Fish population assessment in a temperate Lowveld impoundment of the Transvaal, South Africa

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Abstract

As part of a wider fish ecological study of a temperate North-Eastern Transvaal impoundment, an assessment of the fish stock was made employing three methods of mark-recapture population estimation. During the experiment a total of 21 217 fish were captured, marked and released. Of these, 1 204 were recaptured. With the exception of three of the seven numerically important species studied, the recapture success was statistically sound, providing representative estimates of numbers and mass which can be expected to approximate those of the actual populations. Results showed *Oreochromis mossambicus* to be the dominant species in the impoundment.

Introduction

The construction of impoundments in the major river basins in Southern Africa was originally aimed at the storage of rain water for agricultural and domestic purposes. The development of fish populations in these impounded water bodies led to the intensification of recreational fishing (Cadieux, 1980; Koch and Schoonbee, 1980). To assess the possible impact of anglers on these fish populations, a number of studies were conducted using intensive mark-recapture surveys in selected natural and man-made lakes in Southern Africa (Göldner, 1967; Göldner et al., 1972; Batchelor, 1978; Koch and Schoonbee, 1980). Information obtained on the status of various fish stocks, emphasised the exploitation potential of some of these species on a sustainable yield basis, in particular in the rural areas where numerous impoundments exist and where there is a need for animal protein as food to combat some of the prevailing nutritional diseases (Steyn et al., 1992). The marketing of exploitable fish from such impoundments in the Northern Transvaal (Taylor and Van der Walt, 1985; Saayman et al., 1986) further emphasised the importance of this kind of investigation within the rural areas of the country.

The present study deals with an ecological survey of the Piet Gouws Dam in the Northern Transvaal with emphasis on intensive mark-recapture of the exploitable fish species. This impoundment is located in the Ngwaritsi River, a tributary of the Olifants River and has a catchment area of 650 km^2. When full, it covers a surface area of approximately 80 ha with a capacity of 7.361 x 10^6 m^3. It is situated between latitudes 24° and 25°S and longitudes 29° and 30°E (Fig. 1). Attention was also given to aspects of the water chemistry of this impoundment. Although this investigation was conducted from 1979 to 1980, the increasing importance of the utilisation of fish stocks for human consumption, from this and other water bodies, necessitated the publication of the present research findings.

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Received 22 March 1994; accepted in revised form 18 October 1994.

Materials and methods

Selected physical and chemical conditions of the water were monitored at ten sampling stations (Fig.1). Analyses were done according to *Standard Methods* (1974).

For the population study itself, which took place over a period of 14 days in spring (17 September to 3 October 1979), a total of nine localities were selected in the littoral zone around Piet Gouws Dam (Fig. 1). Five fish samples were taken at each locality, using a beach seine net (122 m long with a net and bag mesh of 25 mm and 10 mm respectively) giving a total of 45 hauls.

This time of the year was specifically chosen to coincide with the onset of the breeding season of most of the fish species (Göldner et al., 1972; Koch and Schoonbee, 1980) in the dam. At this time the fish not only tend to migrate closer to the shallower littoral region of impoundments, from where they can then easily be sampled, but also most of the larvae and fry of this spawning season can still escape through the mesh of the seine nets used. It was, however, important that juveniles from spawns of the previous year should be caught in the nets, thus being included in the population census statistics.

Although there are several ways of marking fish, such as the use of tags (Ricker, 1968), antibiotics (Weber and Ridgeway, 1962), branding of fish with a heated wire (Gerking, 1963), injection of latex under the skin (Davis, 1955) or the use of dyes (Loeb, 1962), the fin clipping technique, whereby part of the anal, pectoral or tail fin of fish is removed (Ricker, 1968; Göldner et al., 1972; Koch and Schoonbee, 1980), was adopted. It is the least time-consuming way of marking fish and large numbers of fish can be handled in a short period of time, thereby reducing the mortality rate of fish caught. Marked fish can be recognised for a period of at least three months, allowing ample time for fish population size investigations to be carried out in a water mass such as the Piet Gouws Dam. The removal of part of the dorsal branch of the tail fin was considered to be the least harmful, as well as one of the quickest ways of marking the fish before returning it to the water.

Mark and recapture methods for the estimation of population size, originally developed from that of Petersen (1896), by Schnabel (1938) and Schumacher and Eschmeyer (1943) and described in detail by Ricker (1958; 1975) are used in the present study. Since the statistical approach of the latter two methods is somewhat different, the population estimates of all three methods obtained are

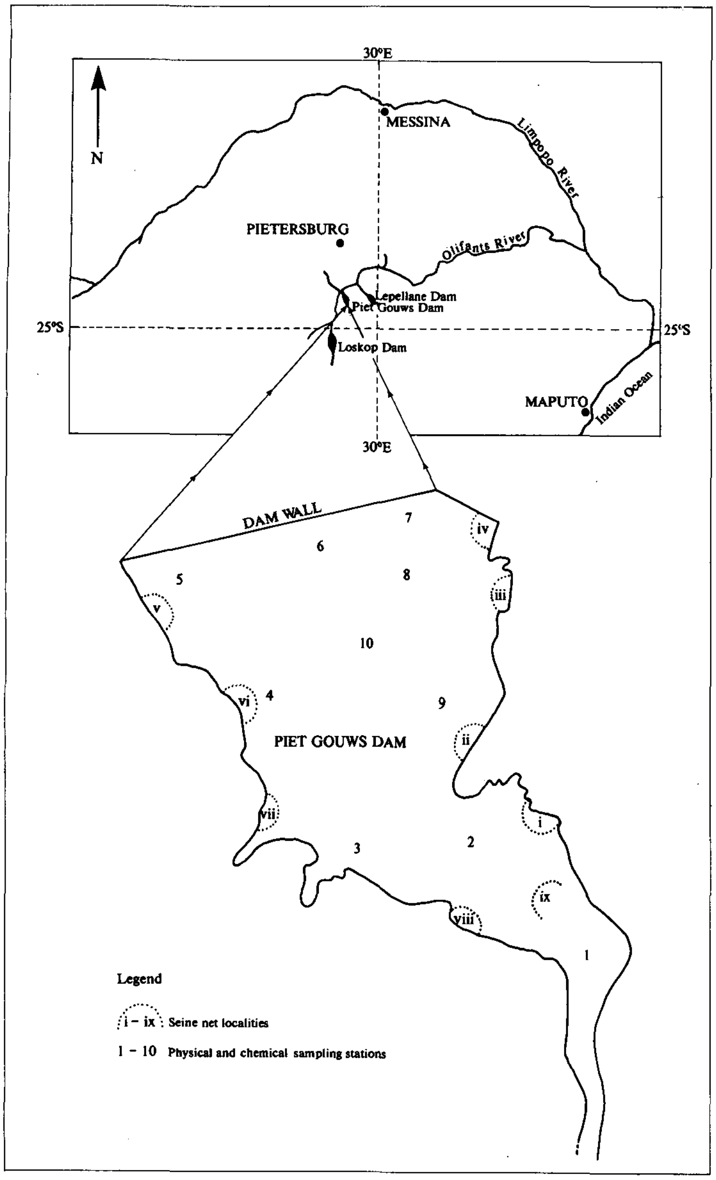

Figure 1
Piet Gouws Dam showing chemical and seine net sampling stations

recorded in the results for comparison purposes. The two formulae employed for the Schnabel and Schumacher and Eschmeyer estimates are as follows:

Schnabel (1938) formula:

$$N = \frac{\sum_{i=1}^{n} t_i m_i}{\sum_{i=1}^{n} r_i}$$

Schumacher and Eschmeyer (1943) formula:

$$N = \frac{\sum_{i=1}^{n} m_i^2 t_i}{\sum_{i=1}^{n} m_i r_i}$$

where:

i = the i'th sample
t = the total number of fish in the i'th sample
r = the number of recaptures (marked fish) in the i'th sample
m = the total number of marked fish in the lake just **before** the i'th sample is drawn
N = the estimate of population size.

Under ideal conditions the main prerequisites for a mark-recapture experiment include conditions as close to the following as possible:

- A 100% random mixing of marked and unmarked fish
- No mortality due to handling, fishing or natural causes
- No recruitment during the survey
- No active avoidance of the nets by the various species.

It is very seldom that all of these conditions are met. However, by conducting the survey in the shortest time possible, some of the

TABLE 1
SELECTED SUMMER AND WINTER PHYSICAL AND WATER QUALITY CONDITIONS OF PIET GOUWS DAM DURING THE SURVEY PERIOD OF 1979 TO 1980

Parameter	Summer (n = 10)		Winter (n = 10)	
	Mean	Range	Mean	Range
Temperature (°C)	19.6	17.0 - 24.0	14.2	13.0 - 15.0
pH		8.3 - 8.4		8.0 - 8.7
Conductivity ($mS \cdot m^{-1}$)	50.1	49.8 - 50.3	58.4	57.0 - 59.0
Turbidity (% light penetration)	31.9	31.0 - 34.0	94.0	90.0 - 96.0
Dissolved oxygen ($mg \cdot \ell^{-1}$)	7.31	4.8 - 7.9	8.98	8.5 - 9.6
Total hardness as $CaCO_3$ ($mg \cdot \ell^{-1}$)	81.5	70.0 - 130.0	-	-
Sulfate SO_4 ($mg \cdot \ell^{-1}$)	9.7	8.0 - 11.0	22.0	15.0 - 40.0
Chloride Cl ($mg \cdot \ell^{-1}$)	67.5	65.0 - 70.0		85.00
NH_4 - N ($mg \cdot \ell^{-1}$)	0.028	0.020 - 0.035	0.440	0.400 - 0.500
NO_3 - N ($mg \cdot \ell^{-1}$)	0.628	0.125 - 1.000	0.202	0.180 - 0.250
PO_4 - P ($mg \cdot \ell^{-1}$)	0.247	0.125 - 0.300	0.164	0.080 - 0.300

TABLE 2
TOTAL NUMBER OF FISH CAPTURED AND MARKED (C_T) AND RECAPTURED (R_T) DURING THE FISH POPULATION CENSUS AT PIET GOUWS DAM, TRANSVAAL

Fish species	C_t	% of ΣC_t	R_t	% of ΣR_t	R_t as % of C_t at t_6
Oreochromis mossambicus	17 892	84.3	976	81.0	13.1
Labeo cylindricus	1 159	5.5	125	10.4	30.0
Labeo rosae	90	0.4	14	1.2	50.0
Barbus marequensis	393	1.9	32	2.7	9.7
Barbus mattozi	505	2.4	26	2.1	13.7
Barbus paludinosus	541	2.5	12	1.0	7.0
Barbus trimaculatus	488	2.3	15	1.2	3.5
Clarias gariepinus	149	0.7	4	0.3	7.5
All fish species	**21 217**		**1 204**		**$\bar{x}$: 16.8**

above conditions could be satisfied.

A Fortran IV programme was developed to calculate estimates of fish population size for each consecutive unit of t (one complete sampling cycle) for the Peterson, Schnabel and Schumacher & Eschmeyer methods of estimate (Ricker, 1975).

In addition to the numerical stock assessment of the various fish species, based on numbers, calculations were also made on their relative contribution in terms of biomass. To facilitate these calculations, the length/mass formula: $w = cL^n$ (Le Cren, 1951) was employed, using representative data accumulated from the same river basin as that of the Piet Gouws Dam.

Results

Physical and chemical water quality conditions

Mean water temperatures for summer and winter varied between 14.2 and 19.6°C (Table 1). The pH of the water was alkaline during both seasons with a maximum of 8.7 during winter. Dissolved solids, as reflected by conductivity, were high during both seasons with a highest mean of 58.4 $mS \cdot m^{-1}$ during the dry season (winter). Turbidity was poorest during the summer rainfall period (31.9%). Dissolved oxygen throughout the water column (7.31 to 8.98 $mg \cdot \ell^{-1}$) was relatively good during both seasons. The total hardness of the water varied between 70 and 130 $mg \cdot \ell^{-1}$ (summer values only), with sulphate concentrations being highest during winter (22 $mg \cdot \ell^{-1}$). Mean chloride concentrations fluctuated between 67.5 and 85.0 $mg \cdot \ell^{-1}$. Concentrations for ammonia, nitrate and phosphate reflected mild organic enrichment of the water in the impoundment during both seasons (Table 1).

Mark-recapture studies

During this part of the investigation a total of 21 217 fish were caught, marked and released and 1 204 marked fish (5.7%) were recaptured in the process (Table 2). Many juvenile *O. mossambicus*, smaller than 6 cm in total length, escaped through the net. Those caught in the smaller mesh of the bag of the net were therefore clearly not a representative sample. This factor must therefore be borne in mind in the final calculation of stock size estimates of the various species concerned (Table 3).

Except for *Barbus paludinosus, B. trimaculatus, B. mare-*

TABLE 3
FISH POPULATION SIZE (N) AND MASS ESTIMATES FOR THE DIFFERENT LENGTH GROUPS OF *OREOCHROMIS MOSSAMBICUS* IN PIET GOUWS DAM, TRANSVAAL, BASED ON MEAN SAMPLE SIZES AND THE LENGTH/MASS RELATIONSHIP: $W = CL^N$ (LE CREN, 1951). POPULATION ESTIMATES ACCORDING TO THE SCHNABEL, SCHUMACHER AND ESCHMEYER (S - E) AND PETERSEN FORMULAE OF A FISH MARK-RECAPTURE STUDY. ($\bar{x}$ = MEAN, % = PERCENTAGE OF POPULATION). VALUES FOR SIZE ROUNDED TO THE CLOSEST cm

Size groups (cm)	Method of estimate	N	$\bar{x}$	%	95% confidence limits	Mass in kg	%
	Schnabel	16053			13457 - 19891		
6 - 10	S - E	16995	16507	13%	11497 - 32566	113.6	0.94%
	Petersen	16472					
	Schnabel	53247			45955 - 63291		
11 - 15	S - E	55411	51825	41%	45474 - 70906	1667.2	13.78%
	Petersen	46816					
	Schnabel	29151			22146 - 42641		
16 - 20	S - E	28684	27507	22%	20262 - 49087	2444.0	20.20%
	Petersen	24687					
	Schnabel	22020			17523 - 29622		
21 - 25	S - E	20102	20693	16%	12427 - 52566	3926.1	32.46%
	Petersen	19946					
	Schnabel	11106			9019 - 14448		
26 - 30	S - E	9816	10418	8%	5894 - 29344	3622.7	29.95%
	Petersen	10331					
	Schnabel	583			399 - 1086		
31 - 35+	S - E	539	561	0.4%	317 - 1753	323.0	2.67%
	Petersen			560			
	Mean total:		**127 511**			**12 096.6**	

quensis and *Clarias gariepinus,* the recapture rate for the other species was highly acceptable, exceeding 13% at t_5 (Table 2). Estimates for *O. mossambicus, Labeo cylindricus, L. rosea* and *B. matozzi* can therefore be expected to approximate those of the actual populations in the dam. Confidence limits were obtained for both the Schnabel and the Schumacher and Eschmeyer estimates (Tables 3 and 4). In the case of *O. mossambicus* the estimate for the population was subdivided into successive 10 cm TL groups as shown in Table 3. In all cases an average was obtained for the three estimates and this figure was then taken as the representative estimate of the population size for a given fish species or, in the case of *O. mossambicus*, for a particular size group of fish. Only in one case (*L. rosae*) did one of the results (Petersen estimate, Table 4) not fall within the confidence limits for both the Schnabel and the Schumacher and Eschmeyer estimates.

Estimates of numbers and biomass of the various fish species

Oreochromis mossambicus

Results for *O. mossambicus* clearly showed this fish to be the dominant species in the dam (compare Tables 3 and 4), comprising 83.6% numerically and 69.0% (±12 t) of the total estimated biomass. Estimated numbers show the 11 to 15 cm group to dominate the *Oreochromis* population, constituting 41% of the more than 127 000 fish larger than 6 cm TL estimated for this species. Fish over 31 cm in length comprised only 0.4% of the estimated population. The bulk of the biomass (3.926 t) is made up by the 21 to 25 cm TL group followed by the 26 to 30 cm group (3.622 t) and the 16 to 20 cm group (2.443 t).

Labeo cylindricus

According to the individual and mean population estimates obtained for this species, the population size of *L. cylindricus* is small compared to that of *O. mossambicus*, with the Schnabel estimate being the more optimistic, showing an estimate of just over 4 000 fish of this species in the dam. Recapture data were good with a success of 30% marked fish caught during t_5 (Table 2). The estimates of population size of all three methods fall within the 95% confidence limits of both the Schnabel and the Schumacher and Eschmeyer estimates. *L. cylindricus* forms only 1.5% (257.5 kg) of the total estimated fish biomass in the dam.

Labeo rosae

Even though this fish species occurs in relatively small numbers in the dam, its recapture success during t_5 (50%, Table 2) was the best of all the species concerned. Its high recapture rate also confirms

TABLE 4
FISH POPULATION SIZE (N) AND MASS ESTIMATES FOR THE SPECIES OF FISH OTHER THAN *OREOCHROMIS MOSSAMBICUS* IN PIET GOUWS DAM, TRANSVAAL, BASED ON MEAN SAMPLE SIZES AND THE LENGTH/MASS RELATIONSHIP: $W = CL^N$ (LE CREN, 1951). POPULATION ESTIMATES ACCORDING TO THE SCHNABEL, SCHUMACHER & ESCHMEYER (S - E) AND PETERSEN FORMULAE OF A FISH MARK-RECAPTURE STUDY. ($\bar{x}$ = MEAN, % = PERCENTAGE OF POPULATION)

Size groups (cm)	Method of estimate	N	$\bar{x}$	%	95% confidence limits	Mass in kg	%
O. mossambicus			127511	83.6%		12096.5	69.0%
	Schnabel	4048		3	243 - 5385		
L. cylindricus	S - E	3751	3728	2.4%	2776 - 5783	257.5	1.5%
	Petersen	3386					
	Schnabel	195			112 - 756		
L. rosae	S - E	173	158	0.1%	120 - 312	53.7	0.3%
	Petersen	107					
	Schnabel	1738			1166 - 3412		
B. marequensis	S - E	2766	2108	1.4%	1018 - 3852	716.4	4.1%
	Petersen	1820					
	Schnabel	3610			2337 - 7924		
B. mattozi	S - E	3690	3886	2.6%	2721 - 5731	950.2	5.4%
	Petersen	4359					
	Schnabel	9092			5047 - 45771		
B. paludinosus	S - E	7050	7050	4.6%	3904 - 36298	104.7	0.6%
	Petersen	5009					
	Schnabel	6152			3584 - 21721		
B. trimaculatus	S - E	6915	6242	4.1%	4342 - 16972	121.4	0.7%
	Petersen	5660					
	Schnabel	2003			839 - 5162		
C. gariepinus	S - E	1711	1802	1.2%	1185 - 3084	3224.8	18.4%
	Petersen	1691					
	Mean total:		**152 485**			**17 525.2**	

the small population size of this fish. This condition is further emphasised by a very low biomass value obtained (53.7 kg, Table 4).

Barbus marequensis

The population size of *B. marequensis* averages at 2 108, with the Schumacher and Eschmeyer estimate (2 766) being the more optimistic. Although relatively few in number, the size of this species is more important with respect to its contribution towards total biomass (716.4 kg, Table 4).

Barbus mattozi

The population size of this species is much the same as that of *Labeo cylindricus* (Table 4) with the Petersen population estimate being the highest. It contributes 5.4% (950.2 kg) towards the estimated biomass.

Barbus paludinosus and *B. trimaculatus*

Population studies of the smaller minnows (*Barbus* spp.) in impoundments have never been undertaken before in South Africa, even though their ecological importance, especially as part of the food chain, may be considerable. Although mortalities were observed for both species during the process, recapture statistics at t_5 for *B. paludinosus* and *B. trimaculatus* were 7.0% and 3.5%, respectively. Both figures fall well below the ideal of 13 to 15% of marked fish recaptured and this can be considered conservative. *B. paludinosus*, with a mean population estimate of 7 050, was slightly higher than that of *B. trimaculatus* (6 242). These two species contributed 0.6% and 0.7% respectively, towards the estimated total fish biomass (Table 4).

Clarias gariepinus

The sharptooth catfish *C. gariepinus* has the ability to avoid seine nets. Where fish population studies were conducted on other impoundments in South Africa, (Göldner, 1967; Göldner et al., 1972; Koch and Schoonbee, 1980) population estimates obtained for this species were always well below the actual numbers. This also applies to the Piet Gouws Dam where an estimate of 1 802 for the population size of these fish must be conservative. Despite these relatively low numbers, it contributed more than 18% towards the total estimated fish biomass in the dam (3 224.8 kg, Table 4).

Discussion

The Piet Gouws Dam must, according to the findings obtained on the population size estimates of fish, be considered a typical *O. mossambicus* impoundment. In the event of any future cropping programme using gill nets, considerable care should be taken not to overfish some of the other larger fish species in this water body. The careful selection of suitable gill net sizes is therefore of the utmost importance for the judicious management of this reservoir during any planned harvesting programme as this approach will ensure a sufficiently high replenishment of the cropable fish stock.

As the population size of *L. rosae* is the smallest of all the larger fish species in the dam, there is the danger that this fish could easily be reduced further in numbers or eliminated from the dam by excessive gill netting during harvesting operations. It should, however, be taken into account that little rain had fallen during the preceding 2 to 3 years in the catchment area of the Piet Gouws Dam and that the breeding habitats of this species, which may be more of a riverine nature, might have been affected, so that conditions for the spawning of *L. rosae* were not very favourable. In the event of exploitation of this fish from the dam, the numbers and size caught should therefore be carefully monitored during any harvesting program.

B. marequensis, although bony, appears to be popular for consumption among the local population, and since it occurs in much smaller numbers than *O. mossambicus*, it should also be closely monitored during future cropping programmes.

In the case of *B. mattozi* care should be taken not to overfish this species during any future harvesting programmes as it is the only true predator fish in the impoundment.

The numerical as well as biomass data obtained during the present study will be helpful towards making recommendations on sustained yield cropping of this and other similar impoundments. However, additional data such as mesh size and selectivity of gill nets coupled to size at sexual maturity of the various fish species needs, of necessity, also to be taken into consideration. The latter aspects will be discussed in more detail in a subsequent paper based on empirical data obtained from other impoundments in the Northern Transvaal.

Acknowledgements

The authors wish to express their gratitude to the Department of Agriculture and Environment Affairs, Lebowa Government Service, for allowing us to work on Piet Gouws Dam. The Department of Development Aid and the University of the North are thanked for their financial support.

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