

Redclaw crayfish: challenge or resource? Voices of fishers in Zambia

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





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Redclaw Crayfish: Challenge or Resource? Voices of Fishers in Zambia

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ABSTRACT

Invasive species severely threaten biodiversity, ecosystem stability and local livelihoods, especially in vulnerable areas. Therefore, understanding community perceptions is vital for creating effective and inclusive management strategies. This study investigated perceived environmental and economic impacts of the invasive, Redclaw crayfish (*Cherax quadricarinatus*) in Lake Itzhi-Tezhi, Zambia, using structured surveys of 325 local fishers. Descriptive statistics and frequency analyses summarised respondent perception, and multiple linear regression models tested predictors of fishers' environmental and economic perceptions. Results revealed that 38% of the respondents first encountered the species within 1–5 years, 55.1% reported harvesting < 250 g per trip and 61.5% encountered crayfish only 1–2 times per seven trips. Most respondents reported negative environmental effects (77.98%), specifically competition with native fish and gear damage, and 62.4% attributed decreased household income to the invasion, though 45.0% expressed positive attitudes, seeing crayfish as a food and income resource. The regression predicting environmental perceptions was significant ($F(9,94)=2.75$, $p=0.007$, $R^2=0.21$), with younger fishers perceiving greater environmental impacts ($\beta=-0.31$, $p=0.005$). The model for economic perceptions was not significant ($F(9,94)=0.54$, $p=0.839$, $R^2=0.05$). There was strong support emerged for community participation (80.7%), along with a notable preference for government-led action (54.1%). Our findings highlight the need for integrated co-management that mitigates environmental harm while exploring sustainable crayfish-based livelihoods.

1 | Introduction

Biological invasions of non-native species are a critical global issue, costing a minimum of \$1.288 trillion loss over the past 50 years and impacting nearly every region on Earth (Diagne et al. 2021), driven mainly by international trade and economic

activity (Pyšek et al. 2010). These processes have led to the widespread establishment of non-native species, with more than 37,000 species introduced by human activities (IPBES 2023), resulting in complex and extensive impacts on ecosystem functioning and human livelihoods (Didham et al. 2005; Pyšek et al. 2020; Soto et al. 2023). Globally, aquatic invasions reduce

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community abundance, particularly macrophytes, zooplankton and fish and can degrade water quality by increasing turbidity and nutrient concentrations (Gallardo et al. 2015). For crayfish specifically, the negative consequences of established introductions, including displacement of native species, disease transmission, reduction of fish stocks and habitat degradation, have been recognised since at least the late 1990s (Holdich 1999; Twardochleb et al. 2013).

The redclaw crayfish, *Cherax quadricarinatus* (hereafter *C. quadricarinatus*), widely spread through aquaculture and the pet trade, exemplifies the risks posed by invasive species. Now established in more than 20 countries and invasive across tropical and subtropical regions, it has become a prominent driver of environmental change (Haubrock et al. 2021). Invasion patterns, however, vary across space and time, complicating broad generalisations about their impacts and management (Soto et al. 2023). Within freshwater systems, invasive crayfish disrupt ecosystem processes and trophic structures (Twardochleb et al. 2013; Grey and Jackson 2012; Jackson et al. 2016) while accelerating leaf-litter breakdown and nutrient cycling (Choi and Kim 2020; Madzivanzira et al. 2021a). In many regions, they further displace native shredders such as *Potamonautes* crabs, with cascading effects on fisheries and water quality (de Moor 2002; Dick et al. 2017; Jackson et al. 2016).

This species is large, highly prolific and tolerant of varied conditions. These traits make it attractive for aquaculture but also potent as an invader (Haubrock et al. 2021). Its recent detection in south Texas, United States, the second continental US record, emphasises its ongoing spread into new subtropical regions (Sanjar et al. 2023). As a group, nonnative crayfish exert strong and consistently negative effects on freshwater food webs (Twardochleb et al. 2013). *The species* has drawn particular attention in Southern Africa, where its introductions for aquaculture have resulted in rapid and widespread establishment (Witt et al. 2019). The introduction and expansion of *the species* in the Zambezi catchment is well documented (Douthwaite et al. 2018).

In Zambia, the species was introduced for aquaculture, escaped captivity and is now established in multiple water bodies, including Lake Kariba, the Kafue River and Lake Itzhi-Tezhi (Mkumbo et al. 2018; Hanley and Roberts 2019; Madzivanzira et al. 2021b). Studies reported its high dispersal rates and negative effects on local artisanal fisheries (Douthwaite et al. 2018). The recent work confirms continued spread into western and southern Zambia, including the Kabompo and the environmentally sensitive Kwando River system that connects to the Okavango Delta (Nambeye et al. 2025). Inland fisheries play a central role in Zambian rural livelihoods, supporting employment and contributing to poverty reduction (Chimba and Musuka 2014; Maulu et al. 2020; Maulu et al. 2021; Hasimuna et al. 2024; Maulu et al. 2024). The further spread of it across the country's estimated 15 million ha of freshwater resources would therefore pose a substantial social and economic threat (Hasimuna et al. 2019, 2022; Zhang et al. 2024).

In addition to the socio-economic risks, the fish poses well-documented environmental threats. Its competitive interactions and predation can reduce native fish populations (Chivambo et al. 2020; Mugwedi 2020). Additionally, burrowing behaviour

alters sediment structure and degrades nesting and breeding habitats (Petersen et al. 2017; Chivambo et al. 2020; Hasimuna et al. 2021). The species is also capable of carrying pathogens, including crayfish plague. These environmental impacts can cascade, reducing catches and damaging fishing gear, for example, through partial consumption of gillnet catches, which in turn lowers fishers' incomes (Madzivanzira et al. 2020). Across invaded systems, the combination of environmental and socio-economic effects increases management costs and threatens the long-term sustainability of fisheries (Lopez et al. 2011; Cowan et al. 2017; Early et al. 2016; Witt et al. 2019; Jamil et al. 2022). Such impacts have been documented in Mozambique, Kenya, Egypt and multiple fisheries across Zambia (Chivambo et al. 2020; Madzivanzira et al. 2021b).

At the same time, it has a high productivity and adaptability that make it a potential source of protein and income, prompting debate over whether careful utilisation could mitigate environmental harms while supporting livelihoods (Nuñez et al. 2012; Marchessaux et al. 2024). However, many management frameworks and impact assessments (e.g., the Ecological Impact Classification for Alien Taxa) rely on data from other regions and may not capture context-specific outcomes in African lakes (Dick et al. 2017). Empirical studies that integrate environmental data with fishers' perceptions remain scarce, even though perceptions shape compliance and the social feasibility of interventions (Kapitza et al. 2019; Bernos et al. 2022). Invasive species often create a socio-economic paradox in resource-dependent communities. This study addresses a critical gap by examining the factors that drive the dichotomy in perception. Specifically, is the redclaw crayfish primarily viewed as an environmental and economic threat that damages gear and reduces fish catches, or as a potential resource that can diversify livelihoods and improve food security? The present study investigates whether the species in Lake Itzhi-Tezhi is primarily perceived as a challenge or as a resource, assesses the frequency and quantity of crayfish in catches as reported by fishers, evaluates attitudes and management preferences and identifies factors influencing these perceptions to inform management options that are both environmentally informed and socially acceptable.

2 | Materials and Methods

2.1 | Study Area

The study was conducted in Itzhi-Tezhi district, located in the Southern Province of Zambia (Figure 1). It is one of the 10 provinces of Zambia, situated approximately 120 km west of Lusaka, 30 km east of the Kafue River, at geographical coordinates 15.7333°S, 26.0333°E. It covers an area of approximately 15,790.8 km². The district's hydrography is dominated by the Kafue River and the man-made Lake Itzhi-Tezhi, which forms the foundation of the local fishery. Constructed in 1977, the Itzhi-Tezhi Dam regulates the river's flow, creating a reservoir with a maximum depth of 55 m and a mean depth of approximately 15.4 m (FAO 1992). The lake and its regulated flows are central to the Kafue Flats ecosystem, a critical wetland system recognised for its high biodiversity and importance to Zambia's inland fish production (WWF 2025).

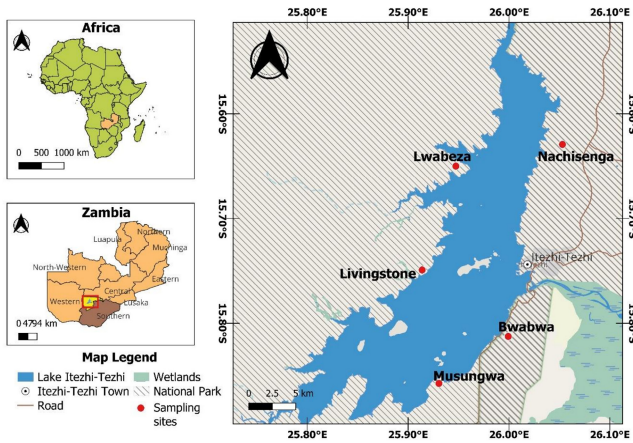


FIGURE 1 | Map of Lake Itezhi-Tezhi showing the locations of the survey sites in Southern Province, Zambia (March–April 2025).

Environmentally, Lake Itezhi-Tezhi supports a diverse aquatic community, including numerous fish species and a range of zooplankton that form the base of the food web (FAO 1992). Socio-economically, the lake underpins local livelihoods: Fishing and agriculture are the main economic activities, with over 800 fishers operating annually and over 1000 individuals directly dependent on the fishery (Nyirenda 2015; Chimiti and Kawimbe 2020). The lake's role extends beyond subsistence, contributing to household incomes, food security and cultural practices. The traditional fishing grounds and practices in the district are closely shaped by the hydrological regime of the Kafue River, which is influenced by the dam's operations and seasonal flow variations, providing the immediate context for this study on the impacts of the invasive, redclaw crayfish.

2.2 | Sampling Techniques and Data Collection

A cross-sectional, perception-based survey was conducted to explore fishers' experiences and views regarding the invasive, redclaw crayfish in Lake Itezhi-Tezhi. Sampling was carried out in four active fishing camps: Nachisenga, Lwabeza, Livingstone Isalnd, Bwabwa and Musungwa. According to records from the Department of Fisheries, the total licensed fisher population in the district was 1500 over the research period.

To ensure representative coverage across all camps, a stratified random sampling design was employed. Each camp was treated as a stratum, and an equal quota of 65 fishers per stratum was randomly selected from official lists, yielding a total sample size of 325. If a selected fisher was unavailable or declined participation, a replacement was randomly chosen. This design ensured balanced representation and minimised selection bias, consistent with established protocols in fisheries perception studies (Bernos et al. 2022; Tonga et al. 2025). Data were collected through face-to-face interviews using a structured questionnaire that incorporated primarily open-ended questions, along with a few simple, descriptive items (e.g., frequency of crayfish in catches). The questionnaire comprised four sections: (i) demographic and socio-economic characteristics, (ii) economic

impacts of the invasive crayfish on fishers' livelihoods, (iii) perceived environmental impacts on the lake fishery and (iv) local coping and management strategies. The open-ended responses were analysed thematically, while descriptive items were summarised using counts and percentages where appropriate. The questionnaire was pretested and refined to ensure clarity, cultural relevance and reliability (Muhala et al. 2021; Mphande et al. 2023; Tonga et al. 2025).

Although the interviews were conducted in English, fluent members of the research team provided translations into Tonga, Bemba and Nyanja for participants with limited English proficiency, thereby ensuring that all respondents could fully understand the questions. This translation process, together with pretesting, followed established procedures to maintain conceptual and linguistic equivalence (Kapitza et al. 2019; Bernos et al. 2022). Furthermore, collaboration with Department of Fisheries officers and fishing camp Chairpersons facilitated participant recruitment and adherence to local protocols, which not only improved response rates but also enhanced the trustworthiness and credibility of the collected data.

2.3 | Data Analysis

The collected data were initially entered into Microsoft Excel version 16.0 for cleaning, which involved checking for and correcting entry errors, handling missing values and standardising response formats to ensure consistency across the dataset. After cleaning, the data were exported to the Statistical Package for the Social Sciences (SPSS) version 23.0 (IBM Corp., Armonk, NY, United States) for statistical analysis. Descriptive statistics, including frequencies and percentages, were generated to summarise responses on fishers. Our analytical approach aligns with recent perception-driven fishery studies that integrate descriptive summaries with multivariate regression to identify predictors of attitudes and perceived impacts at both individual and site levels (Bernos et al. 2022). It also follows recommendations from the social-perception literature regarding transparent reporting of methodological choices and limitations (Kapitza et al. 2019). Furthermore, inferential statistics—specifically multiple regression analysis—was conducted to evaluate the factors influencing fishers' perceptions of the environmental impacts of Redclaw crayfish.

3 | Results

3.1 | Demographic and Socioeconomic Information

The demographic and socio-economic information is shown in Table 1. The majority (97.2%) of respondents were male, with females representing only 2.8% of the sample. The age distribution showed that the largest group (33.23%) fell within the 30–39 years range, followed by those aged 40–49 years (30.16%), while a smaller proportion (25.23%) fell within the 20–29 years group, and the least (1.23%) were aged 50 years and above. In terms of education, the majority of respondents (55.0%) had completed primary education, followed by 36.7% with secondary education. A small proportion (8.31%) had no formal

education, and no fisher attained tertiary education. Regarding fishing experience, the largest group (37.5%) had been involved in fishing for more than 10 years, while 23.9% had 6–10 years of experience. Additionally, 30.3% had been involved in fishing for 1–5 years, and the smallest proportion (8.26%) had less than 1 year of experience.

TABLE 1 | Demographic and socio-economic characteristics of respondents.

Variable	Category	Percentage (%)
Gender	Male	97.2
	Female	2.8
Age group	20–29	25.23
	30–39	33.23
	40–49	30.16
	50–59	1.23
	60 and above	10.15
Education level	None	8.31
	Primary	55.08
	Secondary	36.61
Fishing experience	Less than 1 year	8.26
	1–5 years	30.3
	6–10 years	23.9
	Over 10 years	37.54

3.2 | Frequency and Quantity of Redclaw Crayfish Catch

Survey data revealed that most fishers caught redclaw crayfish at varying catch weights, with 56.32% reporting less than 250 g per trip (Figure 2). Additionally, 15.90% reported catches of 250–500 g, 7.38% reported 501–750 g, 7.38% reported 751 g–1 kg and 13.23% reported more than 1 kg per trip. Additionally, 61.54% indicated that they came across redclaw crayfish only 1–2 times per seven fishing trips, while 21.85% reported always catching redclaw crayfish during their outings. A smaller proportion reported intermediate encounter frequencies, with 11.38% encountering redclaw crayfish 3–4 times, and 5.3% reporting 5–6 encounters during seven trips.

3.3 | Encounter With Redclaw Crayfish

Table 2 presents the first recorded encounters of redclaw crayfish by fishers. The majority of respondents (39.1%) reported their first encounter within the past 1–5 years, while 38.5% indicated having seen redclaw crayfish for the first time more than 10 years ago, and 22.5% reported having encountered crayfish 6–10 years ago.

3.4 | Fisher's Perceptions and Attitudes Toward Redclaw Crayfish

The perception of redclaw crayfish among the surveyed fishers was mixed, based on interview and questionnaire data (Figure 3). Nearly half of the respondents (49%) expressed negative perceptions, citing concerns about the impact of Redclaw crayfish on fishing activities and equipment. Positive attitudes

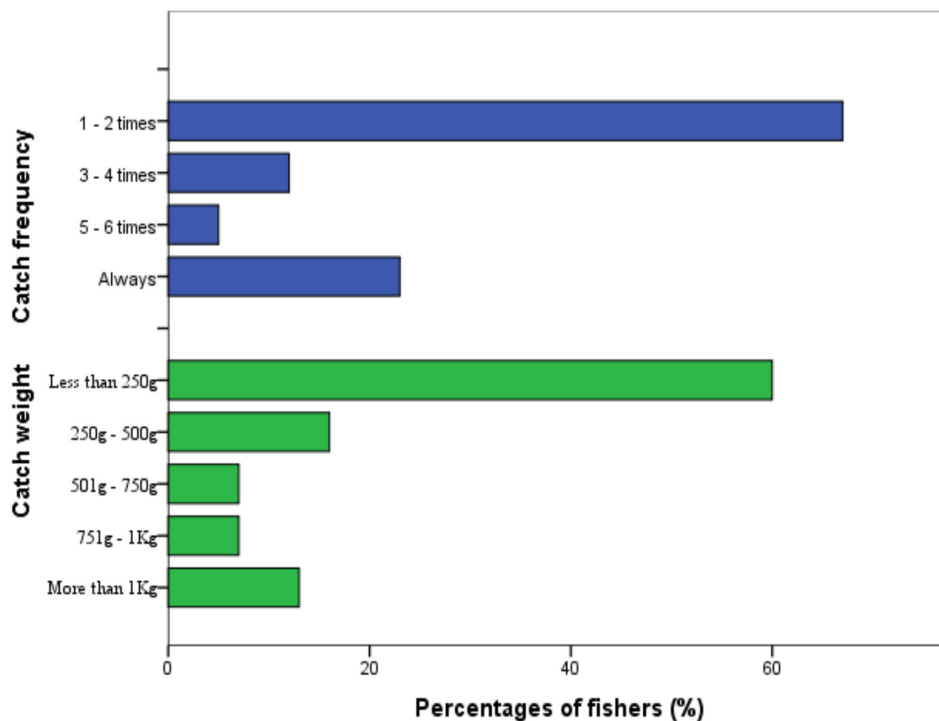


FIGURE 2 | Reported redclaw crayfish catch frequency per week and average quantity per fishing trip.

TABLE 2 | Period when fishers first encountered redclaw crayfish in Lake Itezhi-Tezhi.

Period of first encounter	Frequency (n)	Percentage (%)
1–5years ago	127	39.08
6–10years ago	73	22.46
More than 10years ago	125	38.46

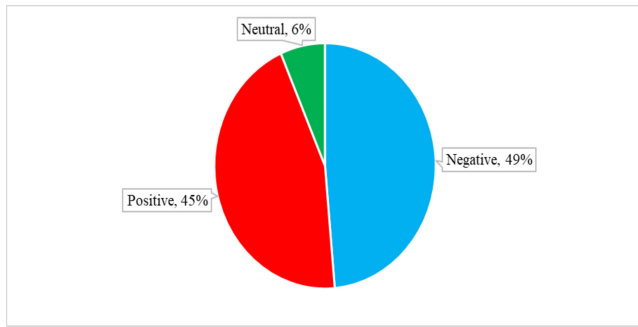


FIGURE 3 | Fishers' perceptions of redclaw crayfish in Lake Itezhi-Tezhi were mixed.

were reported by 45% of the respondents, who considered the species as a potential resource for food or income. A smaller proportion (6.0%) held neutral views, indicating no strong opinion either way.

3.5 | Environmental Impacts of Redclaw Crayfish

The presence of redclaw crayfish in lake Itezhi-Tezhi has significant environmental and economic impacts (Table 3). 78.77% of respondents reported negative environmental implications, including competition with native fish for habitat and interference with breeding. Additionally, 14.46% of respondents reported no impacts. The main concerns include redclaw crayfish eating fish caught in nets (62.46%) and damaging gear (18.15%). Furthermore, 76.92% of respondents believed that redclaw crayfish negatively affected native fish stock dynamics through predation, competition and habitat disruption. A small proportion of respondents (8.31%) perceived the environmental impacts of redclaw crayfish as positively on the fish stock.

3.6 | Economic Impacts on Fishers

The presence of redclaw crayfish has significant economic and food security impacts shown in Table 4, with 62.46% of fishers reporting reduced household income due to decreased fish catches and gear damage, whereas 20% reported increased income from redclaw crayfish sales. Additionally, 67.69% of respondents reported a decline in overall catches, and 72.62%

TABLE 3 | Reported environmental impacts of redclaw crayfish by fishers in Lake Itezhi-Tezhi.

Impact category	Response	Number of respondents	Percentage (%)
Damage to fishing gear	Negative impact	256	78.77
	No impact	47	14.46
	Positive impact	22	6.77
Main concerns	Eat fish caught in nets	203	62.46
	Damages fishing gear	59	18.15
	Disrupts fish habitats	18	5.55
	No concern	24	7.38
	Did not specify any other issue	21	6.46
Fish stock dynamics	Negative impact	250	76.92
	No impact	48	14.77
	Positive impact	27	8.31

TABLE 4 | Reported economic impacts of redclaw crayfish by fishers in Lake Itezhi-Tezhi.

Impact category	Response type	Percentage (%)
Household income	Decreased	62.46
	No change	13.84
	Increased	20
	Unsure	3.7
Catch levels	Decreased	67.69
	No change	18.46
	Increased	13.85
Food security	Negative impact	72.62
	No change	16.92
	Positive impact	10.46

reported negative impacts on household food availability due to reduced fish stocks and dietary changes. A smaller proportion reported no change or improved access to food and income through redclaw crayfish consumption, with 13.84% reporting no change in income, 18.46% no change in catch levels and 16.92% no change in food security, while 10.46% reported improved food access and 13.85% reported increased catches.

3.7 | Management and Control Strategies

3.7.1 | Community-Based and Government Strategies

The results indicate that most respondents (80.7%) supported government-led strategies for managing redclaw crayfish, while 19.3% did not specify the strategy (Figure 4). Similarly, a large proportion (78.7%) supported community-based strategies, whereas 21.3% did not specify the strategy. Support for these strategies included willingness to comply with management rules, participate in monitoring activities and contribute to collective management efforts. It is important to note that respondents' willingness to participate in management activities does not necessarily reflect their preference for who should lead overall management.

3.7.2 | Preferred Management Approach

Survey results on preferred management approaches towards redclaw crayfish are presented in Figure 5. A majority of

respondents (54.13%) favoured government-led interventions, citing the need for stronger regulation and technical support. Community-based management was preferred by 33.0% of respondents, reflecting the belief that local participation is key to effective control. A smaller proportion (12.8%) indicated no clear preference or did not specify an approach.

3.8 | Factors Influencing Fishers' Perceptions of Environmental Impacts of Redclaw Crayfish

The multiple regression model predicting perceived environmental impact of redclaw crayfish was statistically significant ($F(8, 316) = 3.92, p < 0.01$), explaining 18% of the variance in fishers' perceptions ($R^2 = 0.18$, adjusted $R^2 = 0.12$). Age was the only significant predictor ($\beta = -0.31, p < 0.01$), indicating that older fishers were less likely to perceive severe environmental impacts. The observed abundance index showed a marginal effect ($\beta = -0.19, p = 0.07$), suggesting that increased sightings may gradually normalise the species' presence. Other variables,

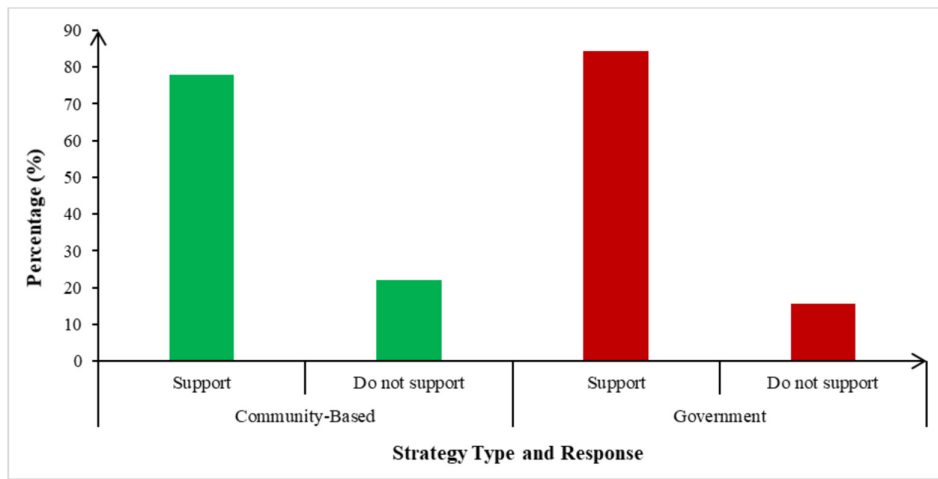


FIGURE 4 | Support for community-based and government-led strategies to manage redclaw crayfish.

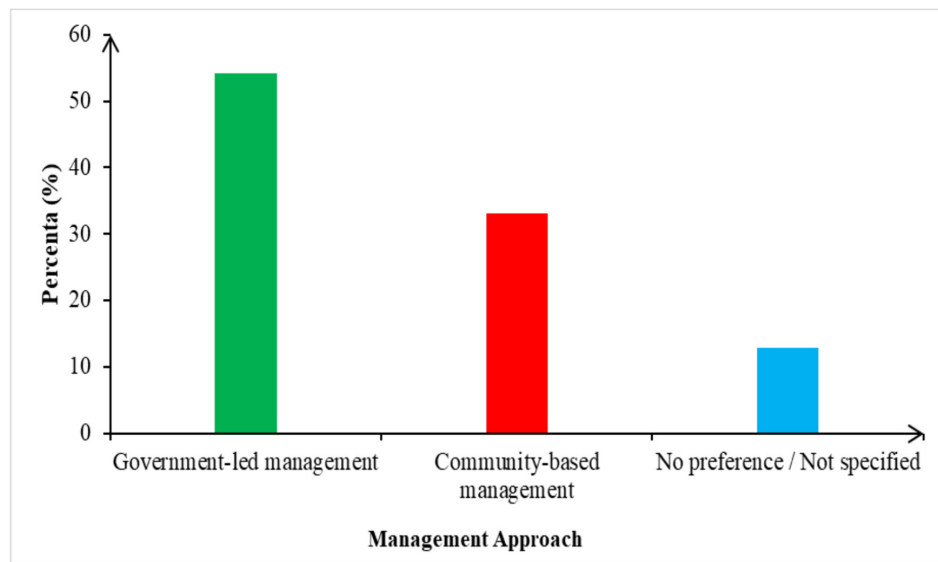


FIGURE 5 | Fishers' preferred management approaches for redclaw crayfish in Lake Itezhi-Tezhi. Most fishers favoured government-led management, while a smaller proportion supported community-based approaches, highlighting the importance of integrating formal oversight with local participation.

TABLE 5 | Multiple regression analysis predicting fishers' perceived environmental impact of redclaw crayfish.

Predictor	B	SE	95% CI	p
Constant	2.40	0.28	2.40 ± 1.96 × 0.28 → [1.85, 2.95]	<0.001
Age group	-0.13	0.05	-0.13 ± 1.96 × 0.05 → [-0.23, -0.03]	0.004
Observed redclaw crayfish abundance index	-0.10	0.06	-0.10 ± 1.96 × 0.06 → [-0.22, 0.02]	0.07
Education level	0.04	0.08	0.04 ± 1.96 × 0.08 → [-0.12, 0.20]	0.63
Fishing experience	-0.01	0.05	-0.01 ± 1.96 × 0.05 → [-0.11, 0.09]	0.81
First encounter	-0.06	0.06	-0.06 ± 1.96 × 0.06 → [-0.18, 0.06]	0.36
Catch frequency	-0.02	0.05	-0.02 ± 1.96 × 0.05 → [-0.12, 0.08]	0.76
Population affected	0.10	0.08	0.10 ± 1.96 × 0.08 → [-0.06, 0.26]	0.21
Concerns	0.07	0.05	0.07 ± 1.96 × 0.05 → [-0.03, 0.17]	0.16
Mostly found	0.10	0.07	0.10 ± 1.96 × 0.07 → [-0.04, 0.24]	0.17

Note: Age was the only significant predictor, indicating that younger fishers perceive greater environmental impact, while other demographic and ecological factors showed no significant influence.

including education, fishing experience and first encounter, were not significant predictors (Table 5). These findings highlight that environmental perceptions vary by age and exposure, which may inform targeted awareness and management interventions.

3.9 | Factors Influencing Fishers' Perceptions of Economic Impacts of Redclaw Crayfish

The factors influencing fisher's economic perceptions of redclaw crayfish in Lake Itzhi-Tezhi are presented in Table 6. The model was not statistically significant ($F(9,94) = 0.544, p = 0.839$) and accounted for only 5% of the variance in perceived economic impact ($R^2 = 0.050$). None of the individual predictors were significant ($p > 0.05$).

4 | Discussion

The introduction of non-native species generates complex socio-environmental dynamics that frequently challenge conventional management frameworks (Wang et al. 2025; Xu et al. 2025). In this context, the present study examined the establishment of the invasive, redclaw crayfish in Lake Itzhi-Tezhi, Zambia, through the perspectives of local fishers. The findings indicate a system undergoing environmental and social reorganisation, wherein the rapid proliferation of the species coincides with heterogeneous human perceptions and responses, creating a critical window for targeted management and intervention.

4.1 | Demographic Patterns of Fishers

In our survey, the composition of respondents reflects well-known gendered patterns in small-scale fisheries: Harvesting is predominantly a male activity, while women more often handle postharvest processing and marketing (Hossain et al. 2015; Frangoudes and Gerrard 2018; Arlinghaus et al. 2021; Tonga

et al. 2025). That division in the physical demands of harvesting and local cultural norms explains why our sample is dominated by male harvesters (Farnworth et al. 2015; Salmi and Sonck-Rautio 2018; Modiri et al. 2025). Most respondents are in their peak working years, which is typical for physically demanding fisheries. Importantly, this study also finds a clear generational divide where younger fishers are significantly more likely to report severe environmental impacts from invasive species. This may reflect greater environmental awareness among younger cohorts due to recent education and different temporal perspectives, a phenomenon related to shifting baseline syndrome where generations establish their own norms for ecosystem health (Kollmuss and Agyeman 2002; Soga and Gaston 2018). By contrast, economic views about the crayfish did not align with demographic factors in our data. However, they appear to be driven by immediate experiences such as gear damage or differential market access. Together, these patterns shape whose experiences inform management discussions and underline the risk that postharvest and market perspectives may be underrepresented in local decision-making.

4.2 | Temporal Patterns of Redclaw Crayfish Encounter and Establishment

Building on this demographic context, the temporal patterns of first encounters with redclaw crayfish provide critical insight into the invasion's timeline. Our findings, which report recent first encounters by fishers, align precisely with the rapid expansion of the species documented in the Zambezi Basin, confirming its status as a high-impact invader in Southern Africa (Madzivanzira et al. 2022). The significant environmental impacts perceived by fishers are consistent with the species' known traits, including a high invader relative impact potential (Dick et al. 2017; Madzivanzira et al. 2021a). However, the socio-economic perception is complex, mirroring the global 'double-edged sword' pattern of crayfish invasions, which threaten traditional fisheries while simultaneously creating new economic opportunities (Lodge et al. 2012; Madzivanzira et al. 2020; Pienkowski et al. 2015).

TABLE 6 | Multiple linear regression predicting perceived economic impact of redclaw crayfish.

Predictor	B	SE	95% CI	p
Constant	2.93	0.37	2.93 ± 1.96 × 0.37 → [2.20, 3.66]	<0.001
Observed redclaw crayfish abundance index	-0.10	0.07	-0.10 ± 1.96 × 0.07 → [-0.24, 0.04]	0.18
Age group	-0.06	0.06	-0.06 ± 1.96 × 0.06 → [-0.18, 0.06]	0.31
Education level	-0.02	0.10	-0.02 ± 1.96 × 0.10 → [-0.22, 0.18]	0.83
Fishing experience	0.02	0.07	0.02 ± 1.96 × 0.07 → [-0.12, 0.16]	0.74
First encounter	-0.04	0.08	-0.04 ± 1.96 × 0.08 → [-0.20, 0.12]	0.63
Catch frequency	0.04	0.06	0.04 ± 1.96 × 0.06 → [-0.08, 0.16]	0.49
Population affected	0.04	0.10	0.04 ± 1.96 × 0.10 → [-0.16, 0.24]	0.63
Concerns	-0.05	0.06	-0.05 ± 1.96 × 0.06 → [-0.17, 0.07]	0.39
Mostly found	-0.00	0.09	-0.00 ± 1.96 × 0.09 → [-0.18, 0.18]	0.99

Note: None of the predictors were statistically significant, suggesting that fishers' perceptions of economic impact are not strongly linked to demographic or ecological factors.

Critically, current catch data indicate that the crayfish is not yet encountered in large quantities by most fishers. These patterns of low-volume, intermittent harvests are characteristic of an early expansion phase, a pattern mirrored in other systems (Marufu et al. 2014; Maurice et al. 2020) and analogous to newly discovered populations like that in south Texas, United States (Sanjar et al. 2023). The rate of this expansion may be moderated by biotic factors, such as competition with native species, which have been shown to suppress crayfish growth in other systems (Jutagate et al. 2023). This early stage of invasion offers a critical window for management, as the documented environmental impacts of established populations in Southern Africa highlight the potential consequences and emphasise that containment and targeted intervention are more achievable now than once the species becomes widespread (Madzivanzira et al. 2022).

4.3 | Fishers' Perceptions and Environmental Impacts

These initial encounters have shaped sharply divided perceptions among fishers, reflecting the invasion's dualistic nature. This dichotomy of viewing the crayfish as both an environmental threat and an economic resource exemplifies the complex cultural impacts of invasive species, which can be simultaneously impoverishing and facilitating (Pfeiffer and Voeks 2008; Lodge et al. 2012). Our results indicate that age strongly influences environmental perception, with younger fishers expressing greater concern about impacts, while older fishers are less likely to perceive severe effects. By contrast, economic perceptions were not significantly predicted by the regression model (Table 6). This indicates that demographic and experiential factors accounted for very little of the variation in fishers' economic views. Instead, these perceptions are likely influenced by immediate, context-specific experiences, such as gear damage or differences in market access. This aligns with prior socio-environmental studies demonstrating that lived experience, rather than formal education, often shapes environmental risk perceptions among resource-dependent communities (Bernos et al. 2022; Kapitzka et al. 2019). This finding

aligns with systematic reviews, which show that social perceptions of invasive species are rarely monolithic but are instead determined by a complex interplay of perceived impacts and benefits, values and livelihood strategies (Kapitzka et al. 2019; Shackleton et al. 2019). A substantial number of respondents held negative views, citing damage to fishing gear and concerns over predation on native fish stocks, aligning with well-documented environmental impacts of invasive crayfish (Westman 2002). Conversely, a significant portion of fishers perceived economic potential, viewing it as a viable alternative source of food and income. Similar divergent responses have been observed globally, including in Jamaica (Pienkowski et al. 2015), Madagascar (Andriantsoa et al. 2020) and southern Spain (Conde and Domínguez 2015), as well as in other regions where invasive crayfish have been integrated into local economies (Bohman et al. 2006; Jussila et al. 2021).

Additionally, the predominant concern regarding environmental impact was supported by fisher observations of predation, competition with native species and disruption of breeding habitats. These on-the-ground accounts are consistent with regional scientific studies showing that redclaw crayfish can displace native decapods and alter trophic dynamics (Madzivanzira et al. 2022; Majdi et al. 2022). However, the outcome of such competition may be context dependent. Experimental research from Thailand suggests that native freshwater crabs (*Esanthelphusa dugasti*) can inhibit the growth of redclaw crayfish, potentially providing a degree of biotic resistance to its invasion (Jutagate et al. 2023). The extent to which native decapod species in Lake Itzhi-Tezhi may restrict the expansion of invasive crayfish remains a critical question for future research. The species' invasive success and significant impact can be attributed to its life history traits, including high fecundity, a broad diet and a high tolerance for environmental stressors (Tyser and Douthwaite 2014; Liu et al. 2024). Invasions of comparable magnitude in other regions have led to profound trophic shifts and biodiversity loss, highlighting the risk of long-term ecosystem change without management (Yau and Lau 2021; Majdi et al. 2022). Therefore, fishers' local environmental knowledge provides critical, real-time evidence that complements formal monitoring.

4.4 | Contrasting Economic Consequences and Management Imperatives

The invasion of *Cherax quadricarinatus* in Lake Itzhi-Tezhi presents a socio-ecological paradox. While most fishers reported negative financial impacts, including reduced catches and increased costs from gear damage, these findings mirror patterns observed in other Southern African fisheries (Chakandinakira et al. 2023). Simultaneously, a segment of fishers derived income from harvesting and selling crayfish, highlighting a positive economic dimension. These contrasting outcomes demonstrate an uneven distribution of costs and benefits, influenced by factors such as market access, processing capacity and seasonal variation in native catches.

Nevertheless, potential food safety risks, including heavy metal bioaccumulation, remain a critical barrier to safe commercialisation without regulatory oversight (Ejaz et al. 2024; Hasimuna et al. 2023, 2024). Policies could adopt 'feasible exploitation' approaches, similar to those used for red swamp crayfish (*Procambarus clarkii*). Such approaches combine regulated harvesting with restrictions on the trade of live, egg-bearing individuals to protect ecosystems while allowing economic use (Shi et al. 2025; Conde and Domínguez 2015).

While evidence from other systems supports the combination of removal and utilisation In Jamaica, invasive redclaw crayfish provided an important supplementary income for fishers, particularly during periods of low native shrimp availability (Pienkowski et al. 2015). Similarly, studies in southern Spain show that combining traps with fine-mesh netting enhances capture efficiency, particularly of juveniles, improving population control while allowing for sustainable harvest (García de Lomas et al. 2020). Public willingness to consume invasive species can also motivate removal efforts; for example, in France, 96% of respondents indicated they would support culling the invasive blue crab (*Callinectes sapidus*) by purchasing and consuming it, particularly younger adults who viewed this as an act of environmental protection and civic engagement (Marchessaux et al. 2024).

In this study, fishers in Lake Itzhi-Tezhi expressed strong support for collaborative management approaches integrating community participation with government oversight. Comparable interventions in Zimbabwe and Indonesia have demonstrated that community-based trapping combined with regulatory oversight reduces ecological impact while supporting livelihoods (Madzivanzira et al. 2022; Taryono et al. 2021). This approach aligns with participatory governance principles, where local stewardship combined with state authority strengthens compliance, resilience and adaptive capacity (Lipper et al. 2014).

4.5 | Management Implications

The case of redclaw crayfish highlights the need for integrated, adaptive management strategies that balance ecological protection with socio-economic opportunities. First, controlled harvesting and value-chain development can create economic incentives for removal, thereby alleviating fishing pressure on native species. Evidence from Jamaica demonstrates that such strategies can supplement incomes for small-scale fishers, particularly those

most dependent on fisheries (Pienkowski et al. 2015). In addition, mixed-method removal strategies, such as combining traps with fine-mesh netting, can increase removal efficiency across life stages, especially juvenile cohorts, supporting both population control and sustainable utilisation (García de Lomas et al. 2020).

Moreover, effective regulatory and governance frameworks are essential. Policies should integrate scientific guidance, community engagement and legal oversight, as global studies suggest that combining ecological control, community-based exploitation and systematic monitoring can maximise both ecological and economic outcomes (Shi et al. 2025). Furthermore, continuous monitoring of population dynamics, native species and fishery yields will facilitate iterative policy adjustments, ensuring that environmental protection and livelihood objectives are met simultaneously. Finally, if commercialisation is pursued, precautionary measures should prevent the release of live, egg-bearing females, while promoting value-added processing to reduce ecological risks and enhance economic returns (Shi et al. 2025).

Taken together, these integrated strategies allow the invasion to be reframed not solely as a threat but as a socio-ecological challenge that provides opportunities for innovation, sustainable livelihoods and adaptive management of Zambia's inland fisheries.

4.6 | Limitations and Future Research

While this study provides valuable insights into the social dimensions of biological invasions, certain limitations warrant cautious interpretation. The reliance on self-reported data, though vital for capturing local perceptions, may reflect recent experiences or subjective beliefs rather than long-term environmental trends. The absence of independent environmental data on crayfish abundance at landing sites further limits direct validation of fishers' observations and the establishment of causal links between species occurrence and reported impacts. Consequently, the regression models presented here primarily describe patterns of perception rather than definitive environmental relationships. Nevertheless, the convergence between fishers' reported impacts such as gear damage, predation and habitat disturbance and the documented environmental effects of redclaw crayfish in Lake Itzhi-Tezhi (Madzivanzira et al. 2022) suggests that these perceptions align with genuine environmental pressures.

Future research should pursue integrative socio-environmental assessments that combine community perspectives with empirical environmental data to clarify the mechanisms driving both invasion dynamics and human responses. Investigating the economic feasibility of small-scale crayfish aquaculture could help transform this invasive species into a sustainable livelihood resource. Further, the development and testing of community-based monitoring frameworks would enable adaptive responses to emerging invasions while strengthening local stewardship. Additional studies focusing on reproductive biology, population dynamics and harvest thresholds are needed to inform sustainable exploitation and minimise environmental disruption. Finally, nutritional and feed potential assessments could determine the species' contribution to food and livelihood security.

Collectively, these priorities advance a holistic framework for balancing environmental control with socio-economic opportunity in managing aquatic invasions.

5 | Conclusion

The establishment of the redclaw crayfish in Lake Itezhi-Tezhi marks a growing environmental and socio-economic concern for local fishing communities. The species' rapid spread and interactions with native fauna have altered fishing practices and habitats, leading most fishers to perceive it as a harmful invader responsible for gear damage, competition with indigenous fish species and reduced income. Nevertheless, a minority view it as a potential resource that could be harnessed for food and income generation. The current lack of structured markets, technical knowledge and institutional support, however, limits its sustainable utilisation. Addressing this invasion requires a shift toward adaptive and inclusive management that recognises both the environmental risks and livelihood opportunities associated with the species. Strengthening local awareness, fostering community-led harvesting initiatives and establishing policy frameworks that guide regulated use could transform the invasion from a purely environmental threat into a managed socio-economic resource.

Author Contributions

Patience Bwalya: methodology, investigation, data curation, formal analysis, visualization, project administration, writing – original draft. **Henry Bwalya:** investigation, writing – original draft, writing – review and editing. **Given Mbewe:** investigation, writing – original draft. **Ipaalo Ndhlovu:** investigation, writing – original draft. **Joyce Mbewe:** investigation, writing – original draft. **Hong Yang:** methodology, resources, writing – review and editing. **Hyun S. Gweon:** methodology, writing – review and editing. **Moses Chibesa:** methodology, writing – review and editing. **Chisomo J. Phiri:** writing – original draft, writing – review and editing. **Mwiinga Kapila:** investigation, writing – original draft, writing – review and editing. **Africa Muzungaire:** investigation, writing – original draft, writing – review and editing. **Stanley Phiri:** investigation, writing – original draft. **Christopher Mulwanda:** resources, writing – review and editing. **Malambo Muloongo:** data curation, formal analysis, writing – original draft. **Brian P. Munganga:** data curation, formal analysis, writing – original draft, writing – review and editing. **Joseph Mphande:** data curation, formal analysis, writing – original draft, writing – review and editing. **Sahya Maulu:** methodology, supervision, writing – original draft, writing – review and editing. **Oliver J. Hasimuna:** conceptualization, methodology, resources, data curation, formal analysis, visualization, supervision, project administration, writing – original draft, writing – review and editing.

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Ethics Statement

Ethical approval for the social data used in this study was obtained under a broader research project approved by the School of Archaeology, Geography and Environmental Science Research Ethics Committee at the University of Reading (Approval Reference: SREC2025/04). All ethical requirements, including informed consent, voluntary participation and the protection of anonymity and confidentiality, were adhered to throughout data collection and analysis.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The datasets generated and analysed during this study are not publicly available due to privacy and ethical restrictions concerning local community data and stakeholder information. The data are available from the corresponding author upon reasonable request and with permission from the relevant community and institutional bodies in Itezhi-Tezhi.

Permission to Reproduce Material From Other Sources

The authors have nothing to report.

References

- Andriantsoa, R., J. P. G. Jones, V. Achimescu, et al. 2020. “Perceived Socio-Economic Impacts of the Marbled Crayfish Invasion in Madagascar.” *PLoS ONE* 15, no. 4: e0231773. <https://doi.org/10.1371/journal.pone.0231773>.
- Arlinghaus, R., Ø. Aas, J. Alós, et al. 2021. “Global Participation in and Public Attitudes Toward Recreational Fishing: International Perspectives and Developments.” *Reviews in Fisheries Science & Aquaculture* 29, no. 1: 58–95. <https://doi.org/10.1080/23308249.2020.1782340>.
- Bernos, T. A., K. M. Jeffries, and N. E. Mandrak. 2022. “Aquatic Invasive Species Specialists' Perceptions on the Importance of Genetic Tools and Concepts to Inform Management.” *Biological Invasions* 24, no. 10: 3019–3034. <https://doi.org/10.1007/s10530-022-02758-x>.
- Bohman, P., F. Nordwall, and L. Edsman. 2006. “The Effect of the Large-Scale Introduction of Signal Crayfish on the Spread of Crayfish Plague in Sweden.” *Bulletin Français De La Pêche Et De La Pisciculture*, no. 380–381: 1291–1302. <https://doi.org/10.1051/kmae:2006026>.
- Chakandinakira, A. T., T. C. Madzivanzira, S. Mashonga, et al. 2023. “Socioeconomic Impacts of Australian Redclaw Crayfish (*Cherax quadricarinatus*) in Lake Kariba.” *Biological Invasions* 25: 2801–2812. <https://doi.org/10.1007/s10530-023-03074-8>.
- Chimba, N., and G. Musuka. 2014. “Impact of Closed Fishing Season on the Livelihood of Fishers: a Case of Stratum I of Kafue Fishery.” *International Journal of Life Sciences Research* 2, no. 1: 49–62. www.researchpublish.com.
- Chimiti, F., and S. Kawimbe. 2020. “Economic Impact of Sustainable Fishing Practices on Lake Itezhi-Tezhi: Balancing Profitability and Environmental Consideration.” *International Journal of Advanced Engineering and Management* 6, no. 4: 28–31. <https://doi.org/10.35629/5252-0604802810>.

- Chivambo, S., A. Mussagy, and A. Barki. 2020. "Assessment of Interspecific Interactions Between the Invasive Redclaw Crayfish (*Cherax quadricarinatus*) and the Mozambique Tilapia (*Oreochromis mossambicus*)." *Brazilian Journal of Biology* 80, no. 4: 717–726. <https://doi.org/10.1590/1519-6984.217868>.
- Choi, J. Y., and S. K. Kim. 2020. "Effects of Aquatic Macrophytes on Spatial Distribution and Feeding Habits of Exotic Fish Species *Lepomis macrochirus* and *Micropterus salmoides* in Shallow Reservoirs in South Korea." *Sustainability* 12, no. 4: 1–14. <https://doi.org/10.3390/su12041447>.
- Conde, A., and J. Domínguez. 2015. "A Proposal for the Feasible Exploitation of the Red Swamp Crayfish *Procambarus Clarkii* in Introduced Regions." *Conservation Letters* 8, no. 5: 414–422. <https://doi.org/10.1111/conl.12164>.
- Cowan, D. F., D. F. Webber, and M. B. C. Hickey. 2017. "Redclaw Crayfish (*Cherax quadricarinatus*) in Jamaica: a Review of the Invasion and Its Impacts." *Management of Biological Invasions* 8, no. 2: 141–154.
- de Moor, I. J. 2002. "Potential Impacts of Alien Freshwater Crayfish in South Africa." *African Journal of Aquatic Science* 27, no. 1: 85–96.
- Diagne, C., B. Leroy, A.-C. Vaissière, et al. 2021. "High and Rising Economic Costs of Biological Invasions Worldwide." *Nature* 592, no. 7855: 571–576. <https://doi.org/10.1038/s41586-021-03405-6>.
- Dick, J. T. A., C. Laverty, J. J. Lennon, et al. 2017. "Invader Relative Impact Potential: a New Metric to Understand and Predict the Ecological Impacts of Existing, Emerging and Future Invasive Alien Species." *Journal of Applied Ecology* 54, no. 4: 1259–1267. <https://doi.org/10.1111/1365-2664.12849>.
- Didham, R., J. Tylianakis, M. Hutchison, R. Ewers, and N. Gemmill. 2005. "Are Invasive Species the Drivers of Ecological Change?" *Trends in Ecology & Evolution* 20, no. 9: 470–474. <https://doi.org/10.1016/j.tree.2005.07.006>.
- Douthwaite, R., S. Vrdoljak, A. Tyser, and E. Jones. 2018. "The Introduction, Spread and Ecology of Redclaw Crayfish *Cherax quadricarinatus* in the Zambezi Catchment." *African Journal of Aquatic Science* 43: 353–366. <https://doi.org/10.2989/16085914.2018.1517080>.
- Early, R., B. A. Bradley, J. S. Dukes, et al. 2016. "Global Threats From Invasive Alien Species in the Twenty-first Century and National Response Capacities." *Nature Communications* 7, no. 1: 12485. <https://doi.org/10.1038/ncomms12485>.
- Ejaz, A., S. Ullah, S. Ijaz, et al. 2024. "Bioaccumulation and Health Risk Assessment of Heavy Metals in *Labeo Rohita* and *Mystus Seenghala* From Jhelum River, Punjab, Pakistan." *Water (Basel)* 16, no. 20: 2994. <https://doi.org/10.3390/w16202994>.
- FAO. 1992. *Introduction of Lake Tanganyika Sardines Into Itezhi-Tezhi*. Food and Agriculture Organization of the United Nations. <https://www.fao.org/4/v2648e/V2648E04.htm>.
- Farnworth, C. R., N. Sultana, P. Kantor, and A. Choudhury. 2015. *Gender Integration in Aquaculture Research and Technology Adoption Processes: Lessons Learned in Bangladesh (Working Paper 2015–17)*. WorldFish.
- Frangoudes, K., and S. Gerrard. 2018. "Gendering Change in Small-Scale Fisheries and Fishing Communities in a Globalized World." *Maritime Studies* 17, no. 2: 117–124. <https://doi.org/10.1007/s40152-018-0113-9>.
- Gallardo, B., M. Clavero, M. Sánchez, and M. Vilà. 2015. "Global Ecological Impacts of Invasive Species in Aquatic Ecosystems." *Global Change Biology* 22, no. 1: 151–163. <https://doi.org/10.1111/gcb.13004>.
- García de Lomas, J., E. D. Dana, and R. González. 2020. "Traps and Netting, Better Together Than Alone: an Innovative Approach to Improve *Procambarus clarkii* Management." *Knowledge and Management of Aquatic Ecosystems* 421: 39. <https://doi.org/10.1051/kmae/2020031>.
- Grey, J., and M. C. Jackson. 2012. "'Leaves and Eats Shoots': Direct Terrestrial Feeding Can Supplement Invasive Red Swamp Crayfish in Times of Need." *PLoS ONE* 7, no. 8: e42575. <https://doi.org/10.1371/journal.pone.0042575>.
- Hanley, N., and M. Roberts. 2019. "The Economic Benefits of Invasive Species Management." *People and Nature* 1, no. 2: 124–137. <https://doi.org/10.1002/pan3.31>.
- Hasimuna, O. J., M. Chibesa, B. R. Ellender, and S. Maulu. 2021. "Variability of Selected Heavy Metals in Surface Sediments and Ecological Risks in the Solwezi and Kifubwa Rivers, Northwestern Province, Zambia." *Scientific African* 12: 00822. <https://doi.org/10.1016/j.sciaf.2021.e00822>.
- Hasimuna, O. J., M. Chibesa, I. Mumbula, et al. 2023. "Contamination of Selected Heavy Metals in *Limnothrissa miodon* (Boulenger, 1906) in the Four Strata of Lake Kariba Zambia: Are the Consumers at Risk?" *Journal of Environmental Science and Health, Part B* 58, no. 7: 521–529. <https://doi.org/10.1080/03601234.2023.2235262>.
- Hasimuna, O. J., W. W. Jere, A. H. Mtethiwa, et al. 2024. "Assessment of Trace Elements (Cu, Fe, and Zn) in *Limnothrissa Miodon* From Lake Kariba, Zambia: Implications for Ecological and Human Health." *Journal of Applied Animal Research* 52, no. 1: 2310753. <https://doi.org/10.1080/09712119.2024.2310753>.
- Hasimuna, O. J., S. Maulu, and M. Chibesa. 2022. "Assessment of Heavy Metal Contamination in Water and Largescale Yellowfish (*Labeobarbus marequensis*, Smith 1841) From Solwezi River, North-Western Zambia." *Cogent Food & Agriculture* 8, no. 1: 2121198. <https://doi.org/10.1080/23311932.2022.2121198>.
- Hasimuna, O. J., S. Maulu, C. Monde, and M. Mweemba. 2019. "Cage Aquaculture Production in Zambia: Assessment of Opportunities and Challenges on Lake Kariba, Siavonga District." *Egyptian Journal of Aquatic Research* 45, no. 3: 281–285. <https://doi.org/10.1016/j.ejar.2019.06.007>.
- Haubrock, P. J., F. J. Oficialdegui, Y. Zeng, J. Patoka, D. C. J. Yeo, and A. Kouba. 2021. "The Redclaw Crayfish: A Prominent Aquaculture Species with Invasive Potential in Tropical and Subtropical Biodiversity Hotspots." *Reviews In Aquaculture* 13, no. 3: 1488–1530. <https://doi.org/10.1111/raq.12531>.
- Holdich, D. M. 1999. "The Negative Effects of Established Crayfish Introductions." In *Crayfish in Europe as Alien Species*, 31–47. Routledge.
- Hossain, F. I., M. I. Miah, R. Pervin, M. H. A. Hosen, and M. R. Haque. 2015. "Study on the Socio-Economic Condition of Fishermen of the Punorvaba River Under Sadar Upazila, Dinajpur." *Journal of Fisheries* 3, no. 1: 239–244. <https://doi.org/10.17017/fish.v3i1.2015.50>.
- IPBES. 2023. In *Thematic Assessment Report on Invasive Alien Species and Their Control of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, edited by H. E. Roy, A. Pauchard, P. Stoett, et al. IPBES Secretariat. <https://doi.org/10.5281/zenodo.7430682>.
- Jackson, M. C., T. Jones, M. Milligan, et al. 2016. "Niche Differentiation Among Invasive Crayfish and Their Impacts on Ecosystem Structure and Functioning." *Freshwater Biology* 61, no. 2: 211–224.
- Jamil, M., R. Shapawi, A. Yong, L. Lim, A. Tuzan, and N. Halid. 2022. "Effects of Different Mineral Inclusions in Anchovy Byproduct-Based Feeds on Growth Performance of Redclaw Crayfish (*Cherax quadricarinatus*)." *Malaysian Applied Biology* 51, no. 3: 137–145. <https://doi.org/10.55230/mabjournal.v51i3.2380>.
- Jussila, J., L. Edsman, I. Maguire, J. Diéguez-Uribeondo, and K. Theissing. 2021. "Money Kills Native Ecosystems: European Crayfish as an Example." *Frontiers in Ecology and Evolution* 9: 648495. <https://doi.org/10.3389/fevo.2021.648495>.
- Jutagate, T., W. Kwangkhwang, and S. Saowakoon. 2023. "Growth and Competitions of the Australian Redclaw Crayfish, *Cherax quadricarinatus* (von Martens, 1868) in Thailand: the Experimental Approaches."

- Aquatic Invasions* 18, no. 1: 103–117. <https://doi.org/10.3391/ai.2023.18.1.103301>.
- Kapitza, K., H. Zimmermann, B. Martín-López, and H. von Wehrden. 2019. “Research on the Social Perception of Invasive Species: a Systematic Literature Review.” *NeoBiota* 43: 47–68.
- Kollmuss, A., and J. Agyeman. 2002. “Mind the Gap: Why Do People Act Environmentally and What Are the Barriers to Pro-Environmental Behaviour?” *Environmental Education Research* 8, no. 3: 239–260. <https://doi.org/10.1080/13504620220145401>.
- Lipper, L., P. Thornton, B. M. Campbell, et al. 2014. “Climate-Smart Agriculture for Food Security.” *Nature Climate Change* 4, no. 12: 1068–1072. <https://doi.org/10.1038/nclimate2437>.
- Liu, Z., J. Zhang, H. Li, and M. Wang. 2024. “Genome Assembly of Redclaw Crayfish Provides Insights Into Its Immune Adaptation and Hypoxia Tolerance.” *Bmc Genomics* 25, no. 1: 120. <https://doi.org/10.1186/s12864-024-10673-9>.
- Lodge, D. M., A. Deines, F. Gherardi, et al. 2012. “Global Introductions of Crayfishes: Evaluating the Impact of Species Invasions on Ecosystem Services.” *Annual Review of Ecology, Evolution, and Systematics* 43, no. 1: 449–472.
- Lopez, M. A., F. Alvarez, and O. Mejia. 2011. “Ecological and Economic Impacts of the Redclaw Crayfish (*Cherax quadricarinatus*) in Mexico.” *Aquaculture Research* 42, no. 10: 1441–1451.
- Madzivanzira, T. C., J. South, B. Ellender, et al. 2021b. “Distribution and Establishment of the Alien Australian Red-Claw Crayfish, *Cherax quadricarinatus*, in the Zambezi Basin.” *Aquatic Conservation: Marine and Freshwater Ecosystems* 31, no. 11: 3156–3168. <https://doi.org/10.1002/aqc.3703>.
- Madzivanzira, T. C., J. South, and O. L. F. Weyl. 2021a. “Invasive Crayfish Outperform Potamonautid Crabs at Higher Temperatures.” *Freshwater Biology* 66, no. 5: 978–991. <https://doi.org/10.1111/fwb.13691>.
- Madzivanzira, T. C., O. L. F. Weyl, and J. South. 2020. “Socioeconomic Impacts of Invasive Crayfish in African Inland Waters.” *Fisheries Management and Ecology* 27, no. 5: 439–449.
- Madzivanzira, T. C., O. L. F. Weyl, and J. South. 2022. “Ecological and Potential Socioeconomic Impacts of Two Globally-Invasive Crayfish.” *NeoBiota* 72: 25–43. <https://doi.org/10.3897/neobiota.72.71868>.
- Majdi, M., J. South, T. C. Madzivanzira, and O. L. F. Weyl. 2022. “First Record of *Cherax quadricarinatus* in the Crocodile River, Kruger National Park, South Africa.” *BioInvasions Records* 11, no. 3: 687–693. <https://doi.org/10.3391/bir.2022.11.3.10>.
- Marchessaux, G., B. Sibella, M. Garrido, A. Abbruzzo, and G. Sarà. 2024. “Can We Control Marine Invasive Alien Species by Eating Them? The Case of *Callinectes sapidus*.” *Ecology and Society* 29, no. 2: 19. <https://doi.org/10.5751/ES-15056-290219>.
- Marufu, L. T., C. Phiri, and T. Nhiwatiwa. 2014. “Invasive Australian Crayfish *Cherax quadricarinatus* in the Sanyati Basin of Lake Kariba: a Preliminary Survey.” *African Journal of Aquatic Science* 39, no. 2: 233–236. <https://doi.org/10.2989/16085914.2014.922457>.
- Maulu, S., O. J. Hasimuna, C. Monde, and M. Mweemba. 2020. “An Assessment of Post-Harvest Fish Losses and Preservation Practices in Siavonga District, Southern Zambia.” *Fisheries and Aquatic Sciences* 23, no. 1: 25. <https://doi.org/10.1186/s41240-020-00170-x>.
- Maulu, S., O. J. Hasimuna, B. Mutale, J. Mphande, and E. Siankwilimba. 2021. “Enhancing the Role of Rural Agricultural Extension Programs in Poverty Alleviation: a Review.” *Cogent Food & Agriculture* 7, no. 1: 1886663. <https://doi.org/10.1080/23311932.2021.1886663>.
- Maulu, S., C. G. Musuka, M. Molefe, et al. 2024. “Contribution of Fish to Food and Nutrition Security in Southern Africa: Challenges and Opportunities in Fish Production.” *Frontiers in Nutrition* 11: 1424740. <https://doi.org/10.3389/fnut.2024.1424740>.
- Maurice, S., N. Bright, H. Llyod, K. Kennedy, and M. Confred. 2020. “Fishers’ Perspective on Abundance and Economic Value of *Cherax quadricarinatus* in Lake Kariba, Zambia.” *International Journal of Agriculture, Forestry and Fisheries* 8: 72–78. <http://www.opensciencenline.com/journal/ijaff>.
- Mkumbo, O. C., T. Nhiwatiwa, and I. G. Cowx. 2018. “The Impacts of Invasive Non-Native Species on Native Fish Populations in Africa.” *Aquatic Conservation: Marine and Freshwater Ecosystems* 28, no. 2: 341–353.
- Modiri, F., R. Sadeghi, and A. Rahimi. 2025. “The Gendered Division of Household Labor and Decision-Making in Tehran, Iran.” *International Journal of Population Studies* 11, no. 2: 109–117. <https://doi.org/10.36922/ijps.3212>.
- Mphande, J., O. J. Hasimuna, E. Kikamba, et al. 2023. “Application of Anaesthetics in Fish Hatcheries to Promote Broodstock and Fish Seed Welfare in Zambia.” *Cogent Food & Agriculture* 9, no. 1: 2211845. <https://doi.org/10.1080/23311932.2023.2211845>.
- Mugwedi, L. 2020. “Harnessing Opportunities Provided by the Invasive *Chromolaena odorata* to Keep It Under Control.” *Sustainability* 12, no. 16: 6505. <https://doi.org/10.3390/su12166505>.
- Muhala, V., T. F. Chicombo, I. E. Macate, et al. 2021. “Climate Change in Fisheries and Aquaculture: Analysis of the Impact Caused by Iddai and Kenneth Cyclones in Mozambique.” *Frontiers in Sustainable Food Systems* 5: 714187. <https://doi.org/10.3389/fsufs.2021.714187>.
- Nambeye, E., C. Katapa, B. Chimai-Mulenga, and M. A. Rice. 2025. “Bio-Invasion and Population Dynamics of *Cherax quadricarinatus* in Zambian Waters.” *African Journal of Aquatic Science* 50, no. 1: 88–98. <https://www.ajol.info/index.php/ajas/article/view/296972>.
- Núñez, M. A., S. Kuebbing, R. D. Dimarco, and D. Simberloff. 2012. “Invasive Species: to Eat or Not to Eat, That Is the Question.” *Conservation Letters* 5, no. 5: 334–341. <https://doi.org/10.1111/j.1755-263X.2012.00250.x>.
- Nyirenda, M. S. 2015. “Fish Trading at Lake Itzhi-Tezhi: a Brief Overview.” https://www.academia.edu/123817727/FISH_TRADING_AT_LAKE_ITEZHI_TEZHI_A_BRIEF_OVERVIEW.
- Petersen, R., A. Hoffman, P. Kotze, and S. Marr. 2017. “First Record of the Invasive Australian Redclaw Crayfish, *Cherax quadricarinatus* (von Martens, 1868), in the Crocodile River, Kruger National Park, South Africa.” *Koedoe* 59, no. 1: a1435. <https://doi.org/10.4102/koedoe.v59i1.1435>.
- Pfeiffer, J., and R. Voeks. 2008. “Biological Invasions and Biocultural Diversity: Linking Ecological and Cultural Systems.” *Environmental Conservation* 35, no. 4: 281. <https://doi.org/10.1017/s0376892908005146>.
- Pienkowski, T., S. Williams, S. McLaren, B. Wilson, and N. Hockley. 2015. “Alien Invasions and Livelihoods: Economic Benefits of Invasive Australian Redclaw Crayfish in Jamaica.” *Ecological Economics* 112: 68–77. <https://doi.org/10.1016/j.ecolecon.2015.02.012>.
- Pyšek, P., P. Hulme, D. Simberloff, et al. 2020. “Scientists’ Warning on Invasive Alien Species.” *Biological Reviews* 95, no. 6: 1511–1534. <https://doi.org/10.1111/brv.12627>.
- Pyšek, P., V. Jarošík, P. Hulme, et al. 2010. “Disentangling the Role of Environmental and Human Pressures on Biological Invasions Across Europe.” *Proceedings of the National Academy of Sciences of the United States of America* 107, no. 27: 12157–12162. <https://doi.org/10.1073/pnas.1002314107>.
- Salmi, P., and K. Sonck-Rautio. 2018. “Invisible Work, Visible Families: the Gendered Realities of Small-Scale Fishing in the Finnish Archipelago Sea.” *Maritime Studies* 17, no. 2: 213–221. <https://doi.org/10.1007/s40152-018-0104-x>.
- Sanjar, A., D. R. Davis, and R. J. Kline. 2023. “Evidence of an Established Population of *Cherax quadricarinatus* (von Martens, 1868) in South Texas, USA.” *Bioinvasions Records* 12, no. 1: 284–291. <https://doi.org/10.3391/bir.2023.12.1.24>.

- Shackleton, R. T., D. M. Richardson, C. M. Shackleton, et al. 2019. "Explaining People's Perceptions of Invasive Alien Species: a Conceptual Framework." *Journal of Environmental Management* 229: 10–26. <https://doi.org/10.1016/j.jenvman.2018.04.045>.
- Shi, J., L. Xiang, and M. H. Wong. 2025. "Sustainable Management of a Globally Invasive Species: the Case of Red Swamp Crayfish." In *Sustainable Management of Invasive Species*, edited by M. H. Wong and T. R. Seastedt, 401–433. World Scientific Publishing Europe Ltd. https://doi.org/10.1142/9781800615847_0014.
- Soga, M., and K. J. Gaston. 2018. "Shifting Baseline Syndrome: Causes, Consequences, and Implications." *Frontiers in Ecology and the Environment* 16, no. 4: 222–230. <https://doi.org/10.1002/fee.1794>.
- Soto, I., D. A. Ahmed, A. Beidas, et al. 2023. "Long-Term Trends in Crayfish Invasions Across European Rivers." *Science of the Total Environment* 867: 161537. <https://doi.org/10.1016/j.scitotenv.2023.161537>.
- Taryono, A., A. Mashar, and S. Aryasa. 2021. "Management Policy of Invasive Species Redclaw Crayfish (*Cherax Quadricarinatus*) at Lido Lake, Bogor Regency." *IOP Conference Series: Earth and Environmental Science* 744: 012090. <https://doi.org/10.1088/1755-1315/744/1/012090>.
- Tonga, A., C. Bwalya, O. J. Hasimuna, K. N. Mukuka, and J. Mphande. 2025. "Perceptions of Fishers and Fisheries Officers of a Fishing Ban in Mpulungu, Lake Tanganyika, Zambia." *Fisheries Management and Ecology* 32: e12820. <https://doi.org/10.1111/fme.12820>.
- Twardochleb, L. A., J. D. Olden, and E. R. Larson. 2013. "A Global Meta-Analysis of the Ecological Impacts of Non-Native Crayfish." *Freshwater Science* 32, no. 4: 1367–1382.
- Tyser, A. B., and R. J. Douthwaite. 2014. "Predation on Invasive Redclaw Crayfish *Cherax Quadricarinatus* by Native Fishes in the Kafue River, Zambia." *African Journal of Aquatic Science* 39, no. 4: 473–477. <https://doi.org/10.2989/16085914.2014.980774>.
- Wang, L., W. Liu, X. Zhou, et al. 2025. "Effects of Plant Invasion and Land Use Change on Soil Labile Organic Carbon in Southern China's Coastal Wetlands." *Soil Ecology Letters* 7, no. 1: 240275. <https://doi.org/10.1007/s42832-024-0275-x>.
- Westman, K. 2002. "Alien Crayfish in Europe: Negative and Positive Impacts and Interactions With Native Crayfish." In *Invasive Aquatic Species of Europe: Distribution, Impacts and Management*, edited by E. Leppäkoski, S. Gollasch, and S. Olenin, 76–95. Dordrecht, Netherlands: Springer. https://doi.org/10.1007/978-94-015-9956-6_9.
- Witt, A., R. Shackleton, T. Beale, W. Nunda, and B. Wilgen. 2019. "Distribution of Invasive Alien *Tithonia* (Asteraceae) Species in Eastern and Southern Africa and the Socio-Ecological Impacts of *Diversifolia* in Zambia." *Bothalia* 49, no. 1: a2356. <https://doi.org/10.4102/abc.v49i1.2356>.
- WWF. 2025. *Kafue Biodiversity Conservation*. African Parks. <https://www.africanparks.org/the-parks/kafue/biodiversity-conservation>.
- Xu, Y., W. Liu, Y. Lin, et al. 2025. "Impact of *Spartina Alterniflora* Invasion and Aquaculture Reclamation on Soil Aggregate Stability and Carbon Sequestration in Chinese Coastal Wetlands." *Soil Ecology Letters* 7, no. 3: 250305. <https://doi.org/10.1007/s42832-025-0305-3>.
- Yau, S., and A. Lau. 2021. "First Record of the Australian Redclaw Crayfish *Cherax quadricarinatus* (von Martens, 1868) in Hong Kong, China." *Bioinvasions Records* 10, no. 2: 385–393. <https://doi.org/10.3391/bir.2021.10.2.15>.
- Zhang, L., S. Maulu, F. Hua, M. K. Chama, and P. Xu. 2024. "Aquaculture in Zambia: The Current Status, Challenges, Opportunities and Adaptable Lessons Learnt From China." *Fishes* 9, no. 1: 14. <https://doi.org/10.3390/fishes9010014>.

Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1:** Supplementary Information.