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The effect of accidentally introduced red swamp crayfish *(Procambarus clarkii)* in Kafue fishery

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Abstract

A study using semi-structured questionnaires, interviews and focus group discussion, was conducted to assess the effect of accidentally introduced red swamp crayfish (*Procambarus clarkii*) in Stratum IV (Namwala district) of the Kafue fishery. The study revealed that gillnets of 2 inches (50mm) and above were more effective in capturing *P. clarkii*. It was also clear that fishers faced greater challenges due to the emergency of crayfish as part of their by-catch since most of them did not consider crustaceans as food and hence, either returned them into the water or threw them away. In addition, fishers faced the problems of net tearing as they removed the crayfish from the nets as the organisms got caught through entangling. The crayfish posed problems of predating on caught fish, thus lowering the quality of the saleable fish. The crayfish had sharp chelates that caused undesirable biting effect, which resulted into injuries to fishers in their effort to remove the organism from the nets. It was also observed that the increase in crayfish was only noticed in the last 5-10 years. However, the numbers of the crayfish caught showed strong seasonal variation, with the hot season recording the highest numbers of crayfish per finfish with cold season recording the least and the rainy season having intermediate catches. The quantity of crayfish caught in gillnets, were also depth dependent, with the bottom setting being the most effective, the mid setting coming after that and top setting being the least. In a similar manner, nets set close to the shoreline realized increased levels of crayfish by-catches. Fishers also attributed low levels of finfish and crabs catches to the emergence of the crayfish.

Keywords

Effect, *Procambarus Clarkii* (Red Swamp Crayfish), Accidentally, Kafue Fishery

1. Introduction

The earliest known attempts to introduce fish and crustaceans in Zambian natural and man-made water systems were made in the 1940s, which coincided with the dawn to culturing aquatic organisms in ponds at Chilanga fish farm (FAO, 2004; FAO, 2011). Many attempts were made to introduce foreign organisms in water bodies where those organisms were not indigenous; not all species that were introduced survived and proliferated, probably because of climate differences especially for organisms that were brought in from cool temperate regions (FAO, 2011). Although some of these introductions were accidental through organism transfer from the aquaculture facilities and fish farms, most of them were intentional and targeted towards the achievement of certain objectives, at least in the short term (FAO, 2004).

Some of those species that managed to survive and multiply elsewhere, have brought about uncertainties to the future of these water resources, at least in the long term (Ogutu-Ohwayo, 2011). For example, the introduction of *Lates niloticus*, *Tilapia zilli* and others species in 1950s in Lake Victoria and Kyoga achieved their short term objectives but their long term effects were not properly understood until later (Ogutu-Ohwayo, 2011).

On the other hand, one of the successful stories of introductions, economically, was the introduction of *Limnothrissa miodon* in Lake Kariba where the species has now become commercially important and seems to be filling up the ecological niche that was left as a result of over-exploitation of the large-sized Tilapia species (FAO, 2011). *Limnothrissa miodon* (Kapenta) from Lake Tanganyika was again deliberately introduced into Itezhi-tezhi in 1992 with the aim of boosting fish stocks in that dam (FAO, 2007).

In addition to finfishes, crustaceans were also some of the exotic aquatic organisms that were introduced into Zambian water bodies (Crandall, 2010). The Kafue River, one of Zambia's major fisheries, has reported a number of accidental and deliberate introductions (FAO, 2006). These range from the aquatic plant, *Eichhornia crassipes* or the Kafue weed (Sikazwe, 2004), through *Oreochromis niloticus*, to the crustacean, *Procambarus clarkii* or the red swamp crayfish. All of the three major introductions, the Kafue weed, *O. niloticus* and *P. clarkii* are considered to be invasive species in areas where they exist and could negatively affect the biodiversity of these ecological zones (Ochieng', 2012).

P. clarkii is believed to have originated from Louisiana in the USA and brought into the country in the 1980s from Zimbabwe and Lake Naivasha (Kenya) to Grubb's Farm near Livingstone and was later transported from Livingstone to some fish ponds near Kitwe, where they escaped after a flood (FAO, 2004; FAO, 2006). Although it is considered to be an agricultural pest outside its home range, in Africa, it has established itself in Kenya, Zimbabwe and now in Zambia particularly in the Zambezi and Kafue River systems where living conditions seemed favorable, and *P. clarkii,* has been reported to have made considerable part of the catches in Kafue fishery in the past few years (FAO, 2004).

The Kafue River, in which *P. clarkii* was introduced, is a multispecies and multi-gear fishery. It is a winding river which is about 1,000 km long from its source on the Copperbelt to the confluence with Zambezi (Heck, 2008). The river is a major tributary of the Zambezi and is found entirely in Zambia. It is a source of portable water for about 40% of the Zambian population and is the major source of water for the capital city, Lusaka (Chabwela and Mumba, 1998).

The Kafue River hosts three of Zambia's major fisheries namely Lukanga, Kafue and Itezhi-tezhi with a combined production of at least 10, 000 metric tons of finfish (DoF, 2010). The bulk of this comes from the 55 indigenous species and the rest from the exotic *O. niloticus.* Apart from being a home to varied species of fish, the Kafue River was also host to quite a good number of wildlife such as water birds, game life and various species of vegetation (Mundy, 2000).

Despite having identified the presence of *P. clarkii* in the Kafue River, (Scudder and Conelly, 2011), its quantification required to be done in order to design a proper policy direction for the management of the fishery. The aim of the study was to assess the effect of the accidentally introduced red swamp crayfish (*Procambarus clarkii*) on Kafue fishery and the fishing operation challenges faced by fishers as a result of the emergence of the crustacean as a by-catch.

2. Materials and Methods

The study was conducted in Stratum IV of the Kafue fishery, which extends from Itezhi-tezhi dam to Banamwaze in Namwala district (Fig. 1). According to 2006 Frame Survey report, there were 31 fishing villages and 264 fishers in stratum IV. Namwala covers an area of approximately 10,000 square kilometers; the rural district has an estimated population of 91,000 people and lies on the southern bank of the Kafue River (Iconet.com and Mukamukuwa Enterprises, 2013).

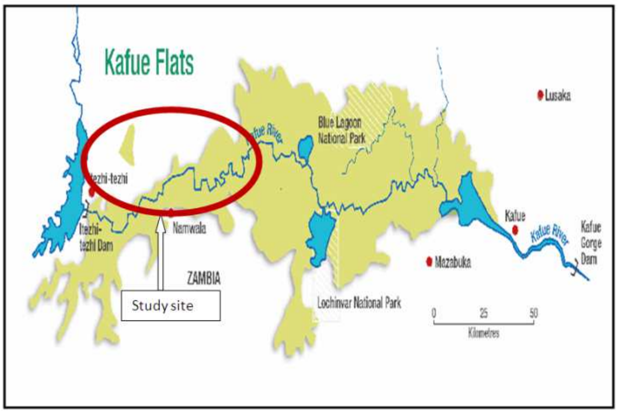

Figure 1. Position of Stratum IV on the Kafue River: Adapted from Expert Africa.

Two sampling techniques were used: stratified and simple random methods. Forty-three (44) fishing camps and villages or Primary Sampling Units (PSUs) were stratified into four minor (4) strata, each with 11 PSUs. A total of 6 PSUs were sampled using simple random sampling method, giving an average of 2 PSUs per single minor strata. Varying number of fishers depending on the sizes of the camps were sampled as respondents with the biggest PSUs being allocated with a largest proportion of respondents. The camp allocation in each stratum was based on their geographical location.

Questionnaires were administered in fishing camps and data was obtained on the perceived fishing operation challenges and any other social effects that could have arisen due to the availability of the crustacean as by catch. The study assessed the contents of what was hauled in each net setting in order to also determine possible operational, social and economic challenges that arose from the presence of those organisms as part of their catches.

A total of thirty one (31) respondents were interviewed from randomly selected six (6) fishing camps and two (2) fishing villages (Table 1), which were enough to give valid data for most statistical analysis as recommended by Kress (1992).

Table 1. *Distribution of respondents according to location.*

	Name of Camp/Village	Settlement status	No. of Respondents
1.	Kakuzu East	Fishing camp	6
2.	Kakuzu West	Fishing camp	5
3.	Munda Wanga	Fishing camp	4
4	Baanga	Fishing village	5
5.	Chizolelwa	Fishing camp	2
6.	Misamu	Fishing camp	1
7.	Shimwandu	Fishing camp	3
8.	Kalundu	Fishing village	5
	Total		31

In order to avoid biasness, catch samples were obtained from areas close to the shores (coastal) and from approximately 300m-400m deep into the river (which was the middle of the river). Since *P. clarkii* was a nocturnal organism that largely feeds at night (Fanjul-Moles, et al., 2004), samples were also taken from all the three net settings (i.e. top setting (0-20m from above the water surface), mid-setting (21-40m from the top of the water) and bottom setting (more than 41m deep).

According to Kolding and Bergestard (2001), all the gears that have so far been designed showed levels of selectivity towards the sizes and species in multispecies water bodies. And since the gill net was largely dependent on entangling to catch the organisms and not gilling, its hanging ratio in all settings was considered and reduced to slightly less than 0.5 in order to enable it became less selective towards sizes (King, 1995).

Two variables were measured:

- No. of *P. clarkii* caught in each overnight gillnet haul in relation to other fish species.
- Qualitative perception of the immediate economical and fishing operational impacts resulting from the emergence of the crustaceans in the fishery.

Statistical package for social sciences (SPSS), version 16.0, was used to analyze the data.

3. Results and Discussion

3.1. Results

Figure 2 shows varying durations respondents had been fishing, which ranged from less than 5 years to as long as 35 years.

The duration of fishing by an individual determined to a large extent the quality of answers given during interviews. Those who had been fishing for a longer period were more knowledgeable and very much aware of many changes to the catch composition in their fishing operations, making their responses valid as long as they did not mention any period outside that.

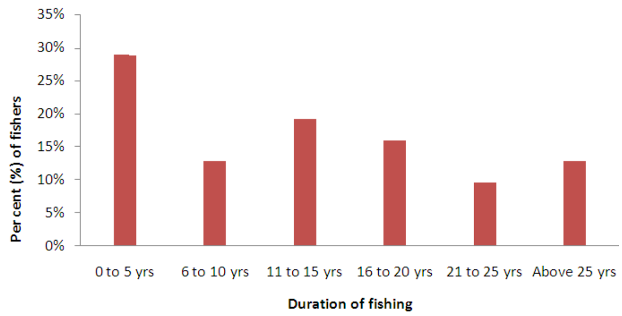

Figure 2. *Years spent in fishing.*

Results on the years spent on fishing, revealed that twenty-nine per cent (29%) had spent only between 0 and 5 years, 19.4% had fished from 11 to15 years, 16.1% from 16 to 20 years, while 12.9% had spent between 6 and 10 years as well as 21 to 25 years in fishing respectively. The lowest number (9.7%) of fishers was in the category of those who had been fishing for more than 25 years.

Most of the fishers indicated that they had seen an increase of more than 50% in the numbers of the crustacean caught in their fishing operation, more especially in the last five (5) years. And for the period above 10 years no fishers indicated that there was any change in the population of those organisms as reflected in the by-catch. Based on the results, at least 61.3% of respondents indicated that the increase was seen between 0 and 4 years ago while 38.7% pointed out that the increases were only seen in the period between 5 and 10 years ago. They further pointed out that the organism formed the largest part of the catch, in their overnight gill net setting (Fig. 3).

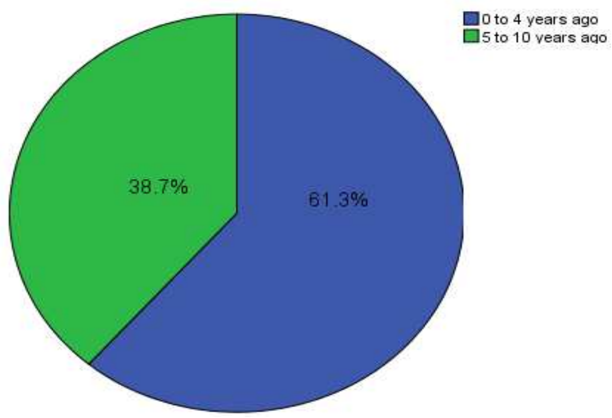

Figure 3. *Increase in crayfish over the years.*

However, it was observed that during the cold season when temperatures were low, catches of crayfish were reduced. Over ninety percent (93%) of fishers indicated that seasonal variation in the number of crayfish caught in the gillnets occurred, 3% of the fishers, however, disagreed that there was any link between season and the number of crayfish caught and another 4 % was not sure if changes in season influenced the crayfish catches (Fig. 4).

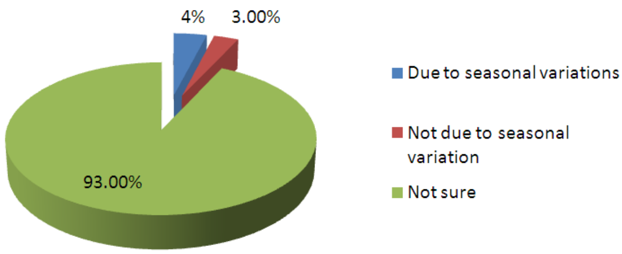

Figure 4. *Effect of seasonal changes on crayfish catches.*

Figure 5 shows seasonal catches of crayfish as indicated by the respondents.

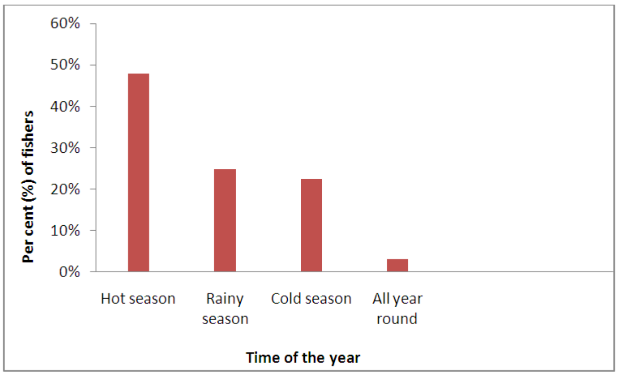

Figure 5. *Variation in crayfish catches with seasons.*

According to results obtained from this study, 48.4% of the crayfish was caught in larger amounts during the hot season (between August and December), 25.8% during the rainy and 22.6% in the cold season, with 3.2% of the fishers having responded that the crayfish was caught in the highest amounts throughout the year (Fig. 5).

It was also noticed that 29% of fishers faced challenges of net damage by the crayfish, while the majority (61.3%), had added problems of having their catch disfigured by the crayfish as they tried to prey on them (Fig. 6). Another 9.7% indicated the undesirable biting effect of the crustaceans as fishers tried to remove them from the nets.

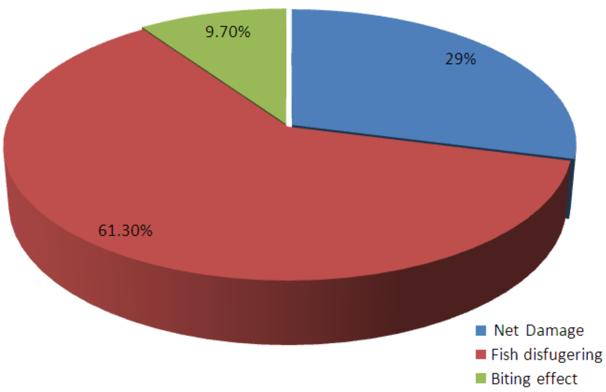

Figure 6. *Challenges caused by crayfish.*

While the fishers had a clear knowledge of the existence of the crayfish in the Kafue River, they shared different views on where exactly the crayfish originated from. Most fishers (74.2%), expressed ignorance of the origin of crayfish; 19.4% attributed the origin of the crayfish to other regions within the country and felt its coming to stratum IV was through the normal water movements. On the other hand, 6.4% implied that the crayfish was brought in by Department of Fisheries (DoF), a government agency (Fig. 7). However, according to FAO (2004), these crustaceans were introduced without the knowledge and the permission of the Department of Fisheries.

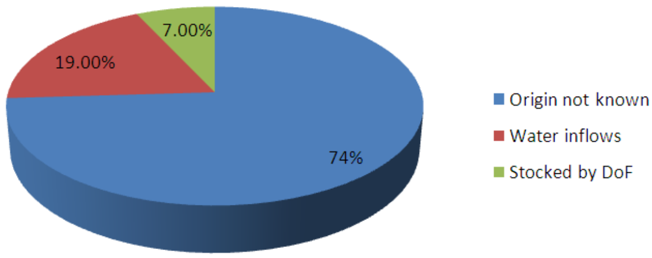

Figure 7. *Perceived origin of crayfish.*

A number of reasons were given related to the flourishing of the Red swamp crayfish in the Kafue River. Twenty nine per cent (29%) of the respondents attributed the increase to food availability, 54.8%, due to lack of strong competition from other organisms and 16.1% was attributed to its high rate of reproduction (Fig. 8).

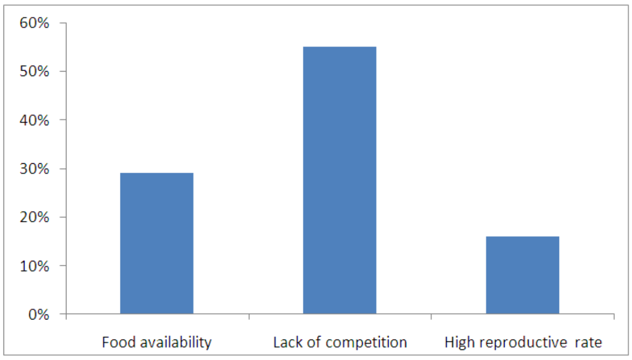

Figure 8. *Ecological conditions that promoted crayfishhh increase in Kafue fishery.*

Regarding a reduction in the population of other organisms, 48% of respondents indicated that they had seen a reduction in the population of finfish especially the tilapia species due to the perceived proliferation of the crayfish, 32.3% showed that crabs were the organisms that had shown a decline in populations and 6% indicated that it was both the finfish and crabs populations that had shown a decline in population, while 14% seemed not to be sure if there was a decrease or not (Fig. 9).

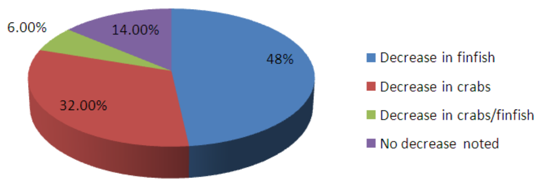

Figure 9. *Reduction in population of other organisms as a result of crayfish emergence.*

Most of the fishers used nets of various mesh sizes, ranging from 13mm (1 inch) all the way up to 102mm (4.5 inches). However, 59% of the crayfish was caught in gillnets of mesh sizes of between 63mm (2.5 inches) and 102mm (4.5 inches), 34% in gillnets of 37 and 50mm mesh sizes and 7% in 13 and 25mm mesh size net (Fig. 10).

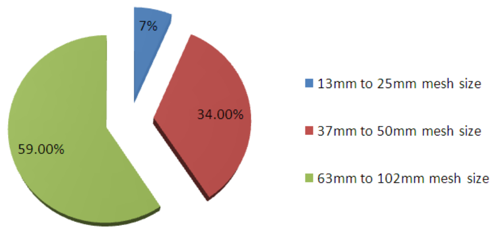

Figure 10. *Effectiveness of gill nets of varying mesh sizes towards crayfish catchability.*

According to the results obtained, there was a very strong correlation between the number of crayfish caught and the depth. About 51.6% of respondents indicated that the bottom set gillnet was the most effective type of setting to catch the crayfish, followed by the mid setting with 25.8%, while the top setting registered 12.9% and 9.7% for those who showed that all the three settings were effective in catching the crayfish (Fig. 11).

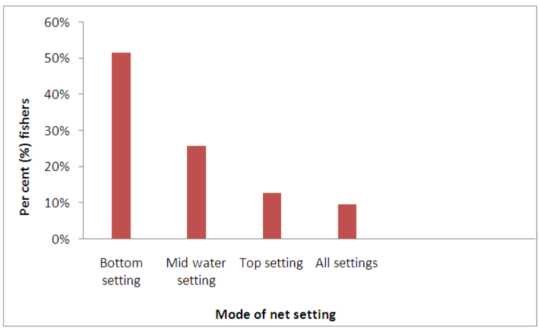

Figure 11. *Variation of crayfish catches according to gear depth setting.*

There were also variations in catches of the red swamp crayfish according to the distance from the shoreline, with 80.6% of the respondents having indicated that they caught most crayfish close to the shoreline, 12.9% showed that most of the crayfish was caught offshore, while 6.5% of the respondents mentioned that the crayfish could be caught anywhere else in the river (Fig. 12).

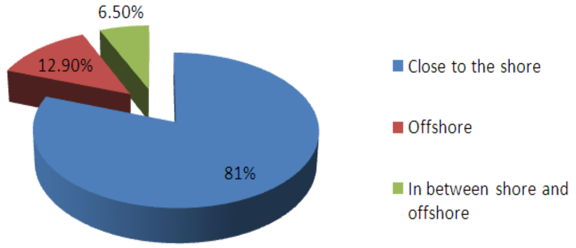

Figure 12. *Perceived catches of crayfish based on distance from the shore.*

3.2. Discussion

The study has revealed that there was an increase in number of crayfish caught in gillnets of mesh sizes of more than 2 inches. It was also observed that the increase in population of the Red swamp crayfish was mainly noticed in the last 5 to 10 years in spite of the crustacean having been in the Kafue River system for the past 30 years. There were many possible factors that could have led to the increase in the crustacean's population in the Kafue river system. One attribute that enabled the Red swamp crayfish to survive and proliferate in different regions of the world was its high adaptability to different environment conditions (FAO, 2004). The crayfish could have adapted itself easily in the Kafue River because the conditions from where it originated, (South East of USA and Mexico) had almost the same climatic condition as those that were found in Zambia (Ellis and England, 2008). The theory that crayfish and barbel (*Clarias spp.*) were not compatible, and that Clarias would in nature eliminate crayfish, evidently did not stand. *Procambarus clarkii*, does reproduce in fresh waters and the exact food niche they occupy and their impact on ecology and fauna was not clear at the moment (FAO, 2004). According to Buglife (2012), *P. clarkii* has high survivability such that even where other aquatic organisms may not survive because of harsh environmental conditions such as drought, itself could still survive and flourish. *P. clarkii* has also been found to be highly adaptable to different environment because it possesses other survival traits that include its ability to walk and swim upstream in rivers that feed lakes. It can as well move easily downstream in rivers and streams (Howard, 2011). Although the study was only conducted downstream of the Itezhi-tezhi dam wall in Namwala, it was likely that equal amounts of *P. clarkii* could also be found in the water body of the dam as in the river since the organism was highly mobile in water and to some extent on land. The general increase in the population of *P. clarkii* in the Kafue River could also be attributed to the crustacean lacking a strong predator to reduce its population. The perceived absence of frequent diseases could also be a reason for the increase of the crayfish in the river. In addition to that, the organism could not have had a strong competitor for food. Witt (2011), reported that the Louisiana crayfish can as well change or switch diets based on whatever food is available, from plankton to amphibians.

There was a very strong correlation between the season and number of crayfish caught as by-catch in gillnets operation. It was therefore; clear that season influenced how much crayfish was caught in a net. The hot season, which spans from August to somewhere in mid-December, recorded the highest number crayfish to finfish while the cold season recorded the lowest numbers, with the rain season having intermediate catches. The hot season was usually associated with reduced waters and high temperatures favoring the flourishing of the ecosystem for both finfishes and crayfish; higher catches were, therefore, automatically expected. The rain season, like the hot season, also was usually associated with somewhat high temperature and the inflow from the stream that fed Kafue and was generally rich in plant nutrient which ultimately promoted both primary and secondary aquatic production. The flooding regimes of the river provided breeding grounds for various forms of organisms which the crayfish fed on.

The cold season, on the other hand, being associated with low temperature caused most of the aquatic organisms to be inactive in movements to conserve their energy for growth and other activities. That, therefore, reduced their ability to move towards the gear and that could also have been reflected in the respondents' answers.

The numbers of crayfish caught in the gillnets, were also depth dependent with the bottom setting being the most effective followed by the mid setting while the least was top setting. It can be deduced from the results obtained that the crayfish still generally maintained its behavior as a bottom dwelling organism based on the fact that most of the catches were realized from the bottom, where they forage the base of the water bodies while the stray ones may also be found in the middle depth of a water body. It can also be concluded that nets close to the shoreline realized increased levels of crayfish by-catches. Some of the reasons attributed to why most of the crayfish was caught close to the shoreline were:

- Major fishing grounds where fishers set their nets there;
- These were breeding grounds for most fish species;
- The shoreline substrate could have been richer in crayfish food generated from organic debris deposited by the flooding river.

From the research results, it was clear that fishers faced great challenges due to the emergency of crayfish as part of the by-catch. The presence of crayfish in the nets of fishers will continue to affect both their operations and to a certain extent, cause great economic losses to them. The economic losses, though not quantified, in terms of their fish being eaten or being disfigured by the crayfish, net damage and the time spent in removing the organisms from the nets, could be large and was worth being investigated.

Respondents did not like the presence of the crayfish as part of the catch. The crayfish posed problems of predating on caught fish in nets hence lowering the quality of the saleable product. Its sharp chelates, also injured fishers in their effort to separate the organism from the nets. In addition to that fishers faced the problems of net tearing as they removed the crayfish from the nets; as the organisms got caught through entangling. Therefore, their manner of disposal of the organism was by either throwing them away or to return them into the water.

Despite the red swamp crayfish being consumed as food elsewhere in the world, it was generally not accepted by the local fishing communities along the Kafue River. Unless the crayfish was accepted as food or if they could sale them to those people who ate them, the crustacean will continuously be seen as an inconvenience to the fishers. FAO (2010*)* reported that *P. clarkii* was widely consumed as food more especially in the USA where different dishes are prepared. It is also an ornamental crustacean in Europe and elsewhere. Apparently, this crustacean seems to be gaining popularity as food among many Zambians although marketing of the crustacean to the hospitality industry seems not to be well developed. According to Witt (2011), though some people have benefited from selling the crayfish in some places in East Africa, particularly around Lake Naivasha, the benefits could be short lived as the crayfish population could quickly explode and then collapse after having eaten all its preys. And in Namwala and probably elsewhere along the river, where the crayfish was not eaten as food by the local people as reviewed by the survey, there was no specific harvesting gear for the crayfish as it was not the intended target in fishers' fishing operation. That could have led to its population growing unchecked as the species was not fully exploited.

The study has shown that either fishers were complying with the regulation that limits the minimum use of mesh sizes above 2 inches or they were afraid to disclose that they were using nets with less than 2 inches mesh size least they be admonished for using the prohibited gear.

Although many of the fishers were of the opinion that there was a remarkable decrease in the population of other organisms as reflected by their reduced ratios in the catches, that could be attributed to other factors such as overfishing and the improved ability of the fish and other organisms to evade the fishing gear. Therefore, it was only those organisms that had the same niche with the crayfish, for example the crabs, that may be directly affected, but finfishes had different dietary requirements to that of the crayfish and the direct competition for survival resources could not have been there. However, since the crayfish was predatory in nature, possibilities of it predating on fry, weak fish and fish eggs of fish species that were substrate spawners, could not be ruled out and that could be a subject for further investigation. Ochieng' (2012) reported that *P. clarkii* was highly omnivorous in nature, feeding on small freshwater fish, fish eggs, mollusks, crustaceans, and aquatic plants. And by the fact that the crustacean was discovered to prey on the caught fish in the stationery gill nets, it was obvious that it also feeds on fish eggs and fish fry; that might have caused an ecological imbalance to the Kafue River system, which might also negatively impact on the livelihood of fishers by reducing their catches as fewer juvenile were being recruited after every spawning season. That, together with the heavy fishing pressure that was already being exerted on the fishery, was likely to reduce the fish stocks to low levels such that fishing may no longer be profitable in the near future.

Based on these results, it may not conclusively be stated that finfishes and other organisms' reduction in catches were directly affected by the increase of crayfish in the Kafue River. Crabs, like the finfish, were also preferred by the locals, which meant that whatever change were made to their populations; it was easily noticed as well. Crabs belonged to the same phylum, crustacean, just as the Red swamp crayfish, meaning the organisms shared the same ecological niche and where they became weaker competitors, it was possible for them to be wiped out or their population reduced drastically. Elsewhere, in the world, where the crayfish was introduced, the indigenous crab population reduced to very low levels (Crandall, 2010). The large size fishes, especially the bream or tilapia were the most exploited species in Zambian fisheries where the *Clupeidae* and *Poecilothrissa spp* were absent. It was, therefore, for this reason that slight changes in their population from empirical catch results would easily be noticed.

And apart from being food for certain communities somewhere, the presence of the species of crayfish in water body basing on how destructive it is to the ecosystem and water infrastructure pose more challenges than benefits. According to Ochieng' (2012), the red swamp crayfish does not only affect the biotic structure of the water body where it is found; it can also destroy the infrastructures of that water body. For instance, the crayfish was once introduced in dams around the Kenyan cities of Nairobi, Kiambu, and Limuru to rid those areas of parasite-carrying snails, (Ochieng' 2012). By burrowing into the edges of dams, rivers, and lakes to make their nests, the red swamp crayfish was found to damage local infrastructure and landscapes. The burrowing caused water canals to leak, earth dams to collapse, and banks of rivers and lakes to erode. The Kafue River has some of the most important infrastructures in the country where hydropower generation, urban water supply and irrigation were concerned. The Itezhi-tezhi Dam and Kafue Gorge power plants were some of the infrastructure that may, in the future, depending on their construction, be affected by the burrowing effects of the red swamp crayfish. The erosion of the river banks of the Kafue River as a result of burrowing effect of the crustacean may also not only affect industrial infrastructures but also other structures located close to the river such as tourism resorts, residential houses and water treatment plants like the Kafue Water treatment plants and bridges.

No matter how much the introduction of the red swamp crayfish in the Kafue River may be justified, its proliferation should definitively be regulated. Various methods to control the crustacean's populations in different areas have been suggested. Trapping and possibly poisoning could control the species in small bodies of water, (Howard, 2011). Physical barriers could also stop the crustaceans' movements but only if a crayfish population's precise distribution is known. The existence of the vegetative water hyacinth in the lower Kafue River could as well offer refuge and a suitable habitat for the proliferation of the crayfish. Removing water hyacinth and other aquatic weed species from water bodies such as was done in Lake Naivasha could allow predatory birds more access to catch the crayfish (Witt, 2012). It may also be advantageous to restrict the crustacean to farm fish ponds where its population can easily be regulated unlike in the natural water systems (Howard, 2011).

4. Conclusion

The study revealed an increase in number of Red swamp crayfish caught in gillnets of mesh sizes of more than 2 inches in the last 5 to 10 years. It was further noted that there was drastic reduction in catches of finfishes and other organisms as a result of the increase of crayfish in the Kafue River. However, it may not conclusively be stated that finfishes and other organisms' reduction in catches were directly affected by the increase of crayfish. The general increase in the population of *P. clarkii* could be attributed to a number of factors; the crustacean easily adapted itself to the local environmental conditions, it may have lacked a stronger predator to reduce its population. The perceived absence of frequent diseases could also be a reason for the increase of the crayfish in the river. In addition to that, the organism could not have had a strong competitor for food. In the same vein, both season and depth influenced how much crayfish was caught in a net. Findings of the study have also shown that nets close to the shoreline realized increased levels of crayfish by-catches. From the research results, it was clear that the presence of crayfish as a by-catch caused a lot of operational challenges to the fishers in that their fish were being eaten or disfigured, hence lowering the quality of the saleable product, nets were damaged and a lot of time was spent in removing the organisms from their nets.

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