw crayfish *Cherax quadricarinatus* (identified by von Martens 1868), spiny cheek crayfish *Faxonius limosus* (identified by Rafinesque 1817), American signal crayfish *Pacifastacus leniusculus* (identified by Dana 1852), Louisiana red swamp crayfish *Procambarus clarkii* (identified by Girard 1852), marbled crayfish *Procambarus virginalis* (identified by Lyko 2017), and White River crayfish *Procambarus zonangulus* (identified by Hobbs and Hobbs 1990). It is noteworthy that the number of crayfish species is disputable, as many new species are discovered every year (Patoka et al., 2014).

In Africa, the enhancement of fisheries (Foster and Harper 2007) and aquaculture development (Lodge et al. 2012) were the factors that led to the introduction of most of the crayfish species. Worldwide, the economic importance of crayfish is being recognized, and thus many of the species are continuously being introduced (Madzivanzira et al., 2021). With their high rate of fecundity, crayfish are able to adapt and bear with a varying range of environmental conditions, thus enabling them to spread rapidly and establish themselves in new locations (Lodge et al. 2012).

2.0 Morphological and genetic methods used in characterization of crayfish species

Different organisms adapt to their environmental conditions in different ways, and this influences their morphology, resulting in differences in phenotypic and genotypic characteristics (Pakkasmaa 2001). Morphometric measurements, in conjunction with multivariate analysis, can be utilized to investigate the existing differences between single groups or populations of organisms (Palma and Andrade 2002). Despite the fact that the crayfish body is remarkably uniform, there are some relevant differences in the body structure. Some have morphological variations in the claws, especially in the female and male species (Reynolds et al., 2013). Generally, the crayfish length-weight relationship is the main tool used in characterizing them. Besides, the body parts have been used to compare and separate female and male crayfish populations from different water sources (Büyükçapar et al., 2006).

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Significant differences have been noted in body mass, length of the claw, and body length, as emphasized by sex dimorphism in different crayfish.

Research studies concerning the genetic characteristics of most crayfish species are scarce (Grosset et al., 2014; Miah et al., 2013). However, the adoption of molecular markers is set to enhance the identification and understanding of different crayfish species. Grosset et al. (2014) propose the use of genetic approaches to determine the origin of crayfish populations, ecological changes, evolutionary genetics, as well as vectors and invasive routes involved during the process of migration by crayfish populations. Genetic diversity is often regarded as an essential tool that can be used for the assessment of the biological qualities of an organism (Miah et al., 2013). Through studies on genetic diversity, we are able to know how organisms are able to survive in different types of environments over time.

In the identification of many species of crayfish, several molecular methods have been utilized. Such methods include the use of markers to determine the genetic variation among crayfish populations (Khoshkholgh and Nazari 2015). For instance, mitochondrial DNA (mtDNA) is used in the identification of species as a genetic marker since it has a distinct haplotype (Ha et al. 2017) and is maternally inherited. The microsatellites have also been used to determine variations in population structure and close relationships among individual species that result from migration rates (Selkoe and Toone 2006). With the development of high genomic technologies, single nucleotide polymorphisms (SNPs) have become the best technique in genotyping and large-scale mapping (Rafalski 2002). SNPs have been used in crustaceans, and therefore this technology can be used to identify genes that are responsible for important traits. In some species that lack whole genome sequencing, SNP markers can be identified by genes that are associated with vital traits (Jin et al., 2014). A very simple method that can be applied for genome-wide genotyping in crayfish is the 2b-RAD technique, which can provide information rapidly on a wide range of SNPs that exist across species genomes (Wang et al. 2012). These DNA-based methods have been used to generate accurate information that can aid in the identification, selection, and even breeding of crayfish and other crustacean organisms.

The association between length, weight, and meat yield has been assessed in freshwater crayfish (*Astacus leptodactylus*) by Büyükçapar et al. (2006). According to the study, a relationship existed between total length and total weight in female and male individuals. It was found that the female and male crayfish demonstrated significant differences in terms of total weight. However, the total length in both sexes was not significant. The total meat yield in the female and male groups was significantly different. In their study, Khoshkholgh and Nazari (2015) examined the population structure and genetic variation of narrow-clawed crayfish (*Astacus leptodactylus*) using the restriction fragment length polymorphism (RFLP) method in the analysis of mitochondrial DNA. The results of the study revealed that narrow-clawed crayfish form two genetically divergent populations. Ha et al. (2017) investigated the genetic diversity of kampung chickens (*Gallus gallus domesticus)* using mitochondrial DNA analysis in three different states in Malaysia and found that there was high genetic variation among the

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kampung chickens in the three states. The data from a study by Jin et al. (2014) demonstrated that utilizing 40 or more SNPs helped to correctly allocate 100% of Pacific oyster (*Crassostrea giga*) to their parents, while using 30 SNPs unambiguously allocated 17% of real offspring to their parents.

3.0 Growth and reproduction of crayfish

Crayfish exhibit intriguing growth patterns, transitioning from tiny larvae to fully developed adults through a series of molts and growth stages. Their growth rate and size vary among species and environmental conditions, making them a diverse and adaptable group of freshwater crustaceans (Munday et al., 2006). Further, their life span depends on the environment and type of species (Venarsky et al. 2012), with some living for years while others survive for decades. Crayfish usually have separate sexes (Martin et al., 2010). The sex ratio tends to be proportional; however, some species, such as the noble crayfish in Norway, have been found to have disproportionately more females with an increase in temperature (Skurdal et al., 2011). It is notable, however, that the high temperatures delay the attainment of maturity. Crayfish reproduce through the hatching of fertilized females, whose fecundity varies greatly, with some individuals producing as many as 4400 eggs per female (Seitz et al., 2005) and others laying a relatively low number of eggs, about 110 to 270 eggs (Reynolds, 2002). The species does not have a larval stage during development, which is dissimilar to marine decapods (Souty-Grosset et al., 2006). The young ones' growth specifically involves the shedding of the hard exoskeleton, like other members of the arthropods. In regions where the environmental conditions are moderate, the juvenile crayfish molt several times, which is followed by once or twice per year of molting as they become larger in size and as they grow older (Reynolds 2002). It is noteworthy that, after molting occurs, individual crayfish must locate a suitable habitat to conceal themselves until the exoskeleton is formed and hardened, which enhances their survival.

Generally, crayfish exhibit an annual breeding cycle, but in some species in Northern Europe, a biennial pattern has been recorded. During the breeding season, there is a significant increase in the size of the reproductive organs, especially in the females. Notably, the ovary enlarges and becomes yellow-brown in color as the vas deferens in males turn milky-white as a result of the production of sperm (Duriš et al. 2015). During the mating period, sexually mature crayfish seek out their partners, and it is characterized by high activity (Buˇriˇc et al. 2009). The behavior is controlled by hormones, which are environmentally mediated and characterized by changes in photoperiod and in water temperatures (Reynolds 2002). The female crayfish releases eggs from the oviduct as a result of stimulation by mating as well as changes in length of light and a reduction in water temperature (Skurdal and Taugbol 2002). Copulation and ovulation differ greatly in time, ranging from days to weeks (Vogt 2002). In some cases, and for some species, even several months. The eggs released by the females are fertilized by the spermatozoa, after which the eggs attach to the pleopods of the females for brooding (Niksirat et al., 2014b).

Crayfish regulate their body temperature by seeking water temperatures suitable for maintaining their life functions (Diaz et al., 2004). There are no ideal temperatures for the

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species, but changes in the temperature regimes can lead to a reduction or loss of their biodiversity (Heino et al., 2009). In freshwater crayfish aquaculture, temperatures of between 10°C and 25°C are required, although a reported temperature of 20°C is preferable, with dissolved oxygen levels of >5 mg/l and a pH of between 7 and 8.5 (Hollows, 2016).

4.0 Feeding and nutrition of crayfish

Generally, crayfish are omnivores, although many of the species are considered to be predatory (Freeman et al. 2010). The species characteristically eats whatever they can hunt, but since they are slow-moving, they are rarely able to harm most types of fish or shrimp (Asgari 2004). A variety of food sources, which include dead fish, macrophytes, algae, zoobenthos, and detritus, have been exploited by crayfish (Twardochleb et al. 2013), implying that they can occupy different trophic niche widths (Alcorlo et al. 2004). Literally, crayfish prefer foods like invertebrate pellets or blanched vegetables (such as zucchini, carrots, and spinach), but will also eat fish food and algae. The feeding strategy of the crayfish varies according to the season change and to the metabolic energy exploitation during the ontogenesis (Asgari 2004). The male and female crayfish have similar feeding habits in their first year, which later differ as a result of a shift in the alimentary system at sexual maturity (Goulding-Wagner 2010). An increase in length seems to be accompanied by a dietary shift, as evidenced by research findings (Goulding-Wagner 2010). Deductions from the findings indicate that animal tissue is a more important component in the diet of juveniles, which have a faster growth rate compared with adults. Moreover, a change in dietary habits may be related to the life cycle. It has also been shown that type and amount of diet are dependent on individual crayfish levels of activity. Research literature indicates that many crayfish species become detritivoes with maturity (Paglianti and Gherardi 2004); however, they still feed on aquatic invertebrates (Hollows et al. 2002). The white-clawed crayfish (*A. pallipes*), which is a wild species, is an omnivore that feeds predominantly on detritus, other invertebrates, and vegetable matter (Gherardi et al., 2004), while the signal crayfish is a grazer or hunter that sometimes exerts disruptive pressure on the ecological flora and fauna (Maitland et al., 2001) as a result of its predatory nature. It occasionally feeds on fish eggs, aquatic invertebrates, and vegetation and competes with fish for food. In scenarios where food sources are limited, crayfish are known to explore new food sources (Herrmann et al., 2018; Alcorlo et al., 2004).

In the commercial rearing of crayfish, a major concern is the provision of a nutritional diet that is well balanced to ensure the growth, development, and survival of the juveniles. The dietary nutrient requirements of different crayfish species vary in terms of production system (Sales 2010) and stage of growth and development (Ruokonen et al. 2012). After hatching, the juvenile crayfish feed on the egg yolk, after which they remain on the female pleopods and undergo ecdysis for the hardening of the exoskeleton and the development of mouth parts that are required for them to start feeding (Reynolds 2002). During the early stages of post-harvest, a high mortality rate can result due to poor nutrition, thus limiting their survival (González et al., 2011). The juvenile and adult female crayfish diets could come from insect larvae, while the male diets could specifically be made from vegetable matter, as supported by the findings of the study by Paglianti and Gherardi (2004). The dietary preferences of crayfish change

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depending on the available food sources (Ruokonen et al., 2012). Suitable diets for captive-bred crayfish species have been decided and developed based on the study findings on feed choices and feeding habits of wild-type crayfish.

Research findings indicate that zooplankton diets can be offered to crayfish in place of commercial feeds, which are mostly expensive and unavailable. Sonsupharp and Dahms (2017) demonstrated this by using zooplankton-based diets in rearing *P. clarkia* crayfish species. They realized significantly greater specific growth rate and fecundity in individuals fed on the experimental diets. Artemia spp. has also been used to feed crayfish. Research by González et al. (2008) on the use of enriched live *Artemia nauplii* in feeding crayfish resulted in an increase in survival rates of 80% in *P. leniusculus* crayfish species. In order to maintain the high growth and survival of species of crayfish like *A. pallipes*, it is important to provide them with an enriched live diet between hatching and maturity, at which point the proteolytic enzymes will have developed. Enriched planktons' diets have high nutritional quality and are highly palatable, thus ensuring the growth and survival of the young ones (Scalici and Gibertini 2007).

In commercial systems, it is important to consider that pellets do not provide an adequate diet, as some species tend to feed on plankton compared to commercial feeds. It is therefore proven that, at all age classes of different crayfish species, zooplankton are essential components of their diets (Stenroth et al., 2006; Sonsupharp and Dahms, 2017). In a study examining the feeding ecology of *P. clarkii* in Uasin Gishu, Kenya, it was found that significant ontogenetic variation in diet was demonstrated by *P. clerkii* (Wato and Oyoo-Okoth, 2014). Habashy et al. (2011) evaluated the feeding behavior of exotic freshwater crayfish, *P. clarkia*, in Egypt and observed that *P. clarkii* preferred a wide range of plant and animal food at each stage of its lifecycle. In general, feed requirements for freshwater crayfish have been reported to include a protein content of between 25 and 30% and a lipid content of about 10% (Xu et al., 2013). Table 1 summarizes the nutritional requirements for crayfish.

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Table 1. Optimum dietary nutritional requirement of freshwater crayfish and its comparison with NRC (2011) standards for penaeid shrimps (usually adopted as status quo).

Parameter	Crayfish standard (calculated)	NRC standards for penaeid shrimps
Crude macronutrient and energy[1]		
Crude protein	29–34% (44%)*	33–42%**
Crude lipid	6.5–9%	5–6%
Crude NFE (nitrogen-free extract)	40–47%	–
Dietary fiber	Up to 7%	–
Total ash	7.8–10.8%	–
Gross energy	3590–4205 kcal kg^{-1}	3666–4888 kcal kg^{-1}**
Protein: Energy	72–91 mg $kcal^{-1}$ (113–119 mg $kcal^{-1}$)*	85–90 mg $kcal^{-1}$
Non-protein energy: Protein ratio	5.3–8.5 cal mg−1 (4.4–4.8 cal mg−1)*	–
Digestible essential amino acids[2] (%)		
Leucine	1.8–2.5	1.8
Valine	1.2–1.6	1.4
Treonine	0.3–1.5	1.3
Isoleucine	1.2–1.7	1.2
Arginine	2.1–2.7	1.8
Phenylalanine	0.8–1.5	1.4
Lysine	1.2–2.4	1.8
Methionine	1.1–4.9	0.7
Histidine	0.6–0.9	0.7
Tryptophan	0.4	_
Available essential minerals[3] (mg kg^{-1})		
Calcium	3000–4000	_
Phosphorus	164–235	3000–7000
Iron	27–125	_
Zinc	10–14	15
Copper	6–9	10–32
Manganese	14.2–17.8	_

* In parentheses, a proposed reconsideration of calculated standards is based on the high TGC obtained in the present trial. **Digestible values converted to crude values, assuming 90% apparent digestibility. (Adapted from Lunda et al., 2020). Based on [1]*Cherax sp*. and *Procambarus sp*., [2] *P. clarkii* only, and [3]*Astacus sp*., *Ornectes sp*., and *Procambarus sp*.

5.0 Economic value of crayfish

Crayfish have predominantly been used by humans as a source of nutrients and income (Skurdal and Taugbøl 2002; Souty-Grosset et al. 2006), as well as as a as a source of nutrients for other aquatic and terrestrial animals. They were originally harvested from the wild, but progress has been made in producing them through systems manipulated by humans for higher productivity and profitability (Thies et al., 2003). A study by Tricarico et al. (2008) revealed that when *P. clarkia* species of crayfish is housed and fed *ad libitum*, the nutritional composition of its abdominal muscle is of high quality. Furthermore, the amount of proteins in the muscles of crayfish is higher (13.24%) on a dry matter (DM) basis, with lower levels of lipids (<0.8% DM) and long chains of fatty acids (Buckup et al. 2008), which are preferred by consumers as they

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are essential in preventing some cardiovascular conditions (Thies et al. 2003). The importance of crayfish has also been noted in aquaculture production (Skurdal and Taugbøl 2002). The production ranges from large-scale systems where large volumes of crayfish are harvested from a single unit to small-scale enterprises, which are primarily characterized by little technological investment (Skurdal and Taugbøl 2002), productivity, and profitability.

There is insufficient production of crayfish in Africa for food, despite the development of farming techniques for species like *P. clarkii* (Huner 2002). There are few documented cases of significant crayfish production in Africa since the 1960s, which has led to reliance on importations (Gherardi 2007). This is despite the increasing population, urbanization, and household incomes on the continent, with a corresponding increase in demand for animal protein. A good way to stimulate the sector is to assemble the existing information on sustainable and profitable production and utilization of crayfish for households' consumption and sale. There is also a great opportunity to produce crayfish for use in feeding other animals with higher-value products.

Extensive and semi-intensive systems are commonly used in crayfish production. There is near-zero feed input in the former, while intensive systems are characterized by input/output resource optimization, as is the case with the use of raceways or recirculating systems (Jiang and Cao 2021). It is technically easier to culture crayfish when compared with other crustaceans (Huner, 2002). Jiang and Cao (2021) noted that, in some countries like China, crayfish is farmed together with crops such as rice. Crayfish aquaculture has also been integrated with other agricultural crops in rotation.

In some countries, particularly North America, some species of crayfish are valued for recreational activities such as sport crayfishing, where they act as bait for sport fish like bass (Guias 2002). Furthermore, some have been used in aquaria for beautification and household pets (Patoka et al., 2014). The red swamp crayfish, which originated in North America, is the most common species that has been introduced and is well established all over Africa, Asia, South America, and Europe (Loureiro et al., 2015). Many crayfish species, such as marbled crayfish, have ended up in Europe as a result of the trade in ornamental crayfish (Peay 2009). Another major economic contribution of crayfish is in science (Vogt 2008). Crayfish have been used as a model organism in cancer research. Moreover, their neurons have been explored in cancer treatment (Fedorenko and Uzdensky 2008). Currently, crayfish is also used in aquatic farming, where it controls the growth of harmful macrophytes (Guias 2002) as well as the treatment of various diseases (Swahn 2004).

6.0 Threats and opportunities in crayfish farming

According to Taylor (2001), most of the crayfish species in the world face the threat of decline in population and extinction. In most cases, the species that are introduced as bait or for food (non-indigenous) are a big threat to the survival of crayfish and their biodiversity (Lodge et al., 2000; Gherardi, 2006; Taylor et al., 2007). For instance, the displacement of the indigenous species by the non-indigenous species of crayfish in North America has been flagged as a threat

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due to direct competition with the native species (Taylor 2001). Besides the resource competition, crayfish plaque has been identified as a potential threat to the crayfish populations, more so in Europe. Other factors that pose a threat to the maintenance and/or expansion of the crayfish population globally include changes in climate, poor water quality, deteriorating habitat, overfishing, and diseases. Habitat fragmentation, as evidenced in many freshwater catchment areas, has contributed to declining water quality, which adversely affects the inhabitation of crayfish (Bentley et al. 2010). Füreder et al. (2006) link the decline in the crayfish population to the silt deposition in streams as a result of human activities such as damming and unsustainable agricultural practices. Gherardi (2006) further notes that the introduction of non-indigenous crayfish stocks to ecosystems should be considered carefully as it can lead to unhealthy competition with the indigenous species. .

According to Reynolds and Souty-Grosset (2011), toxic materials used in supporting different human activities such as farming, mining, and construction, among others, pose a serious threat to crayfish populations. Many organic and inorganic materials accumulating within the aquatic ecosystem result in changes in the biological, chemical, and physical environment in which crayfish live, directly affecting the cellular functioning of the crayfish and leading to mortalities (Füreder et al. 2006). Heavy metals have been found to interfere with the survival of freshwater crayfish (Gherardi et al., 2002). Heavy metals have been detected in samples obtained from the *P. clarkia* species. Climate change effects are adverse to the growth of crayfish. . Although some species are adapted to change to their preferred location, most of the species are still susceptible to deteriorating environmental conditions (Woodward et al., 2010). Climatic changes induce stress on the indigenous species, affecting them negatively, most often favoring the expansion of the non-indigenous crayfish species. . Fires and droughts have been identified as posing a significant threat to crayfish survival in an ecosystem (Fureder et al., 2006). Predation and poor crayfish production management practices have not been noted to greatly affect crayfish populations. . These are positive attributes since they imply that, with the high fecundity, crayfish populations are able to regain their numbers within short periods of time. . Furthermore, species that require very high levels of management tend to be expensive to start and run (Woodward et al., 2010). Currently, many farmers in Kenya are trying to diversify their farming activities in order to satisfy the expanding demand for food and household incomes. . Crayfish farming portends a diversification strategy (Harper and Mavuti, 2004), noting the ease of starting and sustaining small-scale crayfish cultures. .

7.0 Status of crayfish farming in Kenya

Naturally, freshwater crayfish species are not found in mainland Africa (Crandall and Buhay 2008), as most of the ecosystem in this region is inhabited by crabs representing the decapods (Wood et al. 2019), which pose competition with the crayfish. In Kenya, crayfish were introduced with the intent of improving commercial fisheries that were situated in freshwater lakes and dams. The *P. clarkii* species was the first to be introduced in Kenya, and it was sourced from Uganda Fisheries Department Ponds located at Kanjansi, Entebbe, in 1966 by the Kenya Fisheries Department (Lowrey and Mendes 1977; Mikkola 1996). Further research findings by Hofkin et al. (1991) show that the species were also introduced to act as a biological control

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agent for schistosomiasis gastropod vectors. Figure 1 presents the *P. clarkii* crayfish species introduction route from North America to Africa as well as the introduction pathways within the continent.

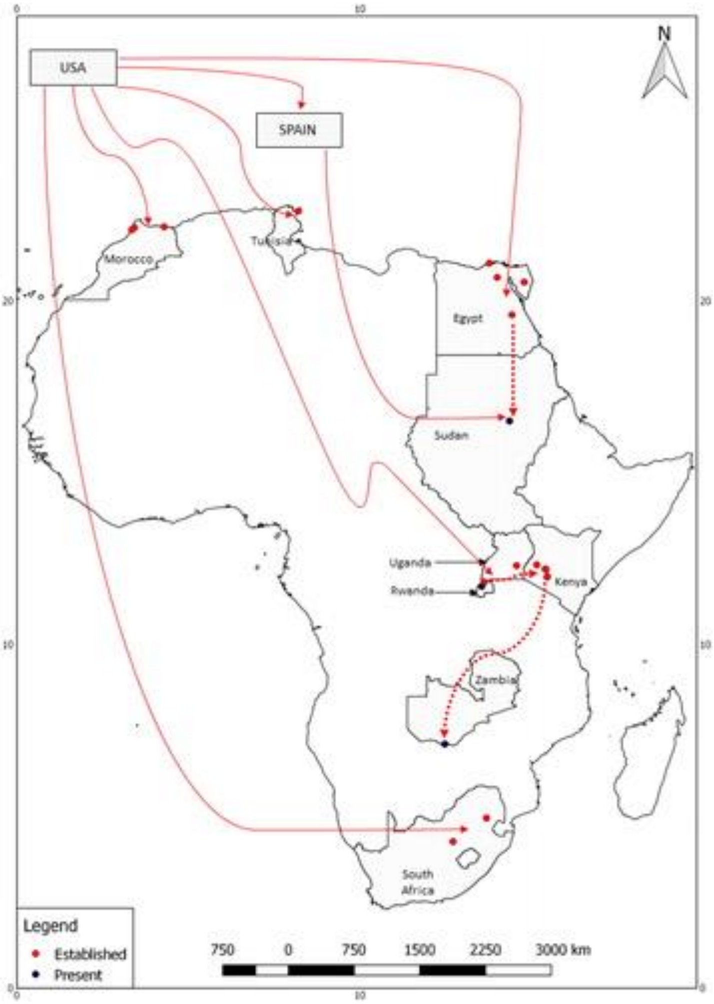

FIGURE 1. Introduction route of *Procambarus clarkii* from North America to Africa and introduction locations within the continent. Dashed red lines show translocations within the African continent, while the continuous red line shows introductions from outside the continent.

Currently, the species is widely spread in many wetland areas of Kenya (Mikkola, 1996). For instance, in the river systems of Eldoret town, there are many *P. clarkia* crayfish, which have also been recorded (Foster and Harper 2007). Close to 300 species of *P. clarkii* crayfish have been introduced into dams and Lake Naivasha for the sole reason of providing food for the largemouth bass (Foster and Harper 2007). *P. clarkii* has been found to be widely distributed in Lake Naivasha and its tributaries (Jackson et al., 2016). When *Procambarus clarkia* is introduced into any habitat, it tends to constitute the largest invertebrate, which impacts the biodiversity of the invaded food webs (Gherardi 2006). Fishing in Lake Naivasha relies heavily on crayfish since it significantly contributes to the diets of most fish, mammals, and birds (Smart et al.,

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2002). The composition of the community and food web around the area has been altered drastically (Ogada et al., 2009). It is noteworthy that *P. clarkia* has affected and changed primary production in the ecosystem, thus impacting food and shelter availability for other aquatic species. Some crayfish species, such as *P. clarkia* and *P. virginalis*, are invasive, and in some countries, their importation, transportation, and use have been restricted as they are known to have negative impacts on native species (EU 2016). The restrictions put in place in Europe and other continents vary greatly, and this may inhibit the introduction and control of native species (Souty-Grosset et al., 2016). Crayfish has been used in aquatic farming to control the growth of harmful macrophytes (Holdich, 2002); therefore, it can be introduced in aquaculture systems in Kenya to control harmful aquatic plants. In addition, crayfish has the potential to be applied in aquariums in Kenya as well as being used as household pets.

The crayfish species, like many other organisms, are faced with many threats (Reynolds et al., 2013). Despite being predominantly freshwater invertebrates, they are subjected to the risk of predation, unsustainable completion of resources with other species, overharvesting by humans, and exposure to activities that negatively impact their production and reproduction, among other factors (Freeman et al. 2010). During harsh climatic conditions such as drought, a lot of the crayfish species are able to survive through burrowing (Reynolds et al., 2013). Despite the highlighted threats, understanding factors' affecting their production and reproduction is vital for their conservation and protection. In addition, the knowledge generated will help in exploring available opportunities for crayfish farmers.

8.0 Conclusion

Findings from the analysis of existing literature information on crayfish indicates that the species is abundant and is distributed worldwide. Different regions have crayfish that is native while in others it has being introduced to perform different functions. In Kenya, the crayfish was mainly introduced for the purposes of diversifying aquaculture production as well as a biological control for human diseases vectors in water systems. The analysis further shows that many of the crayfish species feed on aquatic vegetation while others predate on other invertebrates. It is clear from the review that knowledge on growth conditions, nutritional requirements, morphological and genetic characterization is limited to some species and it is almost non-existent in the African continent despite the potential crayfish production has in provision of nutrients to humans and animals as well as income to households. It is recommendable that more research be oriented towards sustainable production of crayfish.

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9.1 Funding

None

9.2 Ethical Cosiderations

This is a review of existing literature implying minimal ethical concerns.

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9.3 Conflict of interest

None.

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