Water SA 51(4) 352–360 / Oct 2025
https://doi.org/10.17159/wsa/2025.v51.i4.4176

Research paper

Experimental harvesting to assess small-scale fisheries using simple gear, at Krugersdrift Dam, Free State Province, South Africa, with notes on the socio-economic impact on the local community

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To address the key principles and deliverables identified in South Africa's National Freshwater (Inland) Wild Capture Fisheries Policy and Implementation Plan, and the paucity of information on inland small-scale fisheries, a small-scale fisheries pilot research project was implemented at Krugersdrift Dam, Free State Province, South Africa. This paper presents the results of a 12-month seasonal study and pilot research project, with notes on the socio-economic benefit to communities and value of freshwater fish as a natural resource. Nine unemployed youth from Ikgomotseng, a small rural town in close proximity to the dam, attended a basic course on small-scale fisheries development, with only five still actively involved by the end of the research period. Three long-lines to which sixty 6/0 circular hooks on snoods were attached, a beach seine net and three double-ended Dutch type fyke nets were used to harvest fish. The long-lines selected exclusively for sharptooth catfish *Clarias gariepinus*, while catches from the beach seine net were dominated by common carp *Cyprinus carpio*, *C. gariepinus* and moggel *Labeo umbratus*. Catch rates based on the total weight of all species caught during the study period varied from 3 147 kg for long lines, 3 363 kg for the beach seine net and 251 kg for fyke nets. Although fishing was limited to 1 week per month during the experimental phase, results indicate an average monthly income of 6 255.48 ZAR•fisher^{-1} can be expected based on 20 days of harvesting fish per month. Investigations of the price the fishers sold their catch for indicated that *C. carpio* was sold at 28 ZAR•kg^{-1}, *C. gariepinus* at 17 ZAR•kg^{-1}, and *L. umbratus* at 24 ZAR•kg^{-1}. The methodology and gear used during this study may serve as a blueprint for the further development of small-scale fisheries in the Orange-Vaal river system in South Africa.

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DATES
Received: 27 September 2024
Accepted: 18 September 2025

KEYWORDS
freshwater fish
job creation
rural development
inland fisheries

INTRODUCTION

The potential of inland fisheries for rural economic development, poverty alleviation and job creation in South Africa have been highlighted by various authors (e.g., Weyl et al., 2007; Ellender, 2008; Ellender et al., 2009; Ellender et al., 2010; McCafferty et al., 2010; Ellender, 2011; McCafferty et al., 2012; Weyl, 2012; Britz et al., 2015; Barkhuizen et al., 2016; Weyl et al., 2020). Inland fisheries in South Africa are poorly developed (Potts, 2003; Ellender et al., 2009; Ellender et al., 2010; McCafferty et al., 2010; McCafferty et al., 2012; Weyl, 2012), which amongst others is attributed to the lack of a national policy and sufficient capacity to develop the sector.

The Free State Department of Economic, Small Business Development, Tourism and Environmental Affairs (FS DESTEA) has recognised freshwater fish as a potential natural resource to be utilised, with the first permit to harvest 200 t of fish from Kalkfontein Dam issued in 1979 (Barkhuizen, 2015). This was eventually extended to 11 more impoundments from 1979 until 2014. However, most inland fisheries projects failed a few months or years after initiation, with the last having ceased operations in 2014. The reasons for failure were: (i) a lack of fixed markets, (ii) unrealistic goals, i.e., creation of large numbers of permanent jobs, (iii) expected high economic returns and profitable enterprises, and (iv) the low value of freshwater fish that lead to failure of the fisheries to produce the anticipated return on investment (Barkhuizen et al., 2016).

McCafferty et al. (2012) identified a paucity of literature on inland fisheries in South Africa, and noted the importance of determining the economic viability of inland fisheries and assessing the determinants for its success and failure. Weyl et al. (2007) made the first call for the development of a national inland fisheries policy after research conducted on the suitability of 10 dams for small-scale fisheries development in the North West Province. Inland fisheries development became the responsibility of the then Department of Agriculture, Forestry and Fisheries (DAFF) during 2009, which was mandated to take the lead with a policy development process. This was concluded with the approval of the National Freshwater (Inland) Wild Capture Fisheries Policy (NF(I)WCFP) by Cabinet in August 2021, and the subsequent release of the National Implementation Plan in December 2022 (DFFE, 2021; 2022).

The Peoples and Park Programme (P&PP) of the National Department of Forestry, Fisheries and the Environment (DFFE, 2024) was initiated during 2012. One of the main objectives of the P&PP is to facilitate processes for rural communities to take part in, strengthen governance, and allow access to protected areas for their benefit. The main objective of the current study was to initiate a pilot research project to determine the viability of a small-scale inland fisheries cooperative with

beneficiaries selected by the P&PP. The People and Parks Forum at Soetdoring Nature Reserve identified 9 unemployed youth from Ikgomotseng, a small rural town situated 11 km from Krugersdrift Dam located within the Soetdoring Nature Reserve, to participate in a small-scale fisheries pilot research project. All potential fishers attended a basic training course from 22–25 March 2022. As this project was initiated and supported by the FS DESTEA, transport to and from the Krugersdrift Dam, as well as the necessary fishing and protective gear, were provided.

Secondary objectives of the current study were to identify basic gear types that can be used by the small-scale inland fisheries sector to harvest fish and which do not require the use of a boat to operate and set the gear, in order to limit running costs. The potential fisheries species in Krugersdrift Dam had to be identified, as well as the potential socio-economic impact on the local community.

In support of a National Inland Fishery Policy, Weyl et al. (2020) proposed a list of 10 research questions, highlighting major aspects that require further research and actions to guide inland fisheries development in South Africa. The implementation plan for the NF(I)WCFP also listed 11 key deliverables in the planned actions towards the development and management of the freshwater fisheries sector in South Africa (DFFE, 2021). One of these was the need for coordinated inland fisheries management and development, which highlights the need for the implementation of inland fisheries pilot research projects. In order to address the knowledge gaps, lack of information, policy principles and key deliverables, as mentioned in the NF(I)WCFP and Implementation Plan, a small-scale fisheries pilot research project was thus initiated to guide the development of the small-scale fisheries sector in the Orange-Vaal river system.

There is a paucity of information on the prices at which fishers sell freshwater fish in South Africa. Based on several studies (see Andrew et al., 2000; Van der Waal, 2000; Ellender et al. 2010; Swanepoel, 2022), fishers sold their catch based on the fishes' size, and not weight (in kg). During a cost/benefit analysis of fisheries in the Fish River Valley Fishery in the Eastern Cape, Andrew et al. (2000) determined that the average price received for whole and un-gutted *L. umbratus* was 4 ZAR and 25 ZAR for *C. gariepinus*. Van der Waal (2000) found that fishers at the Vondo Dam in the Limpopo Province (then named Northern Province) sold large specimens of *C. carpio* with a length of 80 cm and more, for 80 ZAR. A study by Ellender et al. (2010) at Gariep Dam found the mean fish price was 72 ± 2.60 ZAR·kg^{-1}, with no distinction made between fish species. The most recent study by Swanepoel (2022) determined that small-scale fishers at Gariep Dam also sold their catch based on the fishes' size, and not by weight. However, an average price of 16 ZAR·kg^{-1} for *C. carpio* and 13.50 ZAR·kg^{-1} for all other species (i.e., *L. aeneus, C. gariepinus*) was determined.

During the current study, the fishers involved in the project also sold fish based on the fishes' size, and not weight. In order to determine the approximate monetary value of fish caught and a realistic fish price, investigations were done to determine the price for the main fisheries species based on ZAR·kg^{-1}. The average selling price was determined at 28 ZAR·kg^{-1} for *C. carpio*, 17 ZAR·kg^{-1} for *C. gariepinus* and 24 ZAR·kg^{-1} for *L. umbratus*. These amounts were subsequently used during the study to determine the expected income of the fishers and approximate monetary value.

The findings presented in this paper can guide the further development and implementation of the NF(I)WCFP in the Orange-Vaal River system in South Africa.

MATERIALS AND METHODS

Study site

A large shallow bay (028°51'22" S; 026°02'37" E) with a sand/clay bottom and a gradual slope in Krugersdrift Dam, located within the Soetdoring Nature Reserve, Free State Province, was selected as the study site (Fig. 1). Krugersdrift Dam is categorised as a medium size impoundment (DSO, 2014) and lies at an altitude of 1 241 m asl. The dam, completed in 1970, was built on the Modder River, a secondary tributary of the Orange-Vaal River system, for irrigation purposes. At full supply level the dam covers a total surface area of 1 853 ha, with a total capacity of 66 000 000 m^3 and an average depth of 3.6 m. The dam has a catchment of 6 331 km^2 that is mostly fed by surface runoff and a high percentage of inflow that is contributed by treated effluent from the Mangaung Metropolitan Municipality (MMM) wastewater treatment works. Due to the high nutrient levels, the dam can be categorised as eutrophic to hyper-eutrophic, with regular algal blooms occurring (LM Barkhuizen, pers. obs.).

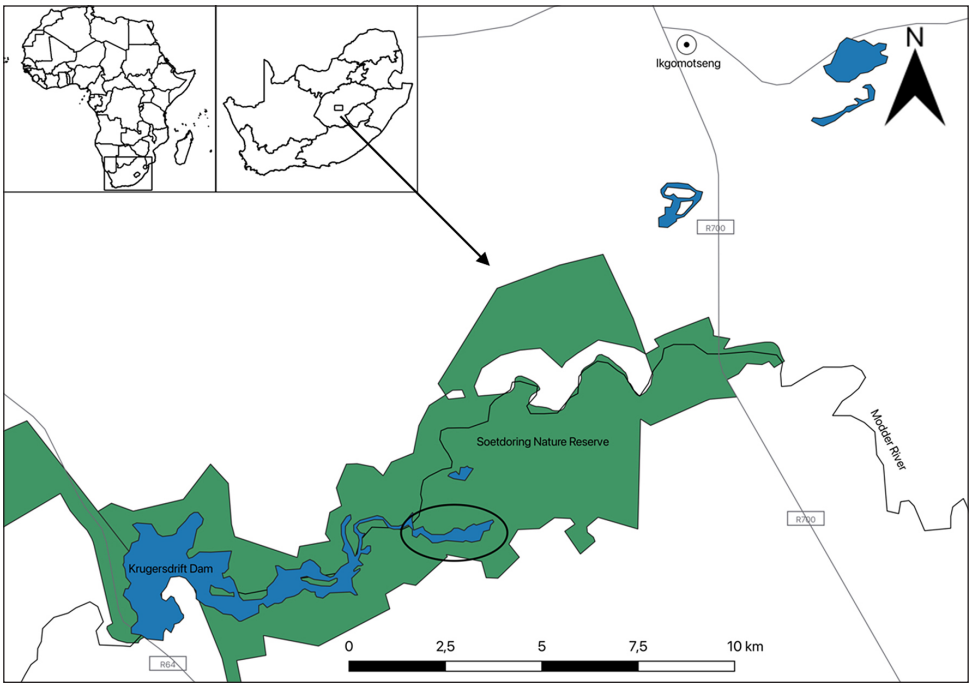

Figure 1. Krugersdrift Dam and Soetdoring Nature Reserve in the Free State Province, indicating the locality, size and profile of the study site

Due to the reservoir's proximity to the MMM (40 km), Krugersdrift Dam is one of the most popular recreational and competitive angling venues in the Free State Province (LM Barkhuizen, pers. obs.). Based on an average of 29 angling tournaments held between 1974 and 2014, the mean number of anglers who took part in tournaments was 502 per year (Barkhuizen et al., 2017). The species composition of the catch for the tournaments during this period was dominated by *C. carpio* (88%) and *C. gariepinus* (10.5%), with two *Labeobarbus* and *Labeo* species contributing to 1.5% of the total anglers' catch.

Barkhuizen (2015), using gill, beach seine and fyke nets, sampled a total of 1 582 fish representing 9 different species during fish surveys in Krugersdrift Dam. The catch was dominated by alien and invasive common carp *Cyprinus carpio* (37%), moggel *Labeo umbratus* (26%), southern mouthbrooder *Pseudocrenilabrus philander* (11%), the Orange River mudfish *Labeo capensis* (9%), straightfin barb *Enteromius paludinosus* (7%), sharptooth catfish *Clarias gariepinus* (6%), smallmouth yellowfish *Labeobarbus aeneus* (3%), goldfish *Carrassius auratus* (0,9%), and the protected largemouth yellowfish *Labeobarbus kimberleyensis* (0.1%).

Based on data received from the Hydrology Section of the national Department of Water and Sanitation, Krugersdrift Dam was at full capacity during the study period, except for short periods during November 2022 and February 2023 when water was released for irrigation. The average water level of the dam for the 12-month sampling period was 101.2%.

Timeframe

Sampling was conducted from May 2022 to April 2023 to include seasonal variations across a full calendar year. During the sampling period, surveys were conducted every month for 5 consecutive days (4 netting nights). Due to severe rainfall and impassable roads, sampling was limited to only 3 netting nights and 4 workdays during November 2022 and March 2023.

Gear used to collect fish

Sampling was done using 3 long-lines, a 100 m beach seine net and 3 double-ended Dutch type fyke nets. The specific gear was chosen as it did not require the use of a boat with an outboard motor, but could be set/used by wading into the water.

Three 120 m long-lines were equipped, each with 20 snoods, which were set 5 m apart. The leader was 50 cm long, to which 6/0 circular hooks were attached (Fig. 2A). The long-lines were set parallel to the shore by wading into the water, and set at a depth of 1 to 1.5 m. Long-lines were set on Day 1, and fish removed and hooks rebaited daily, until they were lifted on the last sampling day. The hooks were baited with juvenile *L. capensis*, *L. umbratus* and *C. carpio*, *C. auratus* or pieces of adult *Labeo* spp. that were found dead in the fyke nets. Every morning the following data were recorded for each long line: number and species of fish caught, number of hooks still baited, and number of hooks without bait and snoods without hooks.

A 100 m x 3 m beach seine net, consisting of green, multifilament nylon netting material with a stretched mesh size of 75 mm, was used to sample fish in the littoral zone. To ensure that a larger area was covered during seining, 50 m polyethylene rope 20 mm thick was added to each end. The seine net was used between 1 and a maximum of 5 times per day, weather permitting. The seine net was never used twice at the same site on the same day, but sampling continued at new sites to the left or right of the first sampling area.

The double-ended Dutch type fyke nets had 9 hoops in each section covered in multifilament light brown netting material with a stretched mesh size of 20 mm. The two entrances of each net (1.5 m wide x 1 m high) were covered with netting material with a 25 mm mesh, while the curtain/guiding nets (10 m long) between the two entrances had a mesh size of 5 mm (Fig. 2B). Fyke nets were not baited and set at a depth between 1 and 1.5 m by wading into the water.

Fish samples

Fish caught were identified to species level according to Skelton (2001), sorted and kept separately per gear type. Depending on the species, fish were measured for fork or total length (to the nearest millimeter) and weighed using an Ishida IPC 1356 scale with a maximum capacity of 15 kg and an accuracy of 5 g. Larger specimens were weighed with a basic spring balance with maximum capacity of 30 kg. All fish caught were kept for the fisheries, while specimens weighing less than 250 g and dead fish found in gear were kept as bait for the long lines. All *L. kimberleyensis* were released.

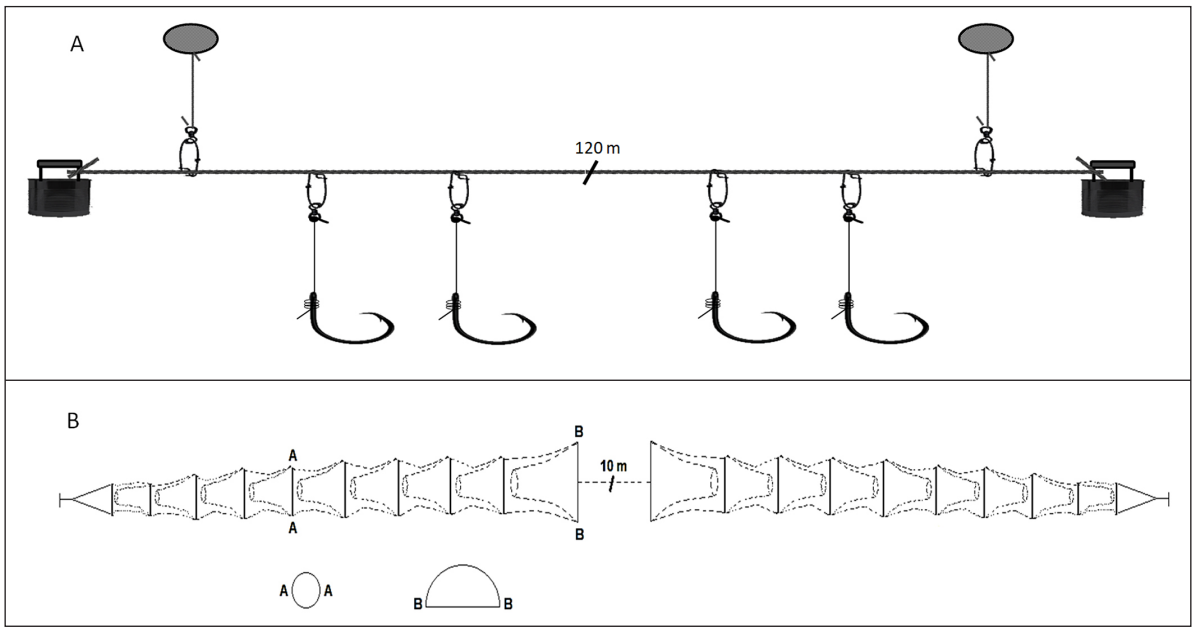

Figure 2. Schematic drawings of a longline (A) (viewed from the side) and a double-ended Dutch type fyke net (B) (viewed from above). Fyke net redrawn from Booth and Potts (2006).

Fate of fish caught and socio-economic aspects

After biological data were collected, fish were kept in a 500-L container filled with water. Just before departure from the study site, fishers sorted the catch per species and size to ensure an equal allocation of fish. No processing of fish is allowed within the borders of nature reserves, and the fish were transported to Ikgomotseng where they were killed by severing the spinal cord and processed. Fish were washed, cleaned and sold fresh, with occasionally only the intestines removed. After each day, fishers recorded the following data: number of each species sold and selling price, fish bartered, fish donated to the community, and fish kept for own use.

Determining a realistic selling price for freshwater fish

Occasionally, at the end of each fishing day, a number of fish from different species were selected and the individual fish's weight recorded in the absence of the fishers. The selected fish were then presented to the fishers individually, where after each fisher had to record at what price they will sell the specific fish. The average selling price was then divided by the weight of each fish to calculate the selling price per kilogram.

RESULTS

Catch composition and catch rate of the long-lines

The long lines selected exclusively for sharptooth catfish *C. gariepinus* (Table 1).

From May 2022 until April 2023, a total of 702 *C. gariepinus* (442 males and 260 females) with a total weight of 3 147 kg were caught (Table 1). The total catch decreased during the colder winter months (i.e. June until August 2022), when mostly large specimens were caught. The average weight of the catch decreased during the warmer summer months with the lowest weight recorded during December 2022 (Table 1). The highest number of *C. gariepinus* were caught during mid-summer (January until March 2023), when the lowest average weight was recorded.

From June until August 2022, the number of hooks still baited was the highest, with the least hooks without bait and snoods without hooks found during June and July 2022, respectively. From September 2022, the catch rate started to increase as the water temperature increased, with a maximum of 90 *C. gariepinus* caught during the peak of summer, i.e., February 2023 (see Table 1). There was a gradual decrease in the number of hooks that were still baited when long lines were checked, which may be attributed to *C. gariepinus* being more active and feeding. This was also evident in the increase in the number of hooks that had no bait or hooks that were broken off from the snoods.

The total monetary value based on a selling price of 17 ZAR·kg^{-1} for the total catch of 3 147.39 kg was 53 506.48 ZAR (total of 58 fishing days) (Table 1). Due to the lower catch rates during the cold winter months, the approximate income per fisher per day (based on 5 fishers) from the sale of *C. gariepinus* was the lowest during June and July 2022, with the highest possible income based on the sale of *C. gariepinus* of 361.44 ZAR·fisher^{-1}·day^{-1} observed for March 2023 (Table 1).

Catch composition and catch rate of the beach seine net

During the sampling period, the 100 m beach seine net was used 163 times. During the colder months, from June until August 2022, despite a higher effort of 14 to 15 times, fewer fish were caught. The catch composition of the seine net was dominated by *C. carpio* (n = 1 766), *L. umbratus* (n = 299) and *C. gariepinus* (n = 238), while 24 *C. auratus* (total weight of 7.35 kg), 26 *L. capensis* (total weight of 5.91 kg), 2 *L. kimberleyensis* (total weight of 0.3 kg), and 1 *Tilapia sparrmanii* (0.07 kg) were caught during the sampling period. Most of the *L. capensis* were juveniles as were the two *L. kimberleyensis*.

Based on the seine net catches, the main fisheries species are *C. carpio, C. gariepinus* and *L. umbratus*. The number of *C. carpio, C. gariepinus* and *L. umbratus* caught during monthly sampling with beach seine net at Krugersdrift Dam for May 2022 to April 2023, as well as the average weight and length per species, are summarised in Table 2. The approximate monetary value of the three fisheries species, i.e., *C. carpio* (28 ZAR·kg^{-1}), *C. gariepinus* (17 ZAR·kg^{-1}) and *L. umbratus* (24 ZAR·kg^{-1}) caught during monthly sampling with beach seine net at Krugersdrift Dam, for May 2022 to April 2023, as well as the approximate income·fisher^{-1}·day^{-1} based on 5 fishers, are summarised in Table 3.

Table 1. Summary of the total number and weight of *Clarias gariepinus* caught in Krugersdrift Dam from May 2022 until April 2023; the number of baited hooks; the number of hooks without bait, and snoods without hooks found in the mornings; the monetary value based on a selling price of 17 ZAR·kg^{-1}; and the average income·fisher^{-1}·day^{-1} (5 fishers) based on the sale of *C. gariepinus*

Sampling event	Total Cg caught (number)	Hooks that still had bait on	Hooks without any bait, and snoods without any hooks	Total Cg weight (kg)	Average length (mm)#	Average weight (kg)	Monetary value (17 ZAR·kg^{-1})	Approximate income/ fisher per day (ZAR) (based on 5 fishers who actively participated)
23–27 May 2022	86	138	16	397.99	901.35	4.63	6 765.83	338.28
6–10 June 2022	26	212	2	130.40	917.42	5.02	2 216.80	110.84
18–22 July 2022	15	223	2	62.11	843.20	4.14	1 055.87	52.79
15–19 Aug 2022	42	193	5	258.66	946.33	6.16	4 397.22	219.86
5–9 Sept 2022	51	158	31	413.39	1 037.41	8.11	7 027.63	351.38
3–7 Oct 2022	70	105	65	297.85	847.13	4.25	5 063.45	253.17
7–10 Nov 2022*	53	40	87	203.15	825.77	3.83	3 453.55	230.24
4–8 Dec 2022	64	104	72	223.35	814.13	3.49	3 796.95	189.85
16–20 Jan 2023	70	89	81	278.15	883.83	3.97	4 728.55	236.43
6–10 Feb 2023	90	69	81	344.58	851.70	3.83	5 857.86	292.89
6–9 March 2023*	84	39	57	318.92	855.50	3.80	5 421.64	361.44
6–10 April 2023	51	139	50	218.89	904.04	4.29	3 721.13	186.06
TOTAL	**702**	**1 509**	**549**	**3 147.39**			**53 506.83**	

*Only 3 nights, # average length based on total length, Cg = *Clarias gariepinus*

Table 2. Number of *Cyprinus carpio, Clarias gariepinus* and *Labeo umbratus* caught during monthly sampling with beach seine net at Krugersdrift Dam, Free State Province, for the period May 2022 to April 2023, as well as the average weight and length per species

Sampling period	Number of netting hauls	Cc n	Cc weight (kg)	Cc average weight (kg)	Cc average length (mm)#	Cg n	Cg weight (kg)	Cg average weight (kg)	Cg average length (mm)#	Lu n	Lu weight (kg)	Lu average weight (kg)	Lu average length (mm)#
23–27 May 2022	7	91	248.09	2.73	369.77	16	15.71	0.98	503.75	3	1.75	0.58	367.67
6–10 June 2022	14	60	100.98	1.68	432.98	6	7.79	1.30	515.5	11	8.3	0.75	0
18–22 July 2022	15	62	163.07	2.63	514.13	0	0	0.00	791	0	0	0.00	0
15–19 Aug 2022	9	110	199.68	1.82	446.49	3	11.5	3.83	816.67	30	14.79	0.49	319.6
5–9 Sep 2022	15	108	179.82	1.67	424.19	16	39.32	2.46	663.94	91	49.27	0.54	327.84
3–7 Oct 2022	13	275	389.17	1.42	390.07	53	103.61	1.95	564.21	65	40.01	0.62	337.46
7–10 Nov 2022*	13	206	378.74	1.84	439.18	14	17.61	1.26	501.21	0	0	0.00	0
4–8 Dec 2022	12	214	276.07	1.29	338.43	17	25.51	1.50	547.65	34	11.69	0.34	278.91
16–20 Jan 2023	13	162	180.34	1.11	360.52	27	73.3	2.71	712	9	5.23	0.58	362.78
6–10 Feb 2023	17	140	155.26	1.11	351.72	24	40.978	1.71	584.58	32	19.01	0.59	346.09
6–9 March 2023*	15	215	254.89	1.19	368.51	27	26.47	0.98	431	11	11.06	1.01	364.27
6–10 April 2022	20	123	232.96	1.89	453.72	35	61.59	1.76	567.06	13	5.77	0.44	329.46
TOTAL	**163**	**1 766**	**2 759.05**			**238**	**423.38**			**299**	**166.86**		

*Only 3 netting nights; *n* – number; Cc – *Cyprinus carpio;* Cg – *Clarias gariepinus;* Lu – *Labeo umbratus;* #Average length for *C. carpio* and *L. umbratus* based on fork length and for *C. gariepinus* on total length

Table 3. Approximate monetary value of the three fisheries species, i.e., *Cyprinus carpio* (28 ZAR·kg^{-1}), *Clarias gariepinus* (17 ZAR·kg^{-1}) and *Labeo umbratus* (24 ZAR·kg^{-1}) caught during monthly sampling with beach seine net at Krugersdrift Dam, Free State Province, for the period May 2022 to April 2023, as well as the approximate income·fisher^{-1}·day^{-1} based on 5 fishers

Sampling period	Number of netting hauls	Cc weight (kg)	Approximate income based on 28 ZAR·kg^{-1}	Cg weight (kg)	Approximate income based on 17 ZAR·kg^{-1}	Lu weight (kg)	Approximate income based on 24 ZAR·kg^{-1}	Approximate income for 3 fisheries species	Approximate income (ZAR·fisher^{-1}·day^{-1}) based on 5 fishers and 3 fishery species
23–27 May 2022	7	248.09	6 946.52	15.71	267.07	1.75	42	7 255.59	362.78
6–10 June 2022	14	100.98	2 827.44	7.79	132.43	8.3	199.2	3 159.07	157.95
18–22 July 2022	15	163.07	4 565.96	0	0	0	0	4 565.96	228.30
15–19 Aug 2022	9	199.68	5 591.04	11.5	195.5	14.79	354.96	6 141.5	307.08
5–9 Sep 2022	15	179.82	5 034.96	39.32	668.44	49.27	1182.48	6 885.88	344.29
3–7 Oct 2022	13	389.17	10 896.76	103.61	1761.37	40.01	960.24	13 618.37	680.92
7–10 Nov 2022*	13	378.74	10 604.72	17.61	299.37	0	0	10 904.09	726.94
4–8 Dec 2022	12	276.07	7 729.96	25.51	433.67	11.69	280.56	8 444.19	422.21
16–20 Jan 2023	13	180.34	5 049.52	73.3	1246.1	5.23	125.52	6 421.14	321.06
6–10 Feb 2023	17	155.26	4 347.28	40.978	696.626	19.01	456.24	5 500.146	275.01
6–9 March 2023*	15	254.89	7 136.92	26.47	449.99	11.06	265.44	7 852.35	523.49
6–10 April 2022	20	232.96	6 522.88	61.59	1 047.03	5.77	138.48	7 708.39	385.42
TOTAL	**163**	**2 759.05**	**77 253.96**	**423.38**	**7 197.59**	**166.86**	**4 005.12**	**88 456.68**	

*Only 3 netting nights; Cc – *Cyprinus carpio*; Cg – *Clarias gariepinus*; Lu – *Labeo umbratus*

Catches from the 163 beach seine net hauls during the study period, were dominated by *C. carpio* (*n* = 1 766; total weight = 2 759.05 kg), followed by *C. gariepinus* (*n* = 238; total weight = 423.38 kg) and *L. umbratus* (*n* = 299; total weight = 166.86 kg). The total monetary value of the total catch for all three species caught with the seine net were 88 456.68 ZAR (i.e. *C. carpio* – 77 253.96 ZAR; *C. gariepinus* – 7 197.59 ZAR; *L. umbratus* – 4 005.12 ZAR). The approximate daily income per fisher per day varied from 157.95 ZAR during June 2022, to a maximum of 726.94 ZAR during November 2022.

Catch composition and catch rate of the three double-ended Dutch type fyke nets

Six different fish species were caught in the fyke nets. The total catch for all fish species from fyke nets, in terms of numbers (total *n* = 202) from May 2022 to April 2023, was dominated by *L. umbratus* (38.6%), *C. carpio* (24.5%), *C. gariepinus* (17.8%), and *L. capensis* (16.8%), with *C. auratus* and *L. aeneus* contributing only 1.5% and 0.5%, respectively (Fig. 3). The total weight of the total catch (total *w* = 251.6 kg), was dominated by *C. gariepinus* (44.6%), *C. carpio* (36.1%), *L. umbratus* (18.4%) and *L. capensis* (0.7%). Throughout the sampling period, the catch rates from fyke nets were low during every sampling event, except during October and November 2022 when spawning *C. carpio* were caught as fyke nets were deployed in the shallow littoral zone.

The total catch for all three gears combined in terms of numbers was dominated by *C. carpio* (*n* = 1 816), *C. gariepinus* (*n* = 977) and *L. umbratus* (*n* = 378) (Table 4). Although *C. carpio* dominated the total catch in numbers, *C. gariepinus* dominated the total weight of the total catch (Table 4).

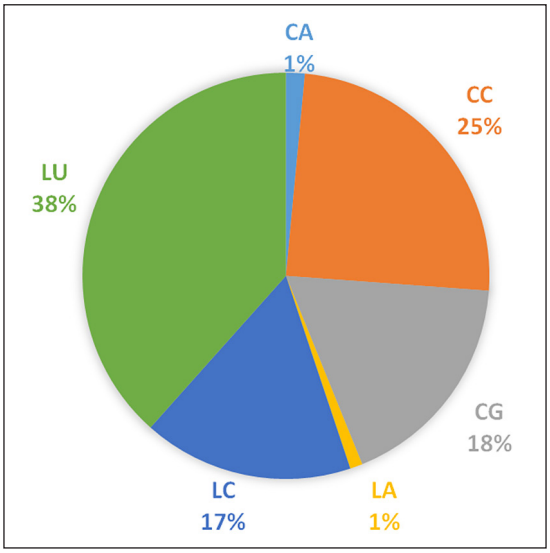

Figure 3. Catch composition from fyke nets deployed at Krugersdrift Dam for the period May 2022 to April 2023 in terms of numbers of each species caught expressed as a percentage of the total number caught (%). Key: CA – *Carassius auratus*; CC – *Cyprinus carpio*; CG – *Clarias gariepinus*; LA – *Labeobarbus aeneus*; LC – *Labeo capensis*; LU – *Labeo umbratus*.

Table 4. Summary of the total catch and total weight (kg) per fish species caught with all three gear types during monthly sampling events at Krugersdrift Dam, Free State Province, for the period May 2022 to April 2023

Sampling period	Ca (*n*)	Ca (*w*)	Cc (*n*)	Cc (*w*)	Cg (*n*)	Cg (*w*)	La (*n*)	La (*w*)	Lc (*n*)	Lc (*w*)	Lk (*n*)	Lk (*w*)	Lu (*n*)	Lu (*w*)	Ts (*n*)	Ts (*w*)
23–27 May 2022	0	0.00	93	122.41	104	421.27	0	0	0	0.00	0	0	8	6.14	0	0
6–10 June 2022	0	0.00	60	100.98	32	138.19	0	0	2	0.57	0	0	20	11.36	0	0
18–22 July 2022	0	0.00	62	163.07	16	65.51	0	0	0	0.00	0	0	6	0.69	0	0
15–19 Aug 2022	0	0.00	112	205.20	48	284.68	0	0	6	0.76	0	0	36	16.65	0	0
5–9 Sep 2022	0	0.00	115	196.01	71	466.91	0	0	6	3.70	0	0	98	53.52	0	0
3–7 Oct 2022	6	1.82	289	416.32	131	426.34	0	0	4	0.79	0	0	95	65.26	1	0.07
7–10 Nov 2022*	2	0.41	213	401.98	76	252.04	0	0	0	0.00	0	0	0	0.00	0	0.00
4–8 Dec 2022	4	1.65	215	276.07	82	252.03	0	0	11	0.60	0	0	44	15.10	0	0.00
16–20 Jan 2023	5	0.89	169	180.49	101	354.77	1	0.05	23	0.41	0	0	13	7.39	0	0.00
6–10 Feb 2023	2	0.67	147	165.14	115	386.55	0	0	2	0.16	0	0	34	20.32	0	0.00
6–9 March 2023*	8	2.36	216	255.70	114	354.11	0	0	4	0.35	0	0	11	11.06	0	0.00
6–10 April 2023	0	0.00	125	237.87	87	282.92	0	0	2	0.19	2	0.39	13	5.77	0	0.00
TOTAL	**27**	**7.79**	**1 816**	**2 721.21**	**977**	**3 685.30**	**1**	**0.05**	**60**	**7.52**	**2#**	**0.39**	**378**	**213.23**	**1**	**0.07**

*Only 3 netting nights; *n* – numbers; *w* – weight in kg; Ca – *Carassius auratus*; Cc – *Cyprinus carpio*; Cg – *Clarias gariepinus*; La – *Labeobarbus aeneus*; Lc – *Labeo capensis*; Lk – *Labeobarbus kimberleyensis* (# – was released); Lu – *Labeo umbratus*; Ts – *Tilapia sparrmanii*

Fate of fish caught and socio-economic aspects

During certain sampling periods, some fishers were not present and that impacted on their total income. The data of 3 fishers who were originally involved in the pilot research project, but later left, are also given to provide the full scope of the socio-economic value (see Table 5).

Fisher #1, who was involved in the project for the full sampling period, received and sold the most fish (389 fish), with a total income of 20 862 ZAR. This fisher donated 25 fish to community members, while 75 fish were kept for own use. The 8 fishers sold a total of 1 892 fish, with a total income of 100 561 ZAR. In total, 115 fish were donated to the poorest of the poor, while 289 fish were kept for own use by the fishers and their extended families (Table 5). On one occasion, Fisher #1 bartered a few *C. gariepinus* for a pack of russian sausages and a cellular phone. Fisher #3 bartered a few *C. carpio* for a cellular phone, while Fisher #4 on a few occasions bartered *C. carpio* and *C. gariepinus* for the use of a wheelbarrow to transport fish to sell.

The total income from fish sales of the 5 fishers (Fisher #1 to #5) who were involved for most of the study period was 93 832 ZAR (see Table 5). The average income per fisher for the 12-month period was thus 18 766.40 ZAR, which was based on only 1 week (5 days) of fishing per month over the 12-month study period. This equates to an average of 1 563.87 ZAR·month^{-1} based on only 1 fishing week per month. Fishers fishing for 4 weeks (20 days) per month may thus earn an income of approximately 6 255.47 ZAR. Fishers, however, did not sell all the fish they received, with Fisher #1 donating and keeping 100 fish; Fisher #2 doing so for 51 fish; Fisher #3 for 63 fish; Fisher #4 for 80 fish; and Fisher #5 for 82 fish. The expected total income per fisher per month from selling all fish could thus have been higher.

Table 5. Summary for the period May 2022 to April 2023 of the total number of fish each fisher received, sold, bartered, donated to the community, or kept for own use, and socio-economic impact of the Ikgomotseng small-scale fisheries pilot research project on the community of Ikgomotseng. (As only three fishers traded fish for other items, that information has been omitted from the table.)

Fisher #	Total number of fish sold	Total earnings (ZAR)	Fish donated	Fish for own use	Months involved in project
Fisher #1	389	20 862	25	75	12
Fisher #2	313	17 045	15	36	11
Fisher #3	359	19 285	25	38	10
Fisher #4	383	19 470	6	74	11
Fisher #5	324	17 170	32	50	11
Fisher #6	75	3 959	3	7	4
Fisher #7	20	1 010	1	3	2
Fisher #8	29	1 760	8	6	3
TOTAL	**1 892**	**100 561**	**115**	**289**	

Shaded area indicates the 5 fishers who were involved in the project for more than 10 months

DISCUSSION

According to the FAO (2018; 2020) global inland fisheries catches were estimated at 12 million tonnes in 2018, which accounted for 12.5% of the total capture fisheries with a value of approximately 26 billion USD. According to Britz (2015) and the FAO (2018), most of the inland fisheries are small-scale and contribute to livelihoods and food security. In Africa, inland fisheries account for 25% of the global catch, and the catch is estimated at 2.56 kg^{-1}·$capita^{-1}$·$year^{-1}$. Weyl et al. (2020) noted that the inland fisheries in Africa employ approximately 4.8 million people, and according to Hara and Backeberg (2014), the sector provides income for 10 million and food security for 200 million people. In Africa, inland fisheries are used as means of rural development, poverty alleviation, food security and rural economic development. Weyl et al. (2020) noted that inland fisheries are poorly developed in South Africa and that they differ from those in other African countries. The key reasons for this are a lack of a national inland fisheries policy, and a lack of capacity to support the development of the sector (Weyl et al., 2007; McCafferty et al., 2012; Hara and Backeberg, 2014). Since the dam building era, recreational angling has been the dominant user of freshwater fish in impoundments in South Africa (McCafferty et al., 2012; Barkhuizen et al., 2017). In recent years, an increase in the number of subsistence fishers, who use fish as a source of food, and/or a source of income, has been noticed (Ellender et al., 2009; McCafferty et al., 2012; Barkhuizen et al., 2017). Unfortunately, limited information is available for the subsistence fisheries sector.

Gear selectivity

Long-lines selected exclusively for *C. gariepinus*, while the total catch from the beach seine net was dominated by *C. carpio* (75.2%), *L. umbratus* (13.2%) and *C. gariepinus* (9.3%). During the research period, the catch rates of the three fyke nets were very low and these are therefore not recommended for use in small-scale fisheries development as a main gear type.

From 1979 until 2005, commercial fisheries in the Free State Province were allowed to use gill nets with a stretched mesh size of 100 mm, and larger long-lines, electro-fishers and seine nets with a stretched mesh size of 50 mm and larger, to harvest fish (Barkhuizen, 2015; Barkhuizen et al., 2016). However, during 2005 the FS DESTEA took a decision to ban the use of gill nets in inland fisheries in the Free State Province as these nets are not selective, and pose a threat to the threatened and protected largemouth yellowfish *Labeobarbus kimberleyensis* (Barkhuizen, 2015). The use of gill nets in South Africa is controversial as they cannot select for species and may catch scarce and threatened species, as well as water birds and other non-target species (Ellender et al., 2012; Barkhuizen, 2015; Ellender et al., 2016).

The largemouth yellowfish *L. kimberleyensis* is endemic to the Orange-Vaal River system (Skelton, 2001; Ellender et al., 2012) and is listed as a Threatened or Protected Species (TOPS) (NEM:BA: RSA, 2014). The species is also listed on the IUCN list of endangered freshwater fish species under the category 'Near Threatened' (IUCN, 2021). Based on national and Free State provincial legislation, this species may not be caught and kept and, if caught, must be released immediately (NCO, 1969; NCR, 1983). Barkhuizen (2015) found that *L. kimberleyensis* is regularly caught in gill nets in Free State dams, and therefore recommended that gill nets are not appropriate gear to be used in small-scale fisheries development in the Orange-Vaal River system. During the current sampling period, only two specimens of *L. kimberleyensis* were caught using the beach seine net, and this, in conjunction with long-lines, is thus deemed appropriate gear in the event of future small-scale fisheries development in the Orange-Vaal River system. However, during the study of Swanepoel (2022) in Gariep Dam, 480 *C. gariepinus* and only 6 *L. kimberleyensis* were caught with long-lines and were successfully released. The two juvenile *L. kimberleyensis* caught during the current study with the seine net were released but died soon after.

Fish selling price

Each fisher had his/her own customers in Ikgomotseng, and also made use of social media, e.g., WhatsApp and Facebook, to advertise their catch. A few fishers sometimes travelled with family members or friends to Bloemfontein (45 km from Ikgomotseng) or Bultfontein (50 km) where fish were sold.

Limited information is available on the price per kilogram at which small-scale and subsistence fishers sell their catch in South Africa. The current study determined that there is a market for fresh fish in the communities studied and that the realized prices (*C. carpio* at 28 ZAR·kg^{-1}; *C. gariepinus* at 17 ZAR·kg^{-1} and *L. umbratus* at 24 ZAR·kg^{-1}) are realistic and could support a small-scale fishery.

Socio-economic impact

In South Africa, due to an underdeveloped inland fisheries sector, there is limited information available on the socio-economic impact/benefit of freshwater fish. A study by Van der Waal (2000) in the Limpopo Province (then named Northern Province), noted

that artisanal fishermen who operated at Vondo and Phipidi Dams earned up to 100 ZAR·day^{-1} with sales of *C. carpio*. The author, however, noted that few fishers sold their catch, but kept most for own use. Ellender et al. (2010) found that the total monetary value of fish caught by an estimated 450 subsistence fisheries at Gariep Dam was 104 676 ZAR·yr^{-1}.

The unemployment rate in South Africa for the 4th quarter of 2022, was estimated at 32.7% (Trading Economics, 2023). The minimum wage for the 2022/23 financial year was 23.19 ZAR·h^{-1} (Briefly News, 2023). The Social Relief of Distress (SRD) Grant that has been implemented since the Covid-19 pandemic was 350 ZAR·month^{-1} for 2023. The SRD grant is a temporary provision of assistance for persons in dire material need that are not able to meet their most basic needs (SASSA, 2023). The real income, based on actual sales for the 5 fishers that were actively involved during the 12-month study period was 93 832.00 ZAR (see Table 5). This equates to an average income of 1 563.87 ZAR·fisher^{-1}·week^{-1} or approximately 6 255.47 ZAR·month^{-1} (based on 4 weeks per month). These estimates are significantly higher than the SRD grant, and also higher than the total income for a 5-day workweek based on the minimum wage of 185.52 ZAR·day^{-1} and 927.60 ZAR·week^{-1}. It needs to be noted that this information is based on the income from fish sales, and does not include the daily running costs or capital investment, as fish harvesting and surveys were part of a pilot research project of the FS DESTEA. This information, however, can serve as a guideline when a business plan and budget for future small-scale fisheries projects is compiled that also includes running costs.

The socio-economic benefit of the Ikgomotseng small-scale fisheries project was further demonstrated by 115 fish being donated to the poorest of the poor in Ikgomotseng, and 289 fish that were kept for own use by the fishers and their extended families. During a study on the annual fish harvest at Gariep Dam, Ellender et al. (2010) found that subsistence fishers consumed or donated 46.9 t·y^{-1} of their catch, with 18.3 t·y^{-1} being sold and 6.2 t·y^{-1} being released. This is in contrast to the current study, where 82.4% of the total catch was sold, and only 12.6% fish kept for own use. Andrew et al. (2000), Van der Waal (2000) and Swanepoel (2022) also highlighted the socio-economic benefits of inland fisheries to local communities in terms of enhanced food security, and income generation for the poorest of the poor.

CONCLUSION

To establish and implement small-scale inland fisheries projects does not require a large capital outlay, boats or high running costs. Previous small-scale fisheries projects in the Free State Province received millions of rands in funding from Government to buy expensive boats and gear that was not appropriate (i.e. gill nets). Using selective gear (seine net and/or long-lines) can target the preferred fisheries species and can prevent species of conservation importance being caught. Two of the reasons why previous fisheries projects failed in the Free State Province were the lack of a fixed market and the low value/price for freshwater fish. The results of this study, however, demonstrate that there is a market for freshwater fish in rural communities that are willing to buy freshwater fish, albeit at a realistic and reasonable price. Acknowledging the high unemployment rate, especially amongst youth in South Africa, the authors call for realistic goals and objectives to be set in the planning of any small-scale fisheries projects, and to limit the number of beneficiaries in a project to ensure financial viability. This paper does not address the important aspect of the management of small-scale fisheries, nor catch per unit effort and long-term trends in population dynamics, but it is important that these be addressed in future fisheries development. Small-scale inland fisheries projects not only contribute to income generation, enhanced food security and livelihoods for fishers, but this study has also shown that the socio-economic benefits for rural communities can be far reaching.

ACKNOWLEDGEMENTS

LMB acknowledges the support of the FS DESTEA during the pilot research project. The research was done under Research Permit number JM 9028/2022 from the FS DESTEA. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and the UFS and FS DESTEA does not accept any liability in this regard.

AUTHOR CONTRIBUTIONS

LM Barkhuizen: conceptualisation, investigation, data curation, data analysis, compiling original draft, review and editing. PJ Swanepoel: visualization, investigation, data analysis, review and editing.

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