

Evaluating the suitability of fyke nets for small-scale fisheries in the Free State Province of South Africa

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South Africa is under increasing pressure to develop small-scale fisheries in inland waters. To inform appropriate development of this sector in the Free State Province, the catch rate of double-ended fyke nets was evaluated using survey data from 20 impoundments sampled during the 2013/2014 summer season. Fyke nets were set over night and the total sample effort was 114 fyke net nights. Overall catch per unit effort (CPUE) was 16.8 ± 28.3 kg-net⁻¹-night⁻¹ and catch composition was dependent on impoundment, but generally comprised of a mixture of common carp *Cyprinus carpio*, African sharptooth catfish *Clarias gariepinus*, smallmouth yellowfish *Labeobarbus aeneus*, Orange River mudfish *Labeo capensis* and moggel *Labeo umbratus*. The influence of temperature and the potential benefits of baiting the nets were subsequently evaluated through monthly sampling in the hyper-eutrophic Krugersdrift Dam and at the oligotrophic Gariep Dam. Baiting did not significantly influence CPUE, which was significantly higher at Krugersdrift Dam (19.97 ± 23.22 kg-net⁻¹-night⁻¹) than at Gariep Dam (5.02 ± 6.05 kg-net⁻¹-night⁻¹). Increasing temperature had a positive effect on CPUE at Krugersdrift Dam but not at Gariep Dam. Species composition also differed between impoundments and, as a result, we conclude that seasonal catch rates and species compositions will need to be evaluated prior to implementation of fyke net fisheries in specific localities.

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INTRODUCTION

South Africa is under increasing pressure to develop small-scale fisheries in inland waters as an avenue for food security and poverty alleviation (Weyl et al., 2007; McCafferty et al., 2012; Britz et al., 2015). As a result, there has been an increased interest in fisheries development, the focus of which includes investigating avenues for increasing catch rates beyond those attainable from angling. The fyke net, a passive gear consisting of one or two valve traps interconnected by a guide net, is used to harvest a variety of fish species by small-scale fisheries in other parts of the world (Hubert et al., 2012). In the former USSR for example, fyke nets were popular fishing methods due to their simple design, low cost and simple construction (Berka, 1990). In Sweden, fyke nets are used extensively in eel fisheries (Königson et al., 2007) and in Canada they are used by commercial fishers to target a variety of species (Colotelo et al., 2013).

Apart from anecdotal reports on the use of fyke nets to attempt to establish an eel fishery in the Eastern Cape Province (Booth and Potts, 2006), there is no information on their use in fisheries development in South Africa where freshwater fishes have generally been harvested by angling or by gill netting and beach seining (Barkhuizen et al., 2016). Fyke nets have, however, been widely used as a sampling gear in South Africa. Hamman (1974) evaluated fyke nets as a sampling method in the Gariep Dam, but considered their catch rates too low to be of interest as a sampling gear. More recently, Booth and Potts (2006) used fyke nets as an alternative non-destructive sampling method to determine the selectivity of gill nets. Olds et al. (2011) used fyke nets in the Wilderness Lakes System in the Western Cape Province as a sampling gear to determine the status of invasive species, while Ellender et al. (2016) reported on the use of fyke nets in eel surveys.

In this paper, the potential of fyke nets as a low-cost small-scale fisheries gear that is easy to deploy in shallow water without the requirement of a boat is evaluated in two experiments. The first was a broad-scale assessment during the 2013/2014 summer season using un-baited fyke nets in 20 impoundments in the Free State Province to provide an overall indication of their suitability. The second was an in-depth assessment of seasonal catch rates from baited and un-baited fyke nets in the oligotrophic Gariep Dam and hypereutrophic Krugersdrift Dam which were sampled over a 12-month period during 2015/2016.

MATERIALS AND METHODS

Study area

The localities of the 20 impoundments that were surveyed during 2013/2014, are indicated in Fig. 1. The two study sites of the 2015/2016 survey are encircled within the figure. Krugersdrift Dam is a

hyper-eutrophic impoundment that is important for recreational fisheries, situated approximately 30 km from Bloemfontein (Barkhuizen et al., 2017). It is the receiving impoundment of most of the treated (and sometimes untreated) sewage from wastewater works within the Mangaung Metropolitan Municipality. Water from the impoundment is mostly used for irrigation. Gariep Dam, the largest impoundment in South Africa, is situated approximately 200 km south of Bloemfontein. There are few urban areas and limited irrigation and industrial activities within the catchment of the impoundment, which is considered to be oligotrophic. The Department of Water and Sanitation monitors and controls the water level with daily releases through the hydro-power station, and regular releases through the Orange-Fish River Inter-Basin Water Transfer Scheme. Small-scale (subsistence) fisheries are the most important fisheries sector, while the dam is also important for recreational angling (Ellender et al., 2010a). At sampling sites in Krugersdrift Dam the substrate consisted of sand and/or mud, while at Gariep Dam the substrate consisted of fine gravel, shale and/or mud.

According to Barkhuizen (2015), freshwater fish communities at impoundments in the Free State are dominated by cyprinids, i.e., smallmouth yellowfish *Labeobarbus aeneus*, Orange River mudfish *Labeo capensis*, moggel *Labeo umbratus* and largemouth yellowfish *Labeobarbus kimberleyensis*. The alien and invasive common carp *Cyprinus carpio* is the dominant species at many impoundments and with African catfish *Clarias gariepinus* they often form the bulk of recreational and small-scale fisheries catches (Ellender et al., 2010b; Barkhuizen, 2015)

Gear used

During the 2013/2014 summer season's surveys at 20 impoundments, three double-ended Dutch-type fyke nets with a 9.7 m guiding (leader) net between the hoop nets which were 1 m high × 1.5 m wide were used. Nets were set between 15:00 and 17:00 on Day 1, checked and re-set between 08:00 and 10:00 on Day 2 and finally lifted between 08:00 and 10:00 on Day 3.

Total sampling effort was 114 net nights. The netting material in the guiding net and covering both sections had a stretched mesh size of 20 mm, while a section of the netting material at the entrances was made from stronger twine with a stretched mesh size of 25 mm. Otter guards were removed to allow for all sizes of fish to be caught. Anchors were tied to the end ropes of each section to secure the net in its position. To emulate their potential use in small-scale fisheries, the nets were set by wading into the water and when the correct depth (1 to 1.5 m) was reached, the first hoops were set first. Each section was then pulled to its maximum to open the cone-shaped netting bags by moving backwards to ensure the bags and the guiding net between the two hoop nets were straight and tight before the anchors were released. All fyke nets were set parallel to the shoreline.

Fish samples

Fish caught were placed in separate containers, identified to species level and measured for fork and total length to the nearest millimetre. The weight was recorded using an Ishida IPC 1356 scale with maximum capacity of 15 kg and graduations of 5 g. Smaller specimens were weighed using a Terraillon T800 scale with a maximum capacity of 3 kg and graduations of 1 g, while specimens >15 kg were weighed with a basic spring balance.

Seasonal surveys

Seasonal surveys were conducted at Krugersdrift Dam and Gariep Dam which were sampled between December 2015 and November 2016. Fyke nets were set in the same way as during the larger survey, but in this case two of the three fyke nets were baited. One net was baited with 500 g uncooked maize which was scattered in front and inside the first hoop and next to the guiding net, and the other with 8 dead fish weighing between 500 g and 1 kg (*L. umbratus* and *L. capensis*) placed halfway between the entrance and end of the net. Nets were set for three to four netting nights, lifted once per day, re-baited and reset immediately. Surveys were conducted monthly.

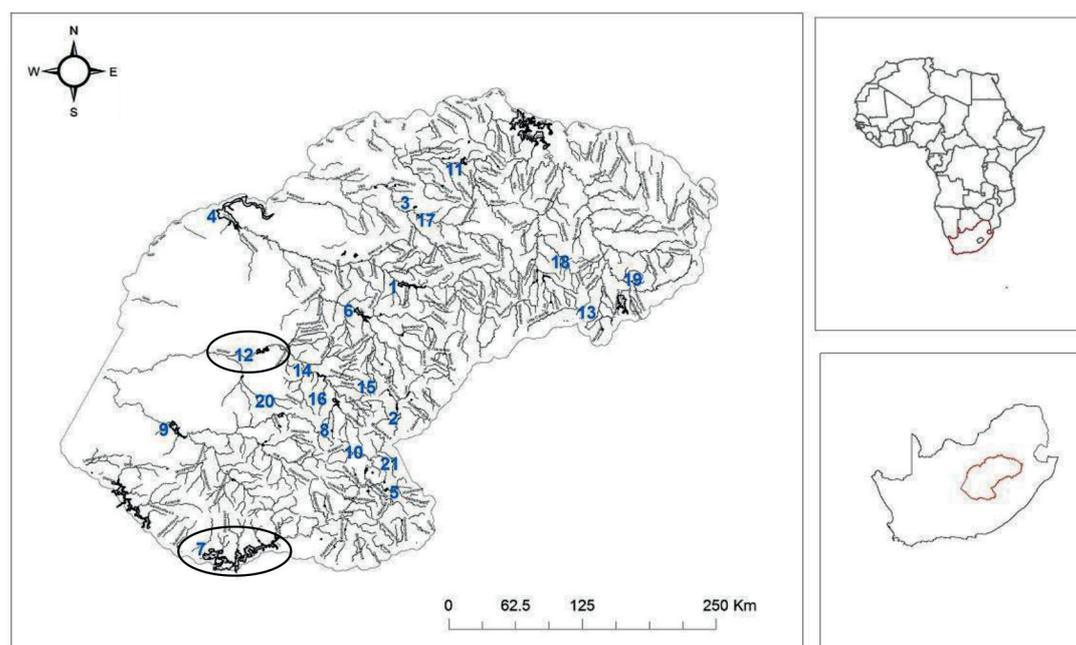


Figure 1. Map indicating the locality of the 20 impoundments that were selected for the 2013/2014 and 2015/2016 studies in the Free State Province of South Africa. The two impoundments that were surveyed during the 2015/2016 study are circled and in bold below. (1 – Allemanskraal; 2 – Armenia; 3 - Bloemhoek; 4 – Bloemhof; 5 – Egmont; 6 – Erfenis; 7 – **Gariep**; 8 – Jimmie Roos; 9 – Kalkfontein; 10 – Knellpoort; 11 – Koppies; 12 – **Krugersdrift**; 13 – Metsi Matso; 14 – Mockes; 15 – Moutloatsi Setlogelo; 16 – Rustfontein; 17 – Serfontein; 18 – Sol Plaatje; 19 – Sterkfontein; 20 – Tierpoort).

Statistical analyses

Catches were standardized to catch per unit effort (CPUE) and expressed as kg-net⁻¹-night⁻¹. Seasonal comparisons between Krugersdrift Dam and Gariep Dam and the effect of temperature and bait on catch rate data were assessed using multiple linear regression analysis with temperature and bait type as independent variables and CPUE as the dependent variable. To conform with the assumption of constant variance the data were log ($n + 1$) transformed. Linear regressions were also performed on a dam-specific basis with temperature as the independent and CPUE as the dependent variable. Pairwise comparisons between the dams were undertaken using the Mann-Whitney *U*-test as data were non-parametric. All analyses were done using the analysis add-on in Sigma Plot for Windows Version 13 (Systat Software Inc.).

RESULTS

Overall fish catches

A summary of the physical attributes, catch and species composition (by weight) from fyke nets set in the 20 impoundments is provided in Table 1. No catches were recorded at Metsi Matso Dam and only two fish were recorded

at Sterkfontein Dam. The highest CPUE was from Koppies Dam (101.8 ± 313.9 kg-net⁻¹-night⁻¹). Overall CPUE was 16.8 ± 28.3 kg-net⁻¹-night⁻¹ and was dependent on impoundment, and species composition was generally comprised of a mixture of *C. carpio* (0.03 – 79.6%), *C. gariepinus* (0.2–89.6%), *L. aeneus* (0.1–18.4%) and two Labeos, i.e., *L. capensis* and *L. umbratus* (0.03–94.2%). At 9 impoundments, *C. gariepinus* dominated the catches while the combination of the two *Labeo* species, i.e., *L. capensis* and *L. umbratus*, dominated catches at 8 impoundments. *Cyprinus carpio* only dominated catches at Sol Plaatje Dam. Other species were an incidental component, generally making up < 1% of the total catch.

Seasonal surveys in Krugersdrift and Gariep Dams

A summary of the catch data in seasonal surveys is provided in Table 2 for Krugersdrift Dam and Gariep Dam. Multiple linear regressions revealed that the inclusion of bait had no significant effect on CPUE ($P = 0.97$) but that CPUE was significantly correlated with temperature ($P \leq 0.001$) and dam ($P \leq 0.001$). Overall nets set at Krugersdrift Dam had a significantly higher CPUE (19.97 ± 23.22 kg-net⁻¹-night⁻¹) than those set at Gariep Dam (5.02 ± 6.05 kg-net⁻¹-night⁻¹) (Mann Whitney Rank Sum, $p \leq 0.001$). The effects of temperature on fyke net CPUE in the two dams are

Table 1. Parameters recorded, CPUE and species composition (% weight) for 2013/2014 survey at 20 impoundments

Name of impoundment	Netting nights	Size (ha)	Water level (%)	Secchi depth (cm)	Water temp. (°C)	CPUE (kg-net ⁻¹ -day ⁻¹)	Species composition (%weight)				
							Carp	Catfish	SMYF	Labeos	Other
Allemandskraal	6	2 667	17.3	20	20.7	4.5	4.9	0.2	0.1	94.2	0.6
Armenia	6	393	15.9	9	23.8	3.4	2.4	8.2	16.6	70	2.8
Bloemhoek	6	370	20	31	26.2	8.8	30.6	40.1	0	24.9	4.4
Bloemhof	6	23 067	36	34	27.8	62.9	10.4	89.6	0	0.03	0
Egmont	6	244	54.5	7	26.9	15.9	1.6	3	8.1	87.3	0
Erfenis	6	3 291	23.1	14	20.7	7.0	6.2	0	18.4	60.5	14.9
Gariep	6	35 216	78	30	27.0	17.7	27.1	67	4.5	1.4	0
Jimmie Roos	6	115	50	22	24.1	23.9	17.2	13.4	0	69.4	0.01
Kalkfontein	6	3 769	37.9	30	25.7	6.6	3.1	19.4	0	77.5	0
Knellpoort	6	977	42.9	34	24.5	13.3	3.9	0	1.6	88.9	5.6
Koppies	6	1 439	58.3	20	23.0	101.8	4.5	87	0.3	8.1	0.1
Krugersdrift	6	1 853	29.7	40	21.9	21	27.1	60.7	0	12.14	0.06
Metsi Matso	6	66	100	>200	24.1	0	0	0	0	0	0
Mockes	6	147	100	10	26.6	7.7	29.2	64.2	0.2	5.5	0.9
Moutloatsi Setlogelo	6	250	10.2	19	20.8	9.9	0.03	57.9	0	41.2	0.87
Rustfontein	6	1 159	27.3	25	19.0	0.9	11.8	0	2.2	85.5	0.5
Serfontein	3	142	100	10	29.6	19.2	27.7	71	0.03	1.3	0
Sol Plaatjie	6	356	100	37	17.9	0.9	79.6	0	0.2	20.2	0
Sterkfontein	6	6 937	100	>200	19.6	0.5	0	0	0	0	100
Tierpoort	3	911	12.4	28	24.5	12.0	32.7	59.4	1.1	6.1	0.7

Key: *carp* – *C. carpio*; *catfish* – *C. gariepinus*; *SMYF*– *L. aeneus*; *Labeos* – *L. capensis* and *L. umbratus*

Others: *L. kimberleyensis*, *straightfin barb* *Enteromius paludinosus*, *southern mouthbrooder* *Pseudocrenilabrus philander*

Table 2. Fish species' contribution to the total weight (%) of the total catch, and CPUE (kg-net⁻¹-night⁻¹) during the seasonal study for Krugersdrift Dam and Gariep Dam

Fish species	Gariep Dam			Krugersdrift Dam		
	Total weight (kg)	Percentage of total weight	CPUE	Total weight (kg)	Percentage of total weight	CPUE
<i>C. carpio</i>	25.5	4.5	0.08	1 023.9	34.8	2.5
<i>C. gariepinus</i>	209.5	37	0.6	1 360.7	46.3	3.3
<i>L. aeneus</i>	216.5	38.3	0.7	2.2	0.1	0.005
Labeos	107.7	19	0.3	55.2	18.8	0.13
* Other	6.6	1.2	0.02	0.8	0	0.002

* *Other*: *Gariep Dam*: *L. kimberleyensis*; *Krugersdrift Dam*: *P. philander*

illustrated in Fig. 2. Temperature significantly influenced fyke net CPUE in Krugersdrift Dam (linear regression: $P \leq 0.01$, $r^2 = 0.36$) but not in Gariep Dam (linear regression: $P = 0.10$, $r^2 = 0.08$). At Gariep Dam, the overall catch during the seasonal survey were dominated by *L. aeneus* (38.3%), followed by *C. gariepinus* (37%). The overall catch at Krugersdrift Dam was dominated by *C. gariepinus* (46.3%), followed by *C. carpio* (34.8%).

DISCUSSION

Small-scale fishing is on the increase at most state dams in the Free State Province (Barkhuizen 2015). Most small-scale fishers harvest the resource by angling and, as reported by Ellender et al. (2010b), the expected end-of-day catch ranges between 2.2 and 6.4 kg-angler⁻¹.d⁻¹ depending on sampling period. However, angling requires active participation which reduces time available for other income-generating activities. In South Africa the use of gill nets, a passive gear widely used in small-scale fisheries in Africa (Tweddle et al., 2015), remains controversial as their bycatch can include threatened fishes and other non-target taxa including birds, reptiles (e.g. Ellender et al., 2012; Ellender et al., 2016) and otters (Barkhuizen, 2015). In addition, unsustainable gill netting may cause major stock reductions to the detriment of species, the ecosystem and other users of the resource, e.g., recreational and subsistence angling. With an average CPUE approximating 16.8 ± 28.3 kg.net⁻¹.night⁻¹ across 20 impoundments, the data from the current study suggests that fyke nets may have some utility as passive gear for use in small-scale fisheries. However, as indicated in Table 1, CPUE and species composition will vary between impoundments because of differences in productivity and fish abundance. Therefore, this gear will not be suitable for use in all impoundments. For example, at impoundments with clear water (Secchi depth > 200 cm) and with steep banks (e.g. Sterkfontein and Metsi Matso Dams) the lowest CPUE was recorded.

South Africa's draft inland fisheries policy looks towards inland fisheries as a source of food security and livelihoods for small-scale fishers. Extrapolating from a fish price of 17 ZAR/kg (based on sales price in the previous Gariep Dam fishery projects, LM Barkhuizen personal observation), the mean catch value of ZAR285/day substantially exceeds the proposed minimum rural wage of 160 ZAR/day (SAnews, 2018). Variation in catch rates between dams, however, suggests that while double-ended fyke nets may be a useful gear in small-scale fisheries on dams, locality-specific data will be necessary. This will prevent misguided development and unrealistic stakeholder expectations in localities where catch rates are likely to be too low (e.g. Sterkfontein and Metsi Matso Dams) to compensate for opportunity costs, which would contribute to the legacy of failure in inland fisheries development in South Africa (Barkhuizen et al., 2016).

This is demonstrated in the comparative assessment of the Gariep and Krugersdrift Dams. In Krugersdrift Dam, for example, catch was dominated by *C. carpio* and *C. gariepinus*, neither of which is a conservation priority species and both of which have established marketability (see Weyl et al., 2007; Ellender et al., 2010a). CPUE was generally high (19.97 ± 23.22 kg.net⁻¹.night⁻¹) but with a significant trend of increased CPUE with increasing temperature (Fig. 2). Here the use of fyke nets is likely to result in a productive (and profitable) enterprise for participants, should it be permitted. In Gariep Dam, on the other hand, the generally low (5.02 ± 6.05 kg.net⁻¹.night⁻¹) CPUE was maintained throughout the year (Fig. 2). In addition, more than half of the catch consisted of *L. aeneus* and Labeos (Table 2). This was unexpected as during the broad-scale summer survey these species made up only 6% of the total catch (see Table 1) and illustrates the weakness of rapid assessments for decision

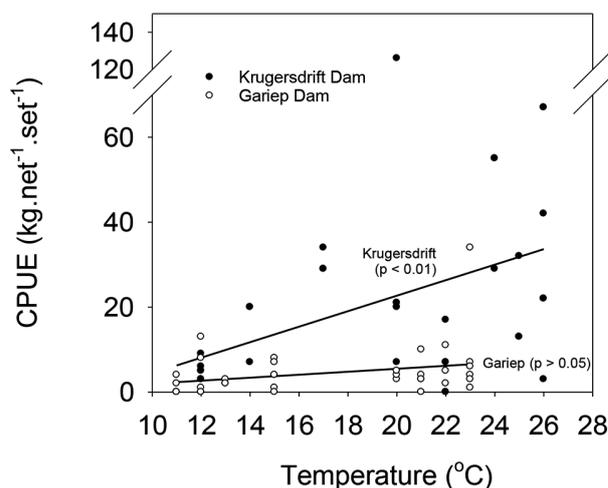


Figure 2. Scatterplot of fyke net CPUE in relation to temperature at Krugersdrift Dam and Gariep Dam for the period December 2015 until November 2016

making. Although these species are widespread and abundant, *L. aeneus* is considered a conservation-priority species and harvests in the Free State Province are regulated (Barkhuizen, 2015). In this case assessments of profitability may need to incorporate the release of a relatively high proportion of the catch. It is therefore imperative that comprehensive surveys are conducted on dams where the implementation of fyke nets are being considered as gears for small-scale fishers.

Within the development and eventual implementation of the National Inland Fisheries Policy in South Africa, fyke nets could be considered as an alternative gear to gill nets as they are less destructive and allow for the release of threatened and protected species with little to no harm. However, it is recommended that small-scale fishery projects using this gear be monitored and regulated as per the envisaged regulations emanating from the National Inland Fisheries Policy.

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