Gill net catch composition and catch per unit effort in Flag Boshielo Dam, Limpopo Province, South Africa

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ABSTRACT

Gill net surveys were conducted in 2013 to determine species composition and fisheries potential of Flag Boshielo Dam. Species contributing the most towards total biomass were *Labeo rosae* (40%), *Oreochromis mossambicus* (15%), *Schilbe intermedius* (10%) and *Labeobarbus marequensis* (9.8%). Catch per unit effort for gill nets set at night (4.4 ± 0.6 kg·100 m-net^{-1}·hr^{-1}) was significantly higher ($P < 0.05$) than for those set during the day (0.9 ± 0.1 kg·100 m-net^{-1}·hr^{-1}). Total fish biomass captured in 30, 50, 70, 90 and 110 mm mesh sized nets was 3.1, 31.5, 43.5, 23.5 and 16.1 kg, respectively. Catch in gillnets with mesh sizes ≥ 70 mm was dominated by *L. rosae* comprising 60% of the catch in the 70 mm mesh; *L. rosae* (40%) and *O. mossambicus* (36%) in the 90 mm mesh; and *O. mossambicus* (40%) and *Clarias gariepinus* (40%) in the 110 mm mesh. If a small-scale fishery were to be initiated, it is recommended that mesh sizes should exceed 70 mm and that further research on the biology and ecology of the main target species and of the current utilisation of the fishery be conducted to guide sustainable utilisation.

Keywords: Arabie Dam, CPUE, fish composition, net selectivity, inland fisheries

INTRODUCTION

South Africa, which is essentially an arid country, has invested heavily in impoundments to store water for domestic, industrial and agricultural use. Inland fisheries on these impoundments are considered to have the potential to support livelihoods and provide food security for rural populations (Britz et al., 2015). As small-scale fisheries are poorly developed in the country (Hara and Backeberg, 2014) and have a history of failure (Barkhuizen et al., 2016), it is important that future development effort be directed towards regions of high potential fish production (Britz et al., 2015). In order to guide such development, a recent baseline study used empirical approaches to identify impoundments in the warmer northern and coastal regions of South Africa as having high fish production potential (Britz et al., 2015). A major weakness of such empirical assessments, however, is that these assessments fail to consider the fish communities within the impoundments. As a consequence, Britz et al. (2015) recommend that the results of the regional assessment should only be used as an indication of fisheries potential and must be accompanied by finer scale analyses.

Since the presence of economically desirable species (e.g. *Oreochromis mossambicus*, *Cyprinus carpio* and *Clarias gariepinus*) is a prerequisite for the development of an inland fishery, knowledge of the composition of the fish population and abundance of species in an impoundment is vital in guiding the decision whether or not to develop a fishery (Weyl et al., 2007). The lack of such assessments in most impoundments is therefore considered a severe bottleneck to the development of inland fisheries in South Africa (McCafferty et al., 2012). For this reason, research on catch composition and catch rates is highly relevant in the context of inland fisheries development in the country (Britz et al., 2015).

Flag Boshielo Dam (24° 46' 50" S; 29° 25' 32" E) was constructed in 1987 to supply water to neighbouring municipal and rural districts for domestic, agriculture and mining purposes (Van Koppen, 2008). The impoundment is located immediately downstream of the confluence of the Olifants and Elands rivers that form part of the Limpopo River system (Fig. 1). Its catchment area is approx. 4 213 km^2 and at full capacity the 1 164 ha reservoir is the second-largest impoundment in the Limpopo Province (DWAF, 2005). The impoundment is a popular venue for recreational and subsistence anglers (Dabrowski et al., 2013; Tapela et al., 2015). A preliminary empirically derived estimate of the potential yield from this reservoir was 88 t·yr^{-1} (Britz et al., 2015), which indicated the potential to develop a small-scale fishery in the Ephraim Mogale Local Municipality; estimated population of 124 500, 88% from rural settlements (Tapela et al., 2015). Unfortunately, the potential for a fishery on this impoundment has never been formally assessed, with recently published information focusing on fish parasites (e.g. Madanire-Moyo et al., 2012a, b), limnology (Heath et al., 2010; Dabrowski et al., 2013), foodwebs (Dabrowski et al., 2014; Lübcker et al., 2014) and heavy metal contamination of fish tissue (Addo-Bediako et al., 2014a, b; Jooste et al., 2014; 2015; Marr et al., 2015; Lebepe et al., 2016). To determine the potential for Flag Boshielo Dam to support a small-scale fishery, a gill net survey was conducted to determine the species composition and relative abundance of potential target species.

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MATERIALS AND METHODS

Gill net surveys were undertaken every second month of 2013 using a 25 m long gill net consisting of five 2 m deep × 5 m wide panels with stretched mesh sizes of 30, 50, 70, 90 and 110 mm. During each sampling event, the net was set at 1 of 3 sampling stations representing the inflow, the main basin and the limnetic waters close to the dam wall. The net was set approximately 2 h before sunset and lifted 5 h later. At sunrise the following morning, the net was set at the same site for 4 h. At each site, water temperature (°C), dissolved oxygen (DO: $mg{\cdot}L^{-1}$), electrical conductivity (EC: $\mu S{\cdot}cm^{-1}$), total dissolved solids (TDS: $mg{\cdot}L^{-1}$) and pH were recorded in situ between 6:00 and 10:00 using a YSI 554 multi-meter.

Catch rate and target species

Fish were identified to species level sensu Skelton (2001), or subsequent taxonomic revisions, e.g., Skelton (2016), with the total length (TL: mm) and mass (g) recorded. The total catch for each species component in each mesh size was reported as percentage abundance or mass. Mean catch per unit effort (*CPUE*) was calculated as:

$$\text{CPUE} = \sum \frac{\left(\frac{C_i}{E_i}\right)}{n}$$

where: C_i is the catch size (either in the number or mass of fish) per gear i, E_i is the effort expended by gear i and n is the number of gears used (Pollock et al., 1994). Effort units were standardized to 100 m $net{\cdot}hr^{-1}$.

Data analyses

Since the application and net setting times were kept the same during each sampling event, the CPUE between mesh sizes, and between day and night netting, were standardised by expressing CPUE effort as $kg{\cdot}100\ m\text{-}net^{-1}{\cdot}hr^{-1}$. Catch data were analysed for significant differences by pooling mesh size and survey data. Preliminary analyses demonstrated that CPUE data did not meet the criteria for normality and homogeneity of variances required for the use of parametric tests. Differences between day and night CPUE were established using the Kruskal-Wallis test while the Mann-Whitney U test was applied to establish whether there were significant differences between the CPUE and mesh size. Similarly, the latter test was used to examine for significant differences of combined day and night CPUE between species captured in mesh sizes > 70mm. Analyses were done using the R statistical software (R Development Core Team, 2016). Target species were identified as those species making up more than 20% of the catch biomass in any of the mesh sizes.

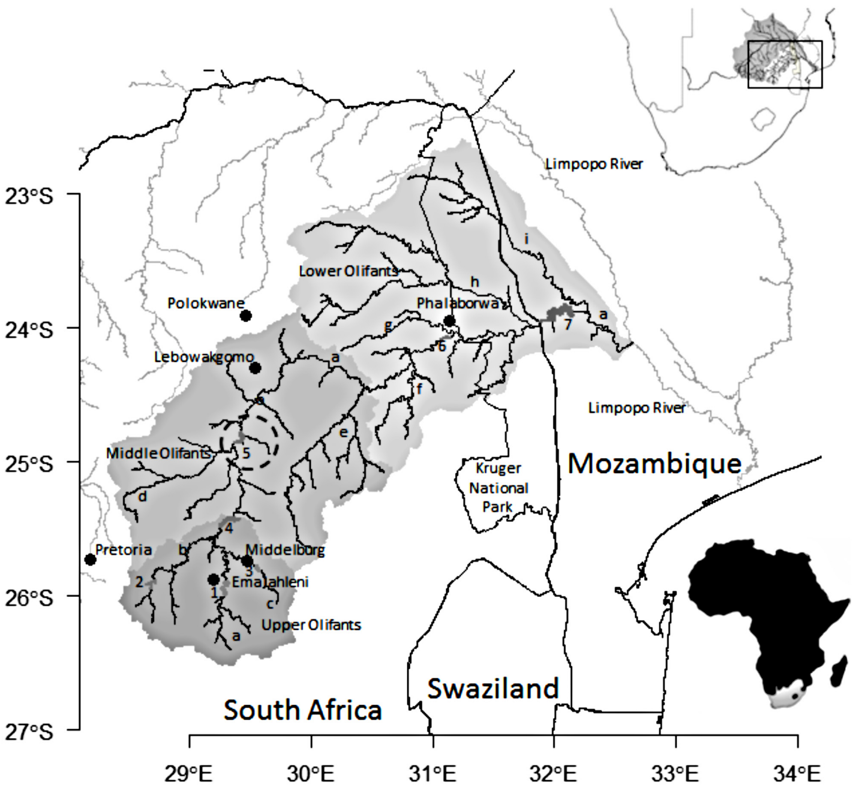

Figure 1
Map of the Olifants River system showing locations of major towns, impoundments and tributaries. Major impoundments are: 1) Witbank Dam, 2) Bronkhorstspruit Dam, 3) Middelburg Dam, 4) Loskop Dam, ***5) Flag Boshielo Dam****, 6) Phalaborwa Barrage and 7) Massingir Dam. The Olifants River and its tributaries are: (a) Olifants mainstem, (b) Wilge, (c) Klein Olifants, (d) Elands, (e) Steelpoort, (f) Blyde, (g) Ga-Selati, (h) Lethaba and (i) Shingwedzi. The study site, Flag Boshielo Dam, is circled.*

RESULTS

Six surveys of fish and water samples were conducted at Flag Boshielo Dam during the months of January, March, May, July, September and November 2013.

Environmental parameters

During the study the recorded mean ± (S.E) for water temperature was 19.0 ± 0.1°C, 6.9 ± 0.1 $mg \cdot L^{-1}$ for DO, 571.6 ± 2.0 $\mu S \cdot cm^{-1}$ for EC and 337.38 ± 1.31 $mg \cdot L^{-1}$ for TDS. Recorded levels for pH ranged between 7.95 and 9.32.

Catch composition

A total of 927 fish, representing 18 species from 8 families, were recorded during the survey (Table 1). *Labeo rosae* constituted 36.9% of the overall biomass of 177.8 kg, followed by *O. mossambicus* (15.7%), *Schilbe intermedius* (10.1%), *Labeobarbus marequensis* (9.8%), *C. gariepinus* (7.6%), *Synodontis zambezensis* (5.9%) and *C. carpio* (4.2%). Cumulatively, all other species contributed less than 18% of the total biomass (Table 1). Species richness decreased with mesh size from 11 species in the 30 mm mesh to 5 species in mesh sizes ≥ 90 mm (Table 2). *Labeo rosae*, *O. mossambicus* and *C. gariepinus* dominated catch biomass in mesh sizes > 70 mm. Fish size typically increased with an increase in mesh size (Table 3).

Catch per unit effort

The CPUE based on mesh size and for day and night setting is summarised in Fig. 2. From Fig. 2 the overall CPUE was significantly higher for nets set at night than those set during the day ($P < 0.05$). Night CPUE biomass increased significantly ($P < 0.05$) with mesh size from 0.6 ± 0.4 ($kg \cdot 100$ $m\text{-}net^{-1} \cdot hr^{-1}$) in the 30 mm mesh to a maximum of 7.9 ± 3.6 ($kg \cdot 100$ $m\text{-}net^{-1} \cdot hr^{-1}$) in the 70 mm mesh, declining significantly ($P < 0.05$) to 3.0 ± 1.7 ($kg \cdot 100$ $m\text{-}net^{-1} \cdot hr^{-1}$) in the 110 mm mesh.

The percentage species composition by mesh size for day and night sampling and the overall contribution specific to species CPUE is shown in Table 4. In nets set out in the morning *O. mossambicus* were dominant contributing > 54% of the total catch composition biomass across all mesh sizes (Table 4). In contrast, catch composition at night had a higher recorded species richness with sample biomass comprising *L. rosae* (38.7%), *O. mossambicus* (11.7%), *S. intermedius* (10.3%), *L. marequensis* (9.9%) and *C. gariepinus* (9.1%). For combined night and day catches for mesh sizes ≥ 70 mm the mean CPUE for *L. rosae* (1.4 ± 1.4 $kg \cdot 100$ $m\text{-}net^{-1} \cdot hr^{-1}$) was the highest but not significantly different ($P > 0.05$) to those of *O. mossambicus* (0.7 ± 0.3 $kg \cdot 100$ $m\text{-}net^{-1} \cdot hr^{-1}$), *S. intermedius* (0.1±0.1 $kg \cdot 100$ $m\text{-}net^{-1} \cdot hr^{-1}$) and *L. marequensis* (0.2 ± 0.2 $kg \cdot 100$ $m\text{-}net^{-1} \cdot hr^{-1}$).

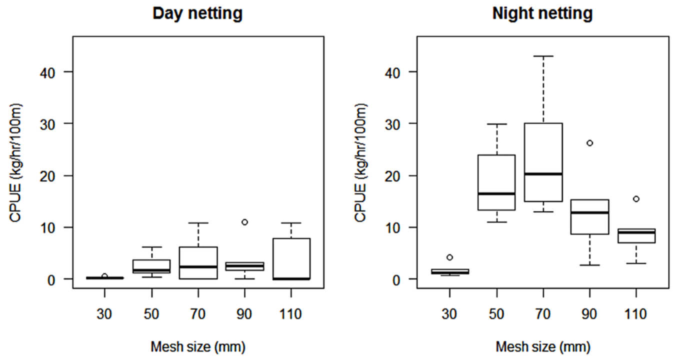

Figure 2
Box whisker plots indicating the CPUE ($kg \cdot 100$ $m\text{-}net^{-1} \cdot hr^{-1}$) for net mesh sizes used in day and night fish surveys conducted in Flag Boshielo Dam from January to November 2013

TABLE 1
The abundance and biomass, expressed as a percentage (%), of fish species collected in Flag Boshielo Dam from January to November 2013

Family	Species	Common name	Abundance (%) (*n* = 927 fish)	Biomass (%) (Total = 117.8 kg)
Alestidae	*Micralestes acutidens* (Peters, 1852)	Silver robber	8.0	0.4
Centrarchidae	*Micropterus salmoides* (Lacepède, 1802)*	Largemouth bass	1.6	3.7
Cichlidae	*Coptodon rendalli* (Boulenger, 1897)	Redbreast tilapia	0.2	0.1
	Oreochromis mossambicus (Peters, 1852)	Mozambique tilapia	10.5	15.7
	Pseudocrenilabrus philander (Weber, 1897)	Southern mouthbrooder	0.1	0.0
	Tilapia sparrmanii A. Smith, 1840	Banded tilapia	0.1	0.0
Clariidae	*Clarias gariepinus* (Burchell, 1822)	Sharptooth catfish	0.6	7.6
Cyprinidae	*Enteromius paludinosus* (Peters, 1852)**	Straightfin barb	0.1	0.0
	Enteromius rapax (Steindachner, 1894)** / ***	Papermouth	0.7	0.5
	Enteromius trimaculatus (Peters, 1852)**	Threespot barb	18.5	1.5
	Enteromius unitaeniatus (Günther, 1867)**	Slender barb	1.1	0.1
	Cyprinus carpio Linnaeus, 1758*	Common carp	1.4	4.2
	Hypophthalmichthys molitrix (Valenciennes, 1844)*	Silver carp	0.2	0.8
	Labeo cylindricus Peters, 1852	Redeye labeo	0.5	0.2
	Labeo rosae Steindachner, 1894	Rednose labeo	14.3	36.9
	Labeobarbus marequensis (A. Smith, 1841)	Lowveld largescale yellowfish	11.0	9.8
Mochokidae	*Synodontis zambezensis* Peters, 1852	Brown squeaker	12.9	5.9
Mormyridae	*Marcusenius pongolensis* (Fowler, 1934)****	Bulldog	3.2	2.4
Schilbeidae	*Schilbe intermedius* Rüppell, 1832	Butter catfish	15.0	10.1

indicates alien species, **indicates the genus previously known as Barbus, see Skelton (2016), ***see Eschmeyer et al. (2017), ** see Maake et al. (2014)*

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TABLE 2
The biomass of fish collected in Flag Boshielo Dam using gillnets with mesh sizes of 30, 50, 70, 90 and 110 mm from January to November 2013. (The biomass of a species is expressed as a percentage of the total biomass for each mesh size and the overall contribution to the total mass collected.) Values in bold indicate species that contributed > 20% of the total catch.

Species	The % biomass for net mesh sizes:					Overall contribution (%)
	30 mm	50 mm	70 mm	90 mm	110 mm	
Clarias gariepinus			3.8	3.2	36.8	7.6
Coptodon rendalli			0.6			0.2
Cyprinus carpio		0.2	2.2	5.7	14.7	4.2
Enteromius rapax		2.3				0.6
Enteromius trimaculatus	**38.7**	1.6				1.4
Hypophthalmicthys molitrix					5.3	0.8
Labeo cylindricus	0.4	0.9				0.2
Labeo rosae		9.2	**63.2**	**39.6**	6.6	**33.7**
Labeobarbus marequensis	5.5	**21.6**	7.4	6.5		9.8
Marcusenius pongolensis	3.2	7.4	0.8	0.5		2.4
Micralestes acutidens	17.2					0.4
Micropterus salmoides		1.2	8.9	8.1		5.1
Oreochromis mossambicus	8.6	8.6	8.6	**36.4**	**36.7**	18.7
Pseudocrenilabrus philander	0.2					0.0
Schilbe intermedius	**22.3**	25.3	4.6			8.9
Synodontis zambezensis	3.3	**21.8**				5.9
Tilapia sparrmanii	0.6					0.0

TABLE 3
The sample size (*n*) and mean total length (TL: mm) of fish sampled from Flag Boshielo Dam using different mesh sizes during surveys conducted from January to November 2013. (Standard deviation is given in parentheses.)

Species	Mesh size (mm)									
	30		50		70		90		110	
	n	TL (mm)	*n*	TL	*n*	TL	*n*	TL	*n*	TL
Clarias gariepinus					1	576	2	457 (21)	3	641 (73)
Coptodon rendalli					1	190				
Cyprinus carpio			1	155	5	227 (22)	5	256 (30)	2	407 (139)
Enteromius rapax			7	209 (18)						
Enteromius trimaculatus	174	77 (33)	9	158 (49)						
Hypophthalmicthys molitrix									2	364 (47)
Labeo cylindricus	1	102	4	164 (46)						
Labeo rosae			20	227 (36)	92	294 (21)	21	333 (38)	1	395
Labeobarbus marequensis	4	136 (66)	84	196 (25)	10	276 (28)	5	281 (64)		
Marcusenius pongolensis	1	212	27	223 (98)	1	286	1	221		
Micralestes acutidens	76	88 (13)								
Micropterus salmoides			3	198 (59)	9	265 (24)	3	318 (17)		
Oreochromis mossambicus	10	98 (34)	39	132 (33)	18	196 (37)	23	258 (24)	8	310 (73)
Pseudocrenilabrus philander	1	60								
Schilbe intermedius	7	218 (36)	122	204 (17)	12	275 (29)				
Synodontis zambezensis	2	156 (8)	119	164 (12)						
Tilapia sparrmanii	1	66								

TABLE 4
The species composition of each mesh size used in the survey from January to November 2013 in Flag Boshielo Dam. The biomass of a species is expressed as a percentage of the total biomass of each mesh size.

Species	Day sampling (% biomass)						Night sampling (% biomass)					
	30 mm	50 mm	70 mm	90 mm	110 mm	All meshes	30 mm	50 mm	70 mm	90 mm	110 mm	All meshes
Clarias gariepinus									4.3	4.1	49.7	9.1
Coptodon rendalli			4.4			1.2						
Cyprinus carpio								0.2	2.5	7.2	19.8	5.1
Enteromius rapax		9.3				1.8		1.3				0.4
Enteromius trimaculatus	46.5	0.3				0.8	37.7	1.8				1.5
Hypophthalmicthys molitrix											7.1	1.0
Labeo cylindricus		2.5				0.5	0.4	0.7				0.2
Labeo rosae		8.5			25.5	7.8		9.2	72.9	50.2		38.7
Labeobarbus marequensis		19.7	12.6	8.0		9.4	6.2	21.8	6.6	6.1		9.9
Marcusenius pongolensis		3.2				0.6	3.6	7.9	0.9	0.6		2.8
Micralestes acutidens	15.7					0.3	17.5					0.4
Micropterus salmoides			45.6	29.7		20.8		1.4	3.3	2.3		2.0
Oreochromis mossambicus	30.2	47.2	37.4	62.3	74.5	54.9	5.9	3.4	4.2	29.5	23.4	11.7
Pseudocrenilabrus philander	1.8					0.0						
Schilbe intermedius		9.4				1.8	25.1	27.5	5.3			10.3
Synodontis zambezensis							3.7	24.7				7.1
Tilapia sparrmanii	5.8					0.1						

DISCUSSION

The survey data show that Flag Boshielo Dam has fish fauna that includes species of potential commercial interest. Large cichlids of the genus *Oreochromis* for example, are the basis for commercial fisheries in the Zambezi River catchment and in Lake Liambezi (Peel et al., 2015; Tweddle et al., 2015), while large cyprinids of the genera *Labeo* and *Labeobarbus* are harvested in small-scale fisheries in Mozambique (Booth and Weyl, 2004) and Malawi (Weyl et al., 2010). It is likely that should a small-scale gill-net fishery be developed at Flag Boshielo Dam, it would be based on species that have a proven ability to support fisheries elsewhere (Weyl et al., 2007).

Species of commercial potential dominated the catch composition in gill nets with mesh sizes > 70 mm. The highest CPUE was obtained using 70 mm mesh nets at night. The considerably higher CPUE in this mesh size was a consequence of the higher species richness and numbers of fish, which compensated for the relatively small average size of fish when compared to the larger mesh sizes. As many African inland fisheries suffer from severe overfishing, the symptoms of which include the depletion of larger, higher value species and decreasing CPUE (Weyl et al., 2010; Tweddle et al., 2015), it is essential that fisheries development be guided by the concept of sustainable natural resource utilisation (Froese et al., 2015).

Typical management approaches for inland fisheries include effort and gear restrictions. Effort restrictions include closed seasons, the demarcation of fishing areas and limitations with regard to participation, while gear restrictions typically restrict gear dimensions (Weyl et al., 2007). Often, recommendations on appropriate harvest strategies rely on outcomes generated by fisheries models that require biological information of target species so as to predict lower risks of stock collapse when fish are harvested after they attain maturity (e.g. Kanyerere et al., 2005; Richardson et al., 2009). In addition, in cases where species have life-histories and behaviour patterns that make them vulnerable at certain stages (e.g. during spawning aggregations may occur at river mouths and inlets), closed seasons are typically recommended (Booth and Weyl, 2004; Winker et al., 2012).

Because of the low CPUE, totalling 3.1 kg for 30 mm mesh size nets in this study, the use of these nets is unlikely to be viable from a harvest perspective in Flag Boshielo Dam. In contrast, the 50 mm and 70 mm mesh sizes yielded the highest catch rates. However, in the 50 mm mesh size, the length at capture of some of the larger bodied fishes was well below reported minimum lengths at maturity of fish from other reservoirs (e.g., 223 – 253 mm TL for *O. mossambicus* (Weyl and Hecht, 1998); 170 – 220 mm TL for *L. marequensis* (Fouché, 2009) and 150 mm TL for *L. rosae* (Skelton, 2001)). As there is also considerable evidence that life-histories can vary considerably between localities (e.g., Weyl and Hecht, 1998; Winker et al., 2010; Weyl et al., 2016), there is a need for research on the biology and ecology of these species in Flag Boshielo Dam as the capture of immature specimens could jeopardise the breeding and recruitment strategy of these species. Such research should focus on data required for the application of fisheries models that allow for the determination of suitable harvest strategies that result in maximum yields at minimum risk of stock collapse in multi-species fisheries (Pikitch, 1987; Hilborn, 2011).

Another consideration is that the current utilisation of fish stocks by recreational and subsistence anglers needs to be determined. This is essential because angling can be an important but often overlooked and underestimated component of an inland fishery (Ellender et al., 2009). Ellender et al. (2010), for example, demonstrated that more than 450 subsistence anglers were utilising the fish resource in the Gariep Dam and cautioned that the development of a commercial fishery could negatively impact on the vulnerable livelihoods of these fishers. It is therefore important that catch compositions in gill nets be compared with those of the anglers to determine the potential competition for resources if a gill-net fishery were to be developed. In addition, the current harvests need to be determined so that the impact can be determined and appropriate harvest levels set.

An important consideration prior to developing a fishery in Flag Boshielo Dam is the potential human health risks associated with the consumption of fish from the Olifants River System. Concentrations of heavy metals that could severely impair human health were found in muscle tissue of *S. intermedius* (Addo-Bediako et al., 2014b; Marr et al., 2015), *O. mossambicus* (Addo-Bediako et al., 2014a), *L. rosae* (Jooste et al., 2014; Lebepe et al., 2016) and *C. gariepinus* (Jooste et al., 2015; Marr et al., 2015) sampled from Flag Boshielo Dam. For this reason, the development of a fishery might be inappropriate even if catch rates are conducive to fisheries development.

In conclusion, this paper has demonstrated that Flag Boshielo Dam contains species used in small-scale fisheries elsewhere. Given the relatively low estimated yield of 88 t·yr^{-1} by Britz et al. (2015), any development of a formal fishery should proceed with caution whereby catches are to be monitored to evaluate the status of the fishery, especially during periods of drought and low dam levels. Monitoring data could be used to regulate fishing effort and close the fishery when threatened with over-exploitation. Moreover, if a small-scale fishery were to be initiated, it is recommended that mesh sizes should exceed 70 mm and that further research on the biology and ecology of the main target species and of the current utilisation of the fishery is conducted to guide sustainable utilisation.

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