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Research Article

Get it before it gets to my catch: misdirection traps to mitigate against socioeconomic impacts associated with crayfish invasion

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Abstract

The threats posed by invasive freshwater crayfish species are one of the greatest concerns for freshwater ecologists, environmental managers, policy makers and local communities in the invaded regions. The invasive Australian redclaw crayfish *Cherax quadricarinatus* is rapidly spreading in southern Africa. Fishers in the Zambezi Basin have reported that crayfish affect their catch through partial consumption of fish caught on static gillnets. Owing to the immeasurable contributions of fishery to socioeconomic livelihoods in Africa, the catch losses that are due to crayfish are of concern. With this problem in Africa, it is imperative to continue researching on adaptive strategies to cope with the invasion. This study tested the effectiveness of "misdirection traps" to prevent fish spoilage and gear damage for gillnet catches by crayfish in Lake Kariba, Zimbabwe. The method involved placing baited traps along a gillnet to misdirect crayfish into the traps rather than fishing gear to prevent fish spoilage by scavenging. The misdirection traps significantly lowered the amount of catch spoilage. Gillnet damage by crayfish in general was minimal, although it was higher for gillnets without baited traps. The misdirection traps pose a pragmatic management initiative to reduce socioeconomic fishery costs from crayfish. We consider this method to be applicable in all the invaded regions where artisanal fishers are experiencing catch spoilage problems making a huge step towards preventing socioeconomic impacts associated with crayfish invasion.

Key words: *Cherax quadricarinatus*, fish, fishers, gillnet, Lake Kariba, trap, costs

Introduction

Biological invasions threaten biodiversity in aquatic and terrestrial ecosystems which challenges conservation efforts (Simberloff et al. 2013). In addition, they have caused detrimental socioeconomic impacts on human livelihoods costing trillions of US dollars worldwide over the past several decades (Diagne et al. 2021). Some of the most successful aquatic invasive alien species (IAS) are crustaceans, especially crayfish (Lodge et al. 2012; Kouba et al. 2022). Crayfish introduction pathways include fisheries, aquaculture purposes and the aquarium trade (Madzivanzira et al. 2020; Haubrock et al. 2021). Negative impacts of invasive crayfish include loss of ecosystem services such as food provisioning through reduction in native species used in subsistence fisheries or of economic value, disruption of food webs, disease vectoring and increased costs to agriculture and water management (Lodge et al. 2012; Madzivanzira et al. 2020). Although represented by just a few species, the global economic losses caused by invasive crayfish are substantial with losses averaging US$5.7 million per year globally, predominantly through fisheries damage (Kouba et al. 2022). Once crayfish are introduced, removal efforts are rarely successful (Nunes et al. 2017; Barkhuizen et al. 2022) therefore preventing their spread and managing established populations is necessary (Gherardi et al. 2011; Lodge et al. 2012; Stebbing 2016).

Nine crayfish species have introduction histories into the African continent with five species establishing populations in Africa: the noble crayfish *Astacus astacus* (Linnaeus, 1758), spiny cheek crayfish *Faxonius limosus* (Rafinesque, 1817), Australian redclaw crayfish *Cherax quadricarinatus* (von Martens, 1868), Louisiana red swamp crayfish *Procambarus clarkii* (Girard, 1852), marbled crayfish *Procambarus virginalis* (Lyko, 2017), establishing naturalized populations in 14 African countries as a result of escape from captivity, intentional releases and unaided spread (Madzivanzira et al. 2020). Amongst the rapidly spreading crayfish species in southern Africa is *C. quadricarinatus*, native to northern Australia and south-eastern Papua New Guinea (Riek 1969). *Cherax quadricarinatus* has established throughout the Zambezi Basin where it was introduced in the early 2000s (Madzivanzira et al. 2020, 2021a). *Cherax quadricarinatus* can have profound impacts on freshwater communities (plants and animals) due to their opportunistic, omnivorous and predatory nature (Madzivanzira et al. 2021b, 2022).

Ecological impacts of invasive species are often not detected until the invasive species is fully established. However, when a species impacts a human-nature coupled system such as fisheries, the impacts are likely to be communicated anecdotally. Lake Kariba, fishers reported damage to gillnet catches in their artisanal fishery soon after *C. quadricarinatus* establishment. The crayfish are attracted to fish caught in the nets and partially consume the catch and in doing so spoil the value of the catch (Weyl et al. 2017). Fish partially consumed are not marketable as buyers consider the fish to be spoiled (Madzivanzira et al. 2022). When crayfish cause a percentage of the catch to be unmarketable, targets are not met and the impacts cascade through the value chain (Madzivanzira et al. 2022). Further the crayfish often become entangled in fishing gear which decreases their fishing efficiency (Weyl et al. 2017). The economic impact of *C. quadricarinatus* makes it a food security concern, as the region is associated with high levels of poverty (Chivenge and Chirisa 2021); with one crayfish estimated to be able to cause damage of $5.42 annually in Lake Kariba (Madzivanzira et al. 2022). Invasion by crayfish in the Zambezi Basin affects the attainment of Sustainable Development Goals (SDGs): SDG 1 (No Poverty) and SDG 2 (Zero Hunger).

Fisheries provide employment as well as a source of income and protein (Magqina et al. 2020; Chan et al. 2021). It is thus important to develop sustainable solutions to mitigate crayfish damage to fish catches. The usual control measures such as mechanical or physical removal, chemical application and biological control are all impractical and costly in a large reservoir such as Lake Kariba. Feasible eradications are possible under a narrow range of specific conditions (i.e. small and isolated localities) and by using of drastic measures such as the long-term dewatering or application of non-selective biocides which may negatively affect the entire aquatic biota (Peay et al. 2019; Manfrin et al. 2019; Chadwick et al. 2020). Nonetheless, various attempts to manage invasive crayfish species have largely failed to successfully eradicate widely established populations or hinder their spread (Gherardi et al. 2011; Stebbing 2016; Haubrock et al. 2018; Madzivanzira et al. 2020; Barkhuizen et al. 2022). Effective management of invasive crayfish is impractical in many habitats e.g., African and Asian freshwater systems because of their broad geographical expanse.

Owing to the impacts of crayfish on the artisanal fishery and the low capacity for population control, we propose a novel approach to reduce crayfish incurred socioeconomic impact. We term them as “misdirection traps.” This involves strategically placing crayfish traps along gillnets to misdirect crayfish from the nets and into the traps instead, which allows them to be captured for removal from the system. The emphasis is on testing the effectiveness in preventing catch spoilage and gear damage by crayfish rather than reducing their population abundance, despite this being a secondary benefit. We further estimate how misdirection traps can reduce the economic losses associated with crayfish impacts. By conducting the study as a field experiment, we hypothesize that misdirection traps can significantly prevent crayfish aesthetic damage to catch and reduce the economic losses associated with crayfish.

Materials and methods

Study area

The study was carried out in Lake Kariba, which is the largest artificial lake by volume in the world (Figure 1). The reservoir was constructed for hydropower generation between Zimbabwe and Zambia on the Zambezi River in 1958 (Magadza et al. 2020). The reservoir is 280 km long, 40 km at its widest, with a mean width of 19.4 km, with a surface area of 5580 km^2 and a volume of 185 km^3. The mean and maximum depth of Lake Kariba is

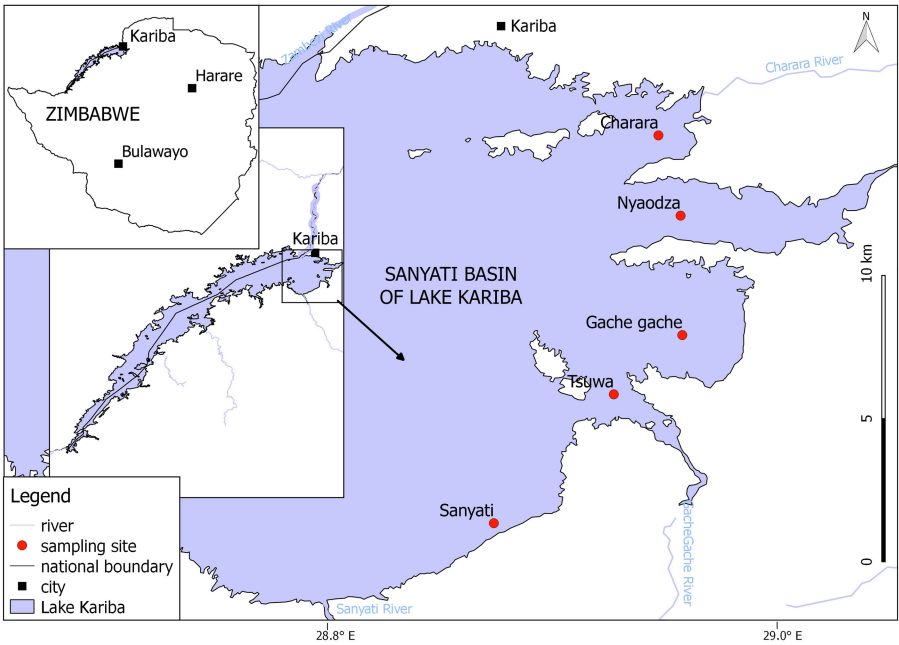


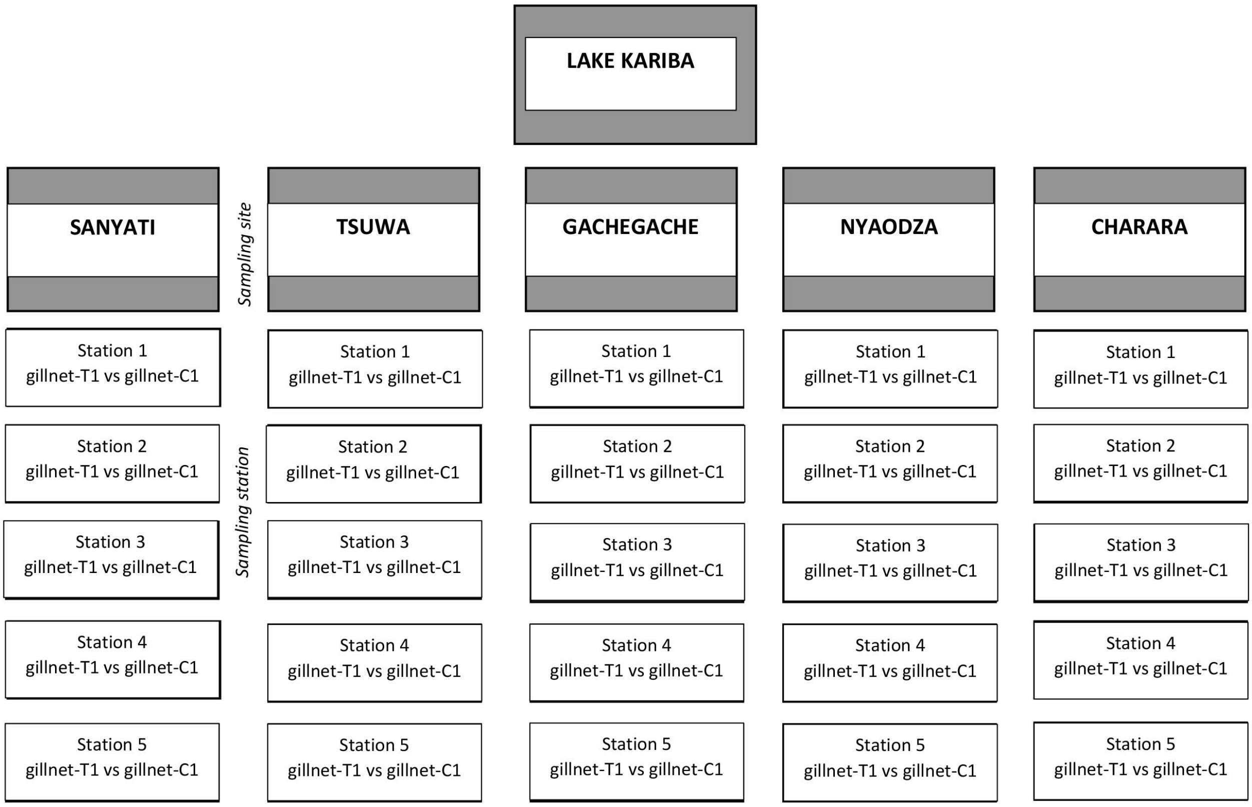
Figure 1. Location of sampling sites in the Sanyati Basin of Lake Kariba. In each sampling site, *n* = 5 stations were sampled.

29 m and 97 m, respectively. The lake supports a wide range of biodiversity and part of it is under the UNESCO Biosphere Reserve (Magadza et al. 2020) with 33 fish species known to be present (Zengeya and Marshall 2008). The study was conducted in the Sanyati Basin which is fed by Charara, Nyaodza, Gache gache and Sanyati rivers.

Sampling

Sampling was conducted between 11–20 January 2022 at five sampling sites within the Sanyati Basin of Lake Kariba. Fishing is permitted in the Nyaodza, Gache gache, Tsuwa and Sanyati sites while Charara is in a non-fishing zone. All sampling sites are a transitional zone between riverine and lacustrine habitats except the Sanyati site which is lacustrine. At each sampling site, physicochemical variables (i.e., temperature, dissolved oxygen (DO), pH, electrical conductivity, turbidity) were measured on the water surface using an Aquaread multimeter (AP-800, Kent).

Fish and crayfish were sampled using five experimental gillnets (with Opera traps) and five control gillnets (without Opera traps) at the five sampling sites (See Figure 2 for sampling design). For each experimental gillnet, 5 opera crayfish traps (dimensions: 100 × 50 × 30 cm; mesh size: 1 cm) were placed ~ 5 m (to prevent entanglement) either side of a 100 m long multifilament gillnet (50, 72, 100 and 140 mm mesh size) (hereafter referred to as gillnet-T) (Figure 3). The Opera traps were baited with a *Synodontis* sp., a readily available, low value, local fish species. Control gillnets (hereafter referred to as gillnet-C) were deployed ~ 200 m away from each experimental gillnet. Gillnets and traps were set and then retrieved the following day (soak time ~ 15 h).



LAKE KARIBA

Sampling site

Sampling station

SANYATI	TSUWA	GACHEGACHE	NYAODZA	CHARARA
Station 1 gillnet-T1 vs gillnet-C1	Station 1 gillnet-T1 vs gillnet-C1	Station 1 gillnet-T1 vs gillnet-C1	Station 1 gillnet-T1 vs gillnet-C1	Station 1 gillnet-T1 vs gillnet-C1
Station 2 gillnet-T1 vs gillnet-C1	Station 2 gillnet-T1 vs gillnet-C1	Station 2 gillnet-T1 vs gillnet-C1	Station 2 gillnet-T1 vs gillnet-C1	Station 2 gillnet-T1 vs gillnet-C1
Station 3 gillnet-T1 vs gillnet-C1	Station 3 gillnet-T1 vs gillnet-C1	Station 3 gillnet-T1 vs gillnet-C1	Station 3 gillnet-T1 vs gillnet-C1	Station 3 gillnet-T1 vs gillnet-C1
Station 4 gillnet-T1 vs gillnet-C1	Station 4 gillnet-T1 vs gillnet-C1	Station 4 gillnet-T1 vs gillnet-C1	Station 4 gillnet-T1 vs gillnet-C1	Station 4 gillnet-T1 vs gillnet-C1
Station 5 gillnet-T1 vs gillnet-C1	Station 5 gillnet-T1 vs gillnet-C1	Station 5 gillnet-T1 vs gillnet-C1	Station 5 gillnet-T1 vs gillnet-C1	Station 5 gillnet-T1 vs gillnet-C1

Figure 2. Sampling design in Lake Kariba, Zimbabwe.

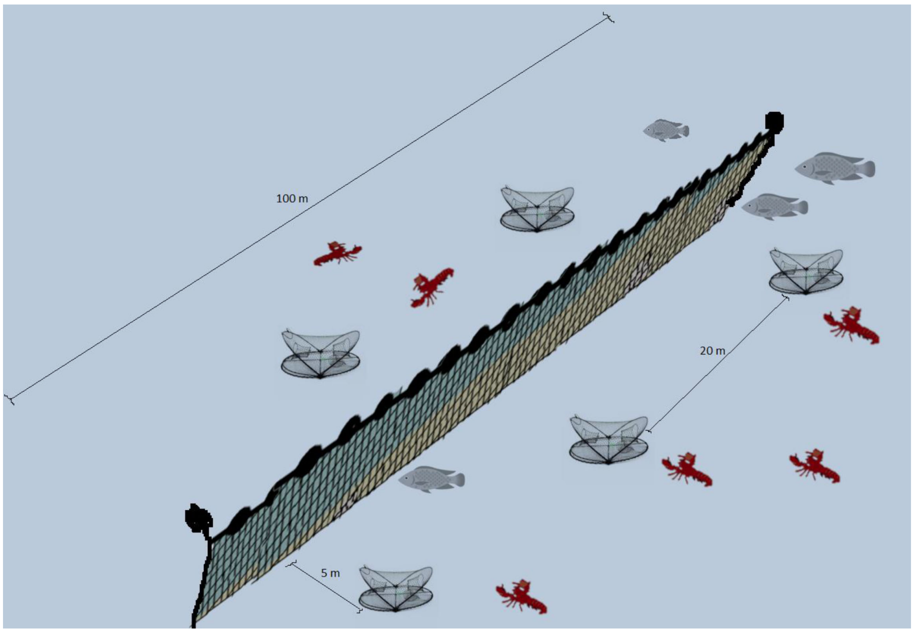


Figure 3. Set up of the misdirection traps experiment. Opera traps placed along a 100 m gillnet in Lake Kariba.

The number of fish and crayfish captured in each trap and gillnet were recorded. Spoiled fish were weighed to the nearest gram.

Gillnet condition was also assessed upon retrieval. Damage intensity was determined based on a semi-quantitative analysis by the fisher using a scale from 0 to 3, with 0 = no damage, 1 = minor damage, 2 = intermediate damage and 3 = extensive damage.

Data analysis

CPUE of spoiled fish (hereafter, $\text{CPUE}_{spoiled}$) data was log transformed before ANOVA to approximate the normal distribution (Shapiro Wilk test ($w = 0.95$, $p = 0.24$)). A t-test was used to test for $\text{CPUE}_{spoiled}$ differences between gillnet-T and gillnet-C stations. One-way ANOVA was used to test for differences in $\text{CPUE}_{spoiled}$ between fishing sites. One-way ANOVA was performed on log-transformed crayfish catch per unit effort (CPUE) (hereafter referred to as $\text{CPUE}_{crayfish}$) data to test for differences between fishing sites and a t-test was used to test for $\text{CPUE}_{crayfish}$ differences between gillnet-T and gillnet-C stations. The overall gillnet damage intensity was analyzed with a 3 × 2 contingency table, and differences among the categories regions were tested with a $\chi 2$ test. Kruskal-Wallis tests were conducted to test for differences in physiochemical variables between fishing sites. A Wilcoxon matched pairs test was used to test for differences in physiochemical variables between gillnet-T and gillnet-C stations within sampled fishing sites.

The mean $\text{CPUE}_{spoiled}$ differences between gillnet-T and gillnet-C were used to estimate economic losses in order to determine how misdirection traps potentially prevent economic losses. The following equations were used:

$$monetary\ loss\ Gillnet - T\ = CPUE_{spoiled}\ Gillnet - T\ \times\ US\$\ 3.00\ (price\ of\ fish\ per\ kg) \tag{1}$$

$$monetary\ loss\ Gillnet - C\ = CPUE_{spoiled}\ Gillnet - C\ \times\ US\$\ 3.00\ (price\ of\ fish\ per\ kg) \tag{2}$$

$$mean\ monetary\ loss\ Gillnet - T\ = \frac{Sum\ (CPUE_{spoiled}\ Gillnet{-}T\ all\ sites)}{Total\ number\ of\ sites} \tag{3}$$

$$mean\ monetary\ loss\ Gillnet - C\ = \frac{Sum\ (CPUE_{spoiled}\ Gillnet{-}C\ all\ sites)}{Total\ number\ of\ sites} \tag{4}$$

$$monetary\ saved\ by\ each\ fisher\ = Eqn\ 4 - Eqn\ 3 \tag{5}$$

All test statistics were computed using STATISTICA version 7 (StatSoft 2004).

Results

The Sanyati Basin had a mean temperature of 25.73 ± 0.06 °C, pH 7.25 ± 0.01, DO 6.75 ± 0.04 $\text{mg}\cdot\text{L}^{-1}$, conductivity 92.73 ± 0.09 $\mu\text{S}\cdot\text{cm}^{-1}$ and turbidity 1.33 ± 0.03 NTU. All physicochemical variables were similar ($p > 0.05$) at all the fishing sites and between the gillnet-T and C sites.

Fishing site did not have an effect on $\text{CPUE}_{spoiled}$ from either gillnet-T or gillnet-C ($F_{(4,\ 20)} = 0.27$, $p = 0.89$ and $F_{(4,\ 20)} = 1.10$, $p = 0.38$ respectively). Gillnet-C sites had significantly higher $\text{CPUE}_{spoiled}$ ($p < 0.05$) than gillnet-T from all the fishing sites except for Gache gache ($p > 0.05$; Table 1; Figure 4). Fishing site neither had an effect on $\text{CPUE}_{crayfish}$ from either gillnet-T or gillnet-C ($F_{(4,\ 20)} = 0.31$, $p = 0.61$ and $F_{(4,\ 20)} = 0.44.$, $p = 0.12$, respectively). Economic losses incurred from gillnet-T and gillnet-C ranged between

Table 1. Catch spoilage ($CPUE_{spoiled}$) between gillnets with and without baited traps in Sanyati Basin, Lake Kariba (Zimbabwe) in January 2022. In bold are significant differences at $p < 0.05$ between the two experiments.

Site	Station	$CPUE_{spoiled}$ gillnet-T (kg/100 m net/night)	$CPUE_{spoiled}$ gillnet-C (kg/100 m net/night)	*p*	Monetary loss Gillnet-T ($)	Monetary loss Gillnet-C ($)
Charara	1	0.290	0.940	**0.005**	0.73	2.35
	2	0.000	1.350		0.00	3.38
	3	0.450	3.340		1.13	8.35
	4	0.630	2.150		1.58	5.38
	5	0.300	1.980		0.75	4.95
Nyaodza	1	0.650	2.230	**0.003**	1.63	5.58
	2	0.000	1.340		0.00	3.35
	3	0.000	1.790		0.00	4.48
	4	0.350	0.930		0.88	2.33
	5	0.450	1.040		1.13	2.60
Gache gache	1	0.000	1.040	0.100	0.00	2.60
	2	0.000	0.000		0.00	0.00
	3	0.790	1.360		1.98	3.40
	4	0.000	3.020		0.00	7.55
	5	0.250	0.570		0.63	1.43
Tsuwa	1	0.470	3.460	**0.003**	1.18	8.65
	2	0.000	2.070		0.00	5.18
	3	0.000	1.670		0.00	4.18
	4	0.350	3.330		0.88	8.33
	5	0.540	0.960		1.35	2.40
Sanyati	1	0.000	0.500	**0.020**	0.00	1.25
	2	0.000	1.110		0.00	2.78
	3	0.000	3.040		0.00	7.60
	4	0.690	1.370		1.73	3.43
	5	0.550	1.880		1.38	4.70
Mean		0.27	1.70		0.68	4.25
SE		0.06	0.19		0.14	0.48

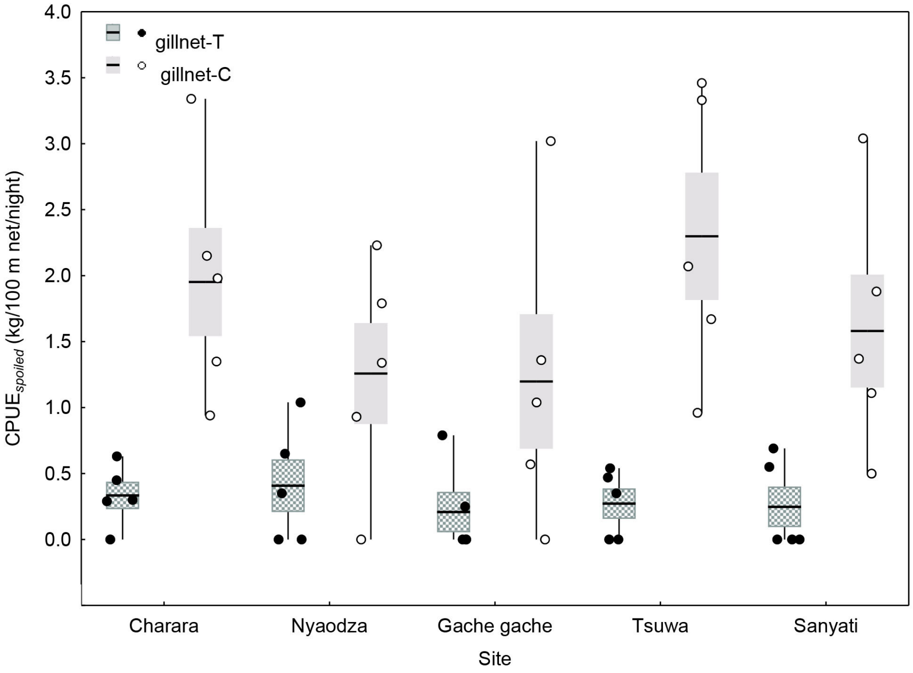


Figure 4. Mean CPUE of spoiled catch between gillnets with baited traps and without, per site in Lake Kariba. Points indicate raw data values, boxplots indicate ± Standard Error and solid line across the box represents the mean.

Table 2. Frequency (%) of gillnet damage by crayfish in Lake Kariba, Zimbabwe.

	gillnet-T	gillnet-C
No damage	84	60
Minor damage	16	32
Intermediate damage	0	8
Extreme damage	0	0

US$ 0.00–US$ 1.98 (average US$0.68) and US$1.25–US$8.65 (mean US$4.25), respectively (Table 1). Using misdirection traps therefore saves each fisher between US$0.80 – US$7.48 (mean US$3.57) a day (Table 1). Damage frequency was considered minimal over the 2 week survey (Table 2) as gillnets that had no damage were significantly higher ($p < 0.001$) than gillnets that had minor and intermediate damage. No extremely damaged gillnets were recorded in this study (Table 2).

A total of 301 crayfish were caught in the traps (mean ± SE CPUE of 2.41 ± 0.26 individuals/trap/night). There was no difference in $\mathrm{CPUE}_{crayfish}$ between fishing sites ($H = 2.43$; df = 4; $p = 0.66$). The number of crayfish removed from gillnet-T (4) were significantly lower ($t\ (48) = -2.64$, $p = 0.01$) than from gillnet-C (20).

Discussion

The control of invasive crayfish is complex, and in some cases requires the application of multiple disciplines for it to be effective (Stebbing 2016). It is useful to identify and isolate the impacts associated with invasive crayfish to aid in the development of targeted management strategies, particularly in situations where resources are limited (Stebbing 2016), such as in Africa. The invasion by crayfish remains a burden for various stakeholders and their irreversible impacts are likely to persist and worsen, especially considering the low level of conservation management in many African countries (Madzivanzira et al. 2022). It is therefore imperative to research on adaptive strategies to cope with crayfish invasions in Africa to counter the associated impacts. This study tested the effectiveness of misdirection traps to prevent or reduce fish spoilage and gear damage by *C. quadricarinatus* in Lake Kariba.

Our results indicate that misdirection traps are an inexpensive, effective and pragmatic means of preventing fish spoilage by *C. quadricarinatus* in Lake Kariba as shown by the low $\mathrm{CPUE}_{spoiled}$ on gillnet-T than gillnet-C. We found 5 traps along a 100 m net to be effective although further studies may be needed to test the effectiveness of less or more traps along a gillnet to determine optimum trap effort. The inexpensiveness aspect is based on the value of the home-made crayfish traps as compared to other crayfish control methods (e.g., chemicals, biocides, draining) which are not feasible in Lake Kariba. Home-made crayfish traps which are rectangular (1 m × 0.25 m × 0.25 m) are valued between US$3–5 (TCM *pers. observation* 2022). Commercially, these traps are priced between US$10–15 per trap in Europe, North America and Asia. Purchasing or making the crayfish traps would be a one-time cost, and other methods would be both expensive (Stebbing 2016) and inapplicable in Lake Kariba.

Misdirection traps are ideally suited to those aquatic systems where other mitigation methods are impractical, such as large floodplains (e.g., Barotse, Kafue) and reservoirs (e.g., Lake Cahora Bassa, Lake Kariba). Baited misdirection traps prevent fish spoilage by attracting and catching benthic dwelling *C. quadricarinatus* before they reach the gillnets. It however, should be noted that misdirection traps is a concept and is not solely defined by the gear that was used in this study. Baited traps to trap crayfish vary by design and dimensions between regions: Promar collapsible traps used in Southern Africa (Madzivanzira et al. 2020, 2021c); Swedish trappy commonly used in Europe; modified Gee minnow traps used in North America; and hoop nets used in Australia (Larson and Olden 2016). Apart from trap design, different baits are used that include liver, chicken, fish, dog food, canned cat food, cooked maize meal (Somers and Stechey 1986; Larson and Olden 2016; Mhlanga et al. 2020; Madzivanzira et al. 2021c; Barkhuizen et al. 2022). Properties of an aquatic system determines the choice of a trapping method and any baited trapping method can be used to misdirect crayfish to prevent aesthetic damage to catch. The use of *Synodontis* sp. fish bait in this study is because it has a very low market value in Lake Kariba. Other low market value fish species that could potentially be used are *Clarias gariepinus* and *Heterobranchus longifilis*.

Misdirection traps will not only prevent fish catch spoilage, but a regular and sustained removal of crayfish is another positive outcome aiding population suppression, and thus constitutes a form of community management and a source of potential secondary socio-economic benefit. When the crayfish population is suppressed, negative impacts on other biotic components are reduced (Hein et al. 2007; Hansen et al. 2013). In Switzerland lakes, trapping and introduction of predatory fish led to the reduction in invasive crayfish (*Faxonius limosus*, *Pacifastacus leniusculus* and *Procambarus clarkii*) densities although complete eradication was not achieved (Krieg et al. 2020). A similar approach was taken to control *P. clarkii* in Mimosa Dam, South Africa although this was not successful in eradication (Barkhuizen et al. 2022). It is almost impossible to eradicate established crayfish species (Madzivanzira et al. 2020), but population suppression remains an option, especially in small dams, however crayfish are much more difficult to control in larger reservoirs (Madzivanzira et al. 2022). Misdirection traps are unlikely to suppress crayfish populations in Lake Kariba, but could rather reduce local crayfish densities in the fishing areas (localized population suppression). Nonetheless, further work is needed to validate this notion, including more trapping and understanding population density and meta-population migration and dispersal throughout the lake. Due to local perceptions of crayfish entangled on gillnets are neither sold nor used for subsistence at household level but are usually killed and thrown back into the lake, therefore no economic benefits are derived from them.

In the present study, fishers lost an average of US$5 per day due to crayfish spoilage which is a significant amount given their monthly income which ranges between US$140–233 per month depending on the season (Magqina et al. 2020). The potential loss in fishery due to crayfish scavenging as calculated for Kafue River, Lake Kariba, Barotse Floodplain in the Zambezi Basin amounted to an average annual loss of US$6.15, US$5.42, and US$3.62 per individual crayfish, respectively – however, there is no data on population size estimates in any of these invasions (Madzivanzira et al. 2022). Globally, economic losses caused by invasive crayfish annually average US$5.7 million (Kouba et al. 2022). These amounts are significantly high and warrant calls for innovative ways to manage and mitigate losses caused by invasive crayfish.

Fish spoilage by crayfish is causing some fishers to use more destructive methods such as fish driving, whereby sticks are used to beat the water driving the fish towards the gillnets (ATC *pers. observation*, 2022). This method causes excessive and unsustainable exploitation of fish which results in declining fish catches. The permitted fishing method by the Zimbabwe Parks and Wildlife Management Authority (ZPWMA) is that of leaving gillnets overnight and collecting them the following morning. As crayfish are nocturnal and predominantly detect food through a chemosensory pathway (Corotto and O'Brien 2002), it is during the night when they are attracted to the fish caught on the gillnets. The fishers have come to understand the nocturnal behavior of crayfish and therefore some of them resort to fish driving methods, especially during the day. Similarly, a change to fish driving methods were also observed in the recently invaded Barotse floodplain in Zambia (TCM and JS, *pers. observation*, 2019).

Minimal damage to nets were recorded in this study, in contrast to the anecdotal fisher reports of high net damage from crayfish. While trying to scavenge the fish catch, the crayfish entangle themselves and damage the net, which may result in the entire net being discarded and in some cases requiring the purchase of new nets (TCM and JS *pers. observation*, 2019). Gillnets with minor or intermediate damage are more easily repaired, however, the fishers then need to spend time repairing nets.

This study presents a novel approach using "misdirection traps" that can be used by artisanal fishers to reduce socioeconomic impacts associated with crayfish invasions in invaded African freshwater systems. Approval for the implementation of this approach by fishers in Lake Kariba lies within the ZPWMA as per the provisions of the Parks and Wildlife Act (20:14). The fishers could each be allowed to set a certain number of traps along their gillnets to prevent catch spoilage and potentially selling the caught crayfish collectively, to cosmopolitan clientele in Kariba town. The approach we are proposing in this study is a targeted management strategy to mitigate socioeconomic impacts associated with crayfish invasions. Management of crayfish invasions in Africa, needs to be prioritized as food security in the invaded regions is continuously being threatened. Government agencies and environmental managers should take measures to prevent further spread of *C. quadricarinatus* (within and across borders), and to improve screening techniques and early warning systems to prevent new introductions.

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Authors’ contribution

TCM, ATC and JS conceived the study. TCM acquired funding. TCM and ATC conducted the fieldwork. TCM and ATC analysed the data. TCM led writing of the manuscript and all authors contributed critically to the drafts and gave final approval for publication.

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