Fish distribution in relation to turbidity gradients in a man-made lake, Sterkfontein Dam (South Africa)

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Abstract

The objective of the study was to investigate the distribution of fish in relation to turbidity in Sterkfontein Dam. *Oncorhynchus mykiss* was found mainly in the limnetic zone of the clear-water section of the reservoir (10 NTU in 80% of the surface area). *Barbus aeneus* and *Labeo capensis* were caught predominantly in the most turbid area (mean 28.32 NTU). *Labeo umbratus* and *Clarias gariepinus* preferred a sheltered, well-vegetated bay in the clear-water area. Total catches indicated that the turbidity pattern found in the reservoir did not influence the distribution of indigenous fish species. Other factors such as availability of breeding and feeding habitats were probably more important.

Introduction

Sterkfontein Dam in the E. Free State can be considered a clear-water reservoir, with a mean turbidity of 10 nephelometric turbidity units (NTU) for about 80% of the surface area and a Secchi disc transparency of about 2 m (Dörgeloh et al., 1993). In contrast, most reservoirs in South Africa are turbid (Walmsley and Bruwer, 1980) with Secchi disc transparencies of about 1 m caused mainly by silty suspensoids (Allanson et al., 1990).

The low turbidity, relatively cold water temperatures, and well-oxygenated water made Sterkfontein Dam (Dörgeloh et al., 1993) a potential site for stocking the alien *Oncorhynchus mykiss* (rainbow trout). Juvenile *O. mykiss* (n = 36 000) were released near the dam wall during February 1984 by staff of the Directorate of Nature and Environmental Conservation of the Free State.

Some of the fish species occurring in Sterkfontein Dam, *Barbus aeneus* (smallmouth yellowfish), *Labeo capensis* (Orange River labeo), *Labeo umbratus* (moggel) and *Clarias gariepinus* (sharptooth catfish) (Dörgeloh, 1987), are indigenous to the Orange-Vaal River system and are also found in Le Roux Dam (Jackson et al., 1983), which is highly turbid (Walmsley and Bruwer, 1980).

High turbidities have a suppressing effect on primary production (Maitland, 1990) and zooplankton production (Walmsley and Bruwer, 1980), and subsequently reduce the food availability for fish (Newcombe and MacDonald, 1991). A lower food availability may in turn affect the distribution and habitat selection of fish. Information on the effects of suspensoids on fish in lentic freshwater environments in the Southern African subregion is limited (Allanson et al., 1990) and in particular on fish distribution. Some work on the influence of turbidity on juvenile marine species present in estuaries has been done (Cyrus and Blaber, 1987).

This study formed part of a larger ecological study in Sterkfontein Dam. The variations in turbidity made this reservoir a suitable site to investigate the effect of turbidity on the distribution of fish for comparison with those fish in a turbid environment such as Le Roux Dam. The objective of this study was to investigate the initial dispersion and ultimate distribution of *O. mykiss*, and the distribution of indigenous fish species in relation to turbidity.

Study area

Sterkfontein Dam (28°23' - 28°35'S and 28°58' - 29°04'E) is situated in the E. Free State at an altitude of 1 620 m (Fig. 1). It forms part of the Tugela-Vaal Scheme. The main water supply of Sterkfontein Dam is pumped from the Tugela River (Natal) over the lower Drakensberg escarpment into the Driekloof Dam from where it flows over a spillway into Sterkfontein Dam (Dept. of Water Affairs, 1986). Siltation takes place in the Driekloof Dam and in the upper reaches of Sterkfontein Dam.

Methods

The study was conducted from March 1984 to February 1985 at Sites 1 to 4 (Fig. 1) in Sterkfontein Dam. Sites 1 and 2 were situated in the clear-water section (≤10 NTU), sampling the limnetic and littoral zones respectively. The limnetic and littoral zones in the turbid section of the reservoir (>10 NTU) were sampled at sampling Sites 3 and 4 respectively.

Fish were caught each month with multifilament gill nets (25 m x 2 m) with stretched mesh sizes of 35, 50, 65, 73, 85, 100, 120 and 150 mm. Gill nets were connected in series with spaces of 2 m between them. The gill nets were left in the surface water overnight for 16 h at each sampling site.

The site and mesh size where each fish was collected, were recorded. Each fish was analysed for species, fork length and mass, sex and gonadal stage. Stomach samples were collected of fish in each length class. Turbidity and water temperature were measured over a period of 30 months at each sampling site. Methods are described by Dörgeloh et al. (1993).

In the analysis, only total numbers of fish (both sexes of adult fish and all reproductive stages combined) were used. Differences in the relative distribution of fish, based on total catches, between sampling sites and seasons were analysed using the Chi-square test and Tukey's t-test ($p > 0.05$).

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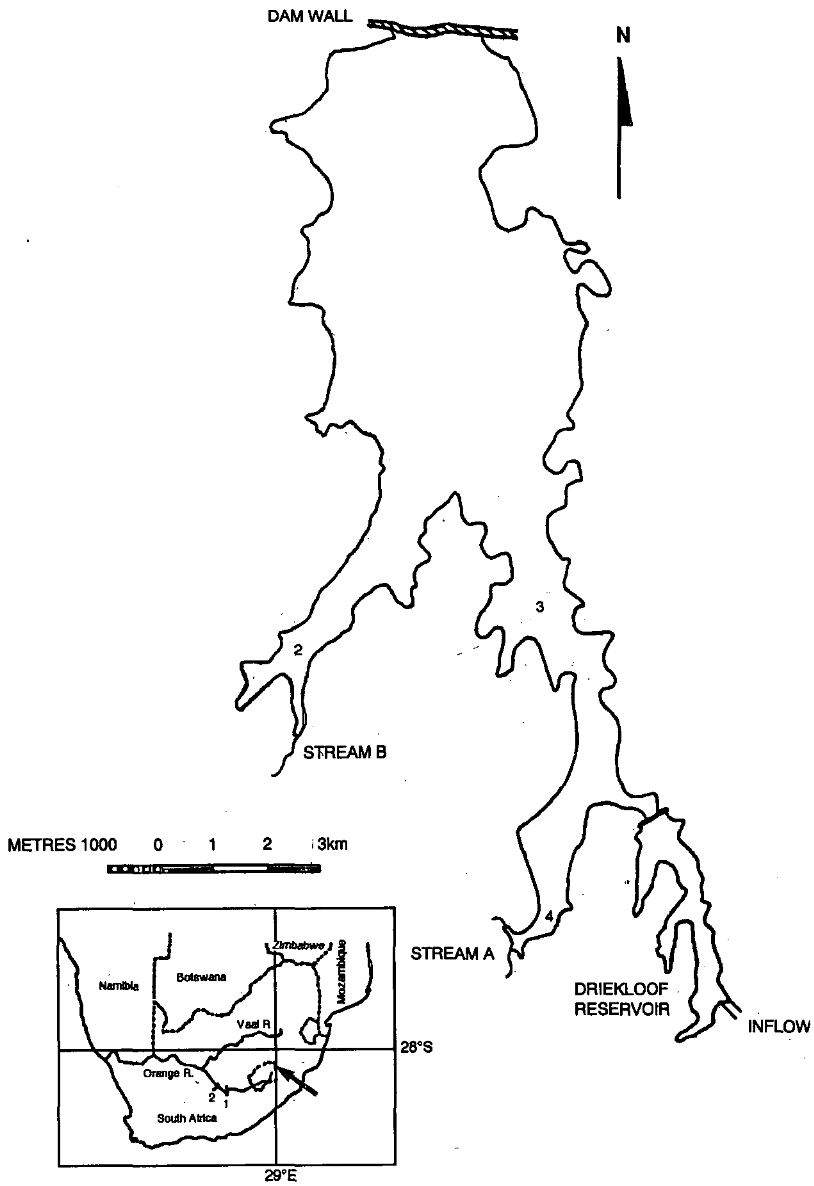

Figure 1
Map of Sterkfontein Dam indicating the sampling sites (1 to 4) for fish. Insert map of Southern Africa indicates the positions of Sterkfontein Dam (↖), Verwoerd Dam (1) and Le Roux Dam (2).

Results

Introduced species

Released juvenile *O. mykiss* had a mean fork length of 18.3 cm (SD 2.25) and a mean mass of 78.5 g (SD 27.03). The *O. mykiss* population in Sterkfontein Dam consisted predominantly of this one cohort (96% of *O. mykiss* caught). During the study period their lengths ranged between 19 and 39 cm. No distinction was made in the catch data between age 0+ and 1+ fish.

Oncorhynchus mykiss were caught at Site 1, one month after their release near the dam wall (Fig. 1) and were distributed throughout the entire system within 4 months. Results of the catch data showed a highly significant ($p > 0.01$) relationship between sampling sites and seasons (Table 2). Seasonal water temperatures were similar between sampling sites (Table 4). Total catches indicated a preference for the limnetic, clear-water zone (Table 1 and 3). The largest number of *O. mykiss* were caught at Site 1 (57.9%) during spring, followed by winter (Table 1). Total catches at this sampling site differed significantly ($p > 0.05$) from Sites 3 and 4, but not Site 2. Few *O. mykiss* were caught at Site 4 (Table 1), the most turbid area of the reservoir (Table 3).

Indigenous species

Nearly all indigenous fish species caught were adults. The catch data of each species are therefore presented for the whole population. The lengths of fish of each species caught were:

- *B. aeneus* 28 to 55 cm (80.8% between 30 - 45 cm; 0.31% <28 cm);
- *L. capensis* 18 to 47 cm (87.0% between 26 - 41 cm; 0.46% <18 cm);
- *L. umbratus* 32 to 47 cm (94.4% between 35 - 46 cm; 1.26% <32 cm); and
- *C. gariepinus* 40 to 101 cm (90.3% between 49 - 83 cm; 1.57% <40 cm).

TABLE 1
TOTAL CATCHES OF 5 FISH SPECIES PER SEASON AND SAMPLING SITE IN STERKFONTEIN DAM. HIGHEST CATCHES PER SAMPLING SITE AND SEASON ARE INDICATED IN BOLD TYPE

O. mykiss

Sampling site / Season	1	2	3	4	Total
Autumn	14	14	2	4	34
Winter	83	36	28	10	157
Spring	**150**	44	11	4	**209**
Summer	30	13	24	11	78
Total	**277**	107	65	29	478

B. aeneus

Sampling site / Season	1	2	3	4	Total
Autumn	34	75	75	161	**345**
Winter	2	34	25	70	131
Spring	3	53	33	117	206
Summer	6	20	74	**217**	317
Total	45	182	207	**565**	999

L. umbratus

Sampling site / Season	1	2	3	4	Total
Autumn	6	**150**	35	52	**243**
Winter	0	103	3	15	121
Spring	5	100	7	8	120
Summer	7	63	20	61	151
Total	18	**416**	65	136	635

L. capensis

Sampling site / Season	1	2	3	4	Total
Autumn	15	103	60	85	**263**
Winter	0	61	20	67	148
Spring	6	50	9	124	189
Summer	13	47	14	**188**	262
Total	34	261	103	**464**	862

C. gariepinus

Sampling site / Season	1	2	3	4	Total
Autumn	3	27	10	23	63
Winter	0	5	0	13	18
Spring	2	**87**	1	9	**99**
Summer	5	39	7	24	75
Total	10	**158**	18	69	255

TABLE 2
CHI-SQUARE ANALYSES (p > 0.01) OF THE TOTAL CATCH PER SAMPLING SITE AND SEASON (TABLE 1) FOR EACH FISH SPECIES

Fish species	χ^2	df
O. mykiss	68.28	9
B. aeneus	88.98	9
L. capensis	124.82	9
L. umbratus	89.55	9
C. gariepinus	64.23	9

A highly significant ($p > 0.01$) relationship was found between sampling sites and seasons for all indigenous species (Table 2). Seasonal water temperatures were similar between sampling sites (Table 4). Total catches of *B. aeneus* (56.6%) and *L. capensis* (53.8%) indicated a concentration at Site 4 (Table 1), the turbid area (Table 3). Catches at this sampling site differed significantly ($p > 0.05$) from all other sampling sites. However, results showed approximately similar numbers of *L. capensis* caught at Sites 2 and 4 during autumn and winter.

Most *L. umbratus* (65.5%) and *C. gariepinus* (62%) were caught at the low turbidity Site 2 (Table 1 and 3). Total catches of *L. umbratus* at Site 2 differed significantly ($p > 0.05$) from all other sampling sites. A significant difference ($p > 0.05$) in catches of *C. gariepinus* was found between Site 2, and Sites 1 and 3, but not between Sites 2 and 4. *Labeo umbratus* was caught in similar numbers at Sites 2 and 4 during summer (Table 1). During winter most *C. gariepinus* were caught at Site 4, but in autumn similar numbers were caught at Sites 2 and 4.

Discussion

Introduced species

Young *O. mykiss* were colonising the reservoir when the study commenced. However, the general trend in the catch data indicated a concentration of *O. mykiss* in the clear, limnetic zone. Borgström et al. (1992) found a similar distribution pattern with brown trout (*Salmo trutta*) which use pelagic areas more extensively after impoundment. Total catches of *O. mykiss* decreased progressively with increasing turbidity towards the inflow. Areas with high suspended sediment loads and high turbidities are generally avoided by *O. mykiss* (Alexander and Hansen 1983; Sigler et al., 1984) and salmonid fish (Newcombe and MacDonald 1991). Turbidity probably played an important role in determining the distribution of *O. mykiss* in Sterkfontein Dam. The distribution of *O. mykiss* was probably not influenced by water temperature, as this was similar throughout the reservoir.

Indigenous species

The adult *B. aeneus* population in Sterkfontein Dam displayed a similar distribution pattern to that found in Le Roux Dam, by concentrating near the inflow of rivers. At the same time catches in Le Roux Dam generally declined with an increase in turbidity (Jackson et al., 1983), probably due to the limitations set by turbidity on their feeding efficiency (Eccles, 1983). However, in

TABLE 3
MONTHLY TURBIDITY READINGS (NTU) AND MEAN DEPTH (m) AT EACH SAMPLING SITE IN STERKFONTEIN DAM (BASED ON DÖRGELOH ET AL., 1993)

Site	Depth (m)	Surface water (NTU)			Bottom water (NTU)		
	mean	mean	S.D.	range	mean	S.D.	range
1	24.66	7.17	2.38	3.1-10.4	8.84	3.37	4.1-13.0
2	7.39	7.61	3.31	2.5-10.9			
3	25.58	10.81	5.23	4.0-21.0	17.05	8.63	5.1-38.5
4	8.33	28.32	20.19	6.1-99.8			

TABLE 4
SEASONAL WATER TEMPERATURES (°C) AT EACH SAMPLING SITE IN STERKFONTEIN DAM. ABBREVIATIONS DENOTE (SURF.) SURFACE, (BOTT.) BOTTOM AND (DIFF.) DIFFERENCE IN WATER TEMPERATURE

Season	Site 1			Site 2			Site 3			Site 4		
	Surf.	Bott.	Diff.	Surf.	Bott.	Diff.	Surf.	Bott.	Diff.	Surf.	Bott.	Diff.
Winter 1983	8.3	7.5	0.8	9.0	7.9	1.1	8.5	8.5	0.0	9.0	8.5	0.5
Summer 1983/1984	21.6	19.4	2.2	22.5	19.8	2.7	21.2	19.4	1.8	21.5	20.5	1.5
Winter 1984	9.8	9.2	0.6	9.0	8.7	0.3	9.8	8.9	0.9	9.5	9.5	0.0
Summer 1984/1985	21.0	15.8	5.2	22.0	22.8	0.8	22.2	15.8	6.4	22.5	21.5	1.0
Winter 1985	10.0	10.0	0.0	9.5	9.5	0.0	10.0	10.0	0.0	9.6	9.4	0.2

Sterkfontein Dam most adult *B. aeneus* concentrated in the turbid area (Table 1) where lower plankton and macrophyte densities were recorded (Dörgeloh, 1986). It is suggested that their distribution was not affected by turbidity.

The general distribution of adult *L. capensis* in Sterkfontein Dam corresponded to that of adult *B. aeneus* (Table 1). Adult *L. capensis* in Sterkfontein Dam showed a similar distribution to those in Le Roux Dam, where this species tended to remain in one area (Jackson et al., 1983; Tomasson et al., 1984).

The relatively small natural catchment area (193 km^2) of Sterkfontein Dam comprised an insignificant seasonal natural inflow for a maximum of 3 months during the rainy season. In comparison the approximate weekly artificial inflow from Driekloof Dam was 11.5 x 10^6 m^3 (Dept. of Water Affairs, 1986). Stream A was the only accessible inflow for breeding fish. The small inflow at stream B was blocked off by thick stands of reeds.

The concentration of adult *B. aeneus* and *L. capensis* (especially during the warmer months) in the turbid area can be explained by the presence of the inflow of a stream near Site 4 (Fig. 1). The area around the inflow probably served as a staging area for both species. These are sites, as defined by Combs and Peltz (1982), where congregations or temporary gatherings of pre-spawning fish occur prior to upstream movement. Casual observations of migrating fish up the stream at Site 4 revealed two dominant species, *B. aeneus* and *L. capensis*. A few fish caught were in a ripe running stage. A lack of potential breeding sites in less turbid areas of the reservoir may be important in influencing the distribution of both adult *B. aeneus* and *L. capensis*, irrespective of high turbidities.

Adult *L. umbratus* and *C. gariepinus* were concentrated at Site 2 for most of the year (Table 1; Fig. 1). This sheltered bay comprising an inundated marsh and large, partly submerged reed beds with an abundance of organic matter, was the only habitat of its kind. Being herbivorous and detrivorous, *L. umbratus* favours detritus and soft mud at the bottom of the lake (Tomasson et al., 1983) while *C. gariepinus* generally prefers flooded tributary valleys (Jackson et al., 1983) and densely vegetated littoral zones within sheltered bay habitats (Bruton, 1978). On the other hand, the low turbidities at Site 2 should reduce the feeding efficiency of *C. gariepinus* which is most efficient in capturing prey in low light conditions (Bruton, 1988).

A shortage of sheltered, vegetated bays in Sterkfontein Dam, could confine adult *L. umbratus* and *C. gariepinus* to Site 2 for the greatest part of the year.

The distribution of indigenous fish species was probably not influenced by water temperature as this was similar between sampling sites. Seasonal catches were a reflection of their higher activity during the warmer months.

Conclusion

The stocking of *O. mykiss* in Sterkfontein Dam resulted in the rapid distribution of this species into the limnetic zone in the low turbidity area. Very few indigenous fish inhabited this area.

The introduction of *O. mykiss* could therefore enhance the overall fish production of this reservoir.

Cyrus and Blaber (1987) found that turbidity had a significant influence on estuarine juvenile fish distribution. This, however, does not appear to apply to indigenous freshwater fish in Sterkfontein Dam. The distribution of indigenous fish in Sterkfontein Dam was generally similar to that of the same species in Le Roux Dam, a turbid system. It is suggested that the location of suitable breeding sites for *B. aeneus* and *L. capensis*, and the location of feeding habitats for *L. umbratus* and *C. gariepinus* primarily influenced the distribution of these species in Sterkfontein Dam.

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