

# Spatial variation in the structure of fish assemblages in the Vaalbos National Park, South Africa

I.A. RUSSELL

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Fish assemblages were sampled at nine sites in the lower Vaal River in the Vaalbos National Park and adjacent properties. A total of 1543 fish from 10 species was recorded. Ordination revealed spatial variation in assemblage structure, with the distinction primarily between communities in rapids and deep pools. Flow velocity, depth and percentage cover were important determinants of fish assemblage structure. The length frequency distribution of abundant species indicated successful recruitment. Several differences in the species compliment compared to earlier studies were evident, including high abundance of *Barbus paludinosus* and *Austroglanis sclateri*, and the absence of *Barbus anoplus*. The length-mass relationships of large cyprinids indicated long-term declines in the physical condition of fish.

Key Words: freshwater fish, community structure, Vaal River, Vaalbos National Park

I.A. Russell, National Parks Board, P.O. Box 176, Sedgefield, 6573 Republic of South Africa.

## Introduction

Heightened awareness of the need to conserve biodiversity in South Africa has led to increased interest in the role of conservation areas as refugia for various biota (Siegfried 1989; Rebelo & Siegfried 1992; Lombard 1995) including freshwater fish (Skelton 1990; Skelton *et al.* 1995). Assessment of the value of conservation areas, such as national parks, in conserving biota is dependant on knowledge of firstly, species diversity (species richness, distribution and abundance), and secondly, environmental factors which influence the distribution and abundance of species. The latter is necessary to assess the significance, relative to conservation goals, of changes in species diversity.

Fish fauna in the Orange-Vaal River complex has been well explored (Skelton 1986) though most published accounts have concentrated on the Orange River basin (Van Schoor 1968; Skelton & Cambray 1981; Cambray 1984), and in particular, the

dynamics of impoundment populations (Cambray *et al.* 1978; Gaigher *et al.* 1980, 1981; Hamman 1980; Jubb 1972). No study has concentrated on fish assemblages within the Vaalbos National Park. Little is known about the ecology of fish communities in the Vaal River, and in particular factors which regulate fish distributions and assemblage structure in riverine habitats. The aims of the present study are to provide an inventory of the fish fauna in the Vaal River in the Vaalbos National Park; where possible assess what changes have occurred in fish assemblages; and investigate the influence of some environmental factors on the distribution of fishes and fish assemblage structure.

## Study Area

The study area was located in the lower reaches of the Vaal River drainage system, North-West Province, South Africa (Fig. 1). The Vaal River rises on the western slopes of the Drakensberg escarpment and flows approximately 900 km south-west across the interior plateau of South Africa to its confluence

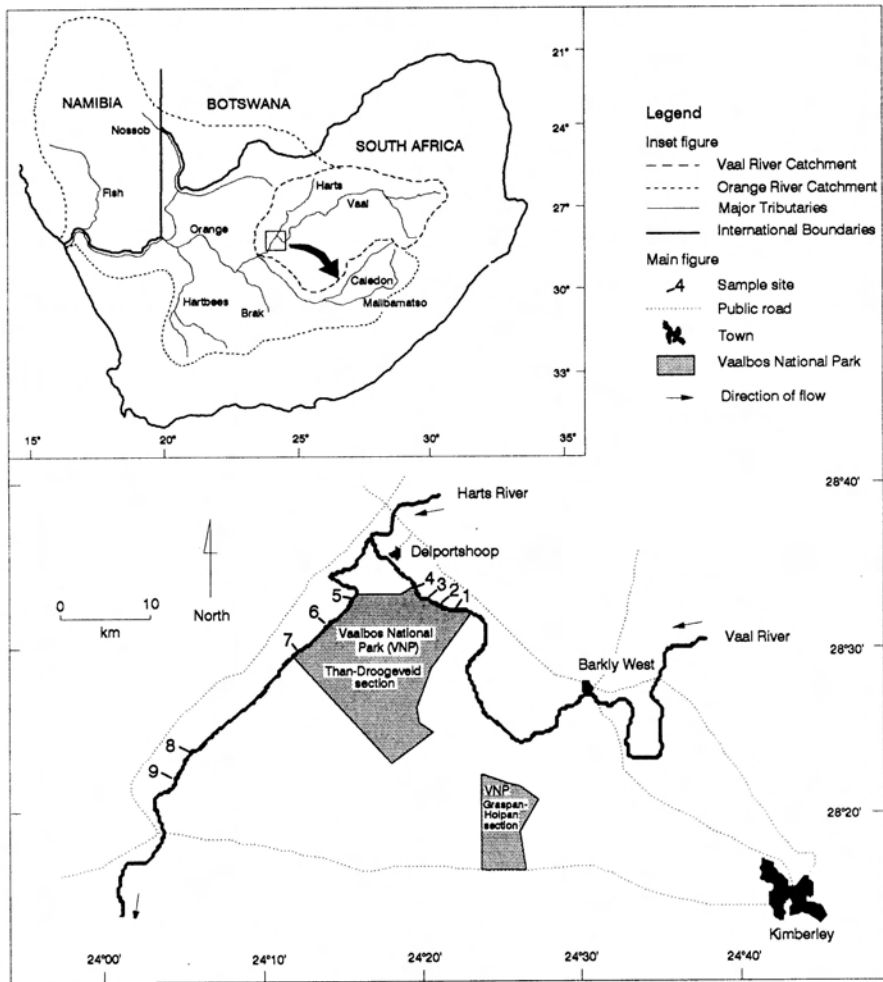


Fig. 1. Location of the study sites in the Vaal River. The location of the Vaal River catchment is shown in the inset.

with the Orange River near the town of Douglas. The catchment of ca. 192 000 km<sup>2</sup> (Braune & Rogers 1987) provides a total mean annual runoff of ca.  $4.4 \times 10^9$  m<sup>3</sup>a<sup>-1</sup> (Kriel 1972) which is approximately eight percent of the total for South Africa.

The Vaal River catchment is extensively developed, and the river is the most heavily utilised in South Africa. It was estimated that in 1975 the Vaal River catchment supported 42 % of South Africa's urban population, 79 % of the mining production, and provided water to the majority of the country's power

generation and oil-from-coal industries (Department of Water Affairs 1985; Braune & Rogers 1987). Extensive agricultural irrigation (ca. 155 000 ha), primarily in the middle and lower reaches, contributes to agricultural production being 42 % of the country's total (Department of Water Affairs 1985; Raubenheimer *et al.* 1985; Braune & Rogers 1987).

Sixteen major impoundments have been constructed in the Vaal River catchment with a combined capacity of  $7.9 \times 10^9$  m<sup>3</sup>a<sup>-1</sup> (Braune & Rogers 1987). These impoundments, along with numerous small weirs

**Table 1**  
*Correlation coefficients and their significance levels for relationships between environmental variables*

	<b>D1</b>																	
D2	0.65		<b>D2</b>															
D3	-0.45	0.11		<b>D3</b>														
D4	-0.79*	-0.92**	-0.14		<b>D4</b>													
V1	-0.91**	-0.71*	0.35	0.79*		<b>V1</b>												
V2	0.95***	0.69*	-0.40	-0.79*	-0.99**		<b>V2</b>											
V3	0.48	0.36	-0.16	-0.42	-0.52	0.52		<b>V3</b>										
V4	0.06	0.43	0.15	-0.29	-0.42	0.33	-0.13		<b>V4</b>									
C1	-0.32	-0.76*	-0.62	0.79*	0.34	-0.32	-0.05	-0.32		<b>C1</b>								
C2	0.83**	0.72*	-0.25	-0.79*	-0.95**	0.94***	0.74	0.36	-0.34		<b>C2</b>							
C3	-0.45	0.03	0.78	-0.02	0.53	-0.54	-0.54	-0.08	-0.59	-0.56		<b>C3</b>						
C4	0.79*	0.80*	-0.20	-0.81*	-0.93**	0.90***	0.31	0.62	-0.47	0.86*	-0.36		<b>C4</b>					
S1	-0.67*	-0.52	0.29	0.57	0.73*	-0.74*	-0.47	-0.18	0.26	-0.73*	0.41	-0.69*		<b>S1</b>				
S2	0.61	0.75*	0.00	-0.75*	-0.84**	0.78*	0.27	0.77	-0.51	0.80*	-0.27	0.96***	-0.57		<b>S2</b>			
S3	0.70*	0.73*	-0.06	-0.77*	-0.79*	0.78*	0.48	0.32	-0.47	0.79*	-0.28	0.78*	-0.89*	0.70		<b>S3</b>		
S4	0.20	-0.18	-0.50	0.14	-0.12	0.17	0.22	-0.32	0.28	0.13	-0.35	0.03	-0.62	-0.11	0.21		<b>S4</b>	

\* = P<0.05  
 \*\* = P<0.01  
 \*\*\* = P<0.001

which hold back water for irrigation, result in the Vaal River being highly regulated. The river is managed to stop flowing at Douglas Weir some 24 km upstream of the Orange-Vaal confluence (Benade 1993).

Water quality is poor, particularly in the lower reaches (Braune & Rogers 1987). Return flows from municipalities, industries and agriculture result in high concentrations of ionic salts (TDS >450 mg/l) in the lower reaches, with concentrations of sulphate, bicarbonate and chloride in particular being high (Bruwer *et al.* 1985).

The Vaal River forms portion the eastern and western boundaries of the Than-Droogeveld section of the Vaalbos National Park (28°25'S–28°40'S; 24°12'E–24°26'E) (Fig. 1). Environmental features in these portions of the Vaal River have been influenced by alluvial diamond mining and flow modifications. Mining has been intensive in the eastern reaches, with the resultant removal of fine sediments, and creation of artificial rapids and riffles by canalisation of flow over rocky mining spoils. The rocky substratum has retarded the re-establishment of rooted aquatic plants, except in very deep pools, where flow reduction has enabled sediment deposition. In several

places the primary channel has been substantially broadened though the removal of alluvial bank sediments, with consequent loss of riparian vegetation.

In the western reaches mining appears to have been confined to only a few small areas. Thus channel morphology and riparian vegetation are possibly more characteristic of the natural state. The deposition of fine sediments (< 0.1 mm), however, appears to have been substantial, and rooted aquatic plants are prolific. These changes are possibly the consequence of substantial flow reductions and high ionic salts concentrations which facilitate the flocculation of suspended particulate matter.

## Materials and Methods

### Location of study sites

Nine study sites were located in the Vaalbos National Park and adjacent properties (Fig. 1). The location of study sites was determined primarily by the availability of road access, but covered the range of habitats available within the river section.

### Fish assemblage sampling

Fish were sampled at each study site in July 1994 and August 1995. In deep pools and open channels sampling was undertaken with a 40 m fleet of multi-filament gill nets (50, 55, 70, and 80 mm stretched mesh) and 20 m monofilament gill net (100 mm stretched mesh), a seine net (40 m x 3 m x 3 mm) with 50 m warps, and baited longlines (two 20 m lines each with 10 hooks). Gill nets and longlines were set overnight from 17:00 to 8:00. In rapids, stony runs and along channel margins fish sampling was undertaken with a hand-held electro-fishing apparatus, powered by a 220V AC, 2 kva portable generator. Dense stands of rooted aquatic plants (principally *Myriophyllum spicatum*) in the north-western reaches (sites 5 to 9), and rocky substrata in the north-eastern reaches (sites 1 to 4) prevented effective seine netting at most sample sites. Sampling effort for all methods are indicated on Table 2.

All fish collected were identified using identification keys in Skelton (1993), measured (fork length), and weighed to the nearest 0.01 g on a Metler electronic balance. Voucher specimens were preserved in 10 % formalin, and housed at the National Parks Board research laboratories at Rondevlei.

### Quantification of aquatic environment

Complexity of the aquatic environment at each study site was quantified using descriptions of water depth, flow velocity, substratum and cover. Environmental parameters were measured at equidistant points along transect lines which covered the areas where fish were sampled. Transect lines at sites where gill nets and long-lines were used to sample fish assemblages (sites 3 to 9) extended from shore to shore, and were orientated perpendicular to the banks. Environmental parameters were measured at three-meter intervals along transect lines. Transect lines at sites where only electro-fishing was used (sites 1 & 2) extended from the shore to approximately 1.2 m depth in open channels, and from shore to shore in rapids and secondary channels, with environmental parameters measured at one meter intervals.

Depth was measured to the nearest centimetre with a meter rule in areas less than one meter deep, and with a weighted line in areas more than one meter deep. Depth was classified into four groups (D1-4) corresponding to the ranges 0-33, 34-66, 67-100, and >100 cm.

Flow velocity was measured by timing (to the nearest 0.01 second) the duration that a submersed

Table 2

Number of fish collected at different sample sites by electro-fishing (E), gill nets (G), seine nets (S) and long lines (L). Sampling effort for electro-fishing is minutes sampled, gill netting is number of overnight settings of fleet, seine netting is number of effective hauls, and long lines is number of overnight settings of 20 hook lines

Site	1			2			3			4			5			6			7			8			9						
Method	E	E	E	G	L	L	E	G	L	E	G	L	E	G	L	E	S	G	L	E	G	L	E	S	G	L	E	S	G	L	
Effort	80	80	35	1	1	90	1	1	1	60	1	1	50	2	1	1	50	1	1	60	2	1	1	60	2	1	1	40	2	1	1
<i>Austroglanis sclateri</i>	16	4	-	-	-	11	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Barbus aeneus</i>	7	6	-	10	-	7	4	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	39	-	-	43	1	-	
<i>Barbus kimberleyensis</i>	-	-	-	1	-	-	1	1	-	14	-	-	-	-	5	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	
<i>Barbus paludinosus</i>	2	-	1	-	-	-	-	-	-	37	-	-	61	24	-	-	5	-	-	10	22	-	-	-	-	79	-	-	-	-	
<i>Barbus trimaculatus</i>	-	1	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Clarias gariepinus</i>	-	-	-	2	2	-	2	2	-	3	3	1	-	1	2	-	-	-	-	-	-	-	-	5	1	-	-	-	-	-	
<i>Labeo capensis</i>	3	5	-	35	-	22	33	-	19	56	-	-	-	8	-	-	3	-	-	-	-	-	-	27	-	-	-	11	-	-	
<i>Labeo umbratus</i>	-	-	-	4	-	-	3	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	9	3	-	-	
<i>Pseudocrenilabrus philander</i>	26	44	13	-	-	34	-	-	135	-	-	45	27	-	-	85	-	-	40	28	-	-	-	-	-	38	1	-	-	-	
<i>Tilapia sparrmanii</i>	82	18	4	-	-	42	-	-	63	-	-	19	21	-	-	7	-	-	21	21	-	-	-	-	-	21	2	-	-	-	
Total number of individuals	136	78	18	52	2	123	44	3	254	87	3	126	72	14	2	97	3	0	71	71	78	1	138	55	15	0	0	0	0	0	
Total number of species	6	6	3	5	1	6	6	2	4	5	1	4	3	3	1	3	1	0	3	3	5	1	3	4	3	0	0	0	0	0	

orange took to move one meter downstream with the current. Flow velocity was classified into four groups (V1-4) corresponding to the ranges 0-0.333, 0.334-0.666, 0.667-1.0, and >1 m/s.

Cover and the nature of the substratum were assessed by visual inspection following the key of Bovee (1982). Cover was classified into four groups (C1-4) corresponding to no cover, object cover, overhanging cover, and object and overhanging cover. Substrata were classified into four groups (S1-4) corresponding to sand (<4 mm diameter), gravel (4-75 mm), cobble (76-300 mm) and boulders (>300 mm).

The percentage occurrence of different categories of depth, flow, substratum and cover were used as overall descriptors of habitat structure.

### Statistical analysis

Principal component analysis (PCA) was applied to the environmental and fish abundance data using the program STATGRAPHICS version 4.0 (STSC, Inc. 1989) to investigate between site differences in habitat structure and community composition. Environmental categories were transformed to percentage occurrence because the sampling intensity of environmental parameters in different study sites was unequal. Fish abundances from electro-fishing were standardised to the number of specimens collected in 60 minutes. Species abundances were not log transformed as the relative abundances of common and rare species was not high (less than 100:1), thus making transformation unnecessary (Gauch 1982).

Relationships between the complexity of fish assemblages and the aquatic environment were examined in two ways. Firstly, regression analysis of ordination scores (axes 1 and 2) of fish abundance data with percentage occurrence of different categories of depth, flow, substratum and cover at each site was used to investigate the relationships between the structure of fish assemblages and the aquatic environment. Correlations were deemed significant if  $P < 0.05$ . Secondly, regression analysis was used to investigate the relationship between the diversity of fish assemblages and the aquatic environment. The  $\alpha$  (log series) index was used to quantify diversity because of its good discriminate ability and low sensitivity to sample size (Magurran 1988). Diversity of the aquatic environment was based on the frequency of different combinations of categories for depth, flow, cover and substratum outlined above. The system of categorisation used enabled  $4^4$  (256) potential different combinations of environmental parameters. In reality only 62 different combinations were recorded at all study sites.

Relationships between length and mass of fish species were determined for populations as a whole using the equation (Le Cren 1951):

$$M = cLn$$

where M = mass in grams

L = fork length in millimetres

c and n are constants obtained from linear regression of length with mass

(Log M = Log c + n.Log L).

Length distribution of abundant ( $n > 100$ ) species was described to enable assessment of the occurrence of different age cohorts, and hence assessment of recruitment success.

## Results

### Aquatic environment

Ordination (PCA) of environmental parameters revealed that most of the difference between study sites was expressed on axis 1 (60.9 % of the total variability) with differentiation predominantly between sites with rapids (shallow, strongly flowing water over stony substrata which provide object cover - sites 1, 2 and 4), and sites in open channels without rapids (deep, slow flowing water over predominantly muddy substrata - sites 3 and 5 to 9) (Fig. 2). Axis 2 of this ordination (24.7 % of the variability) was related to depth and cover in open channel sites, with differentiation between deep pools with little overhead or object cover (sites 3 and 9), and shallower pools with a high proportion of overhead cover due to abundant emergent macrophytes (sites 5 to 8).

Correlations between environmental parameters (Table 1) emphasised the occurrence of two biotopes, namely deep pools in open channels and rapids. Deep pools were characterised by low flow velocities, a substratum consisting predominantly of fine particulate matter, and a high incidence of both object and overhead cover. Rapids were characterised by shallow water, flowing at

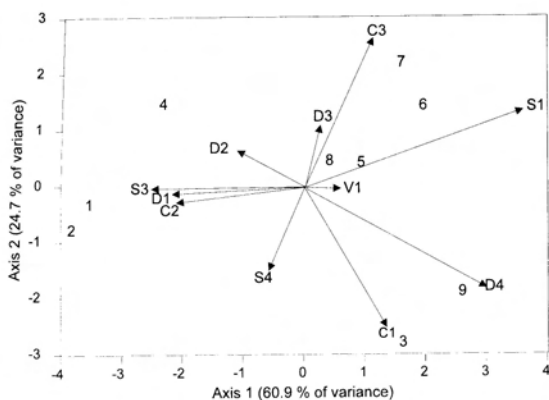


Fig. 2. Site-environment biplot of components 1 and 2 of a PCA ordination. Sites are indicated by number, and environmental variables by letters (see methods for codes). Arrows represent the direction of maximum variation of the environmental variable, and are drawn for the most important variables only.

moderate velocity over gravel or cobble substrata, and a high incidence of object cover.

All sites with rapids occurred in the eastern reaches of the study area, whereas all sites in the western reaches were open channels without rapids. Site 3 was an anomaly in that it was the only deep water pool in eastern reaches of the study area, and

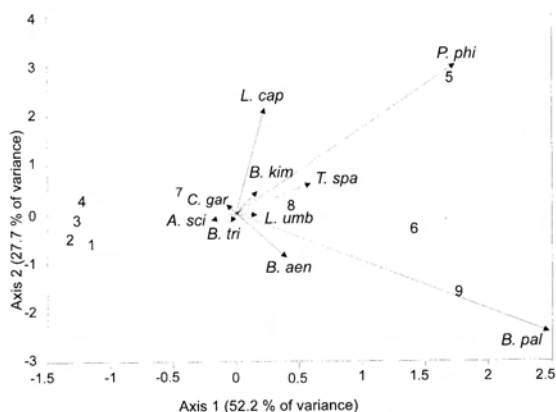


Fig. 3. Species-site biplot of components 1 and 2 of a PCA ordination. Sites are indicated by numbers, and fish species by letters which represent the first letter of the generic name and first three letters of the specific name. Arrows represent the direction of maximum variation of abundance of species.

was dissimilar to both upstream and downstream sample sites.

### Fish assemblages

A total of 1543 fish from 10 species was recorded during both sample periods (Table 2). Eight species (*Austroglanis sclateri*, *Barbus aeneus*, *Barbus paludinosus*, *Barbus trimaculatus*, *Clarias gariepinus*, *Labeo capensis*, *Pseudocrenilabrus philander* and *Tilapia sparrmanii*) and 67 % of the total individuals were collected by electro-fishing. Gill netting collected six species and 19 % of the total individuals. Two species collected in gill nets (*Barbus kimberleyensis* and *Labeo umbratus*) were not collected by electro-fishing. Seine netting collected five species and 13 % of the total individuals, and long lines two species and one percent of the total individuals. No new species were collected by either seine netting or long lines. Eighty four percent of the total catch was comprised of only four species (*B. paludinosus*, *L. capensis*, *P. philander* and *T. sparrmanii*).

The results of PCA ordination of fish assemblage structure (Fig. 3) demonstrate spatial variation in assemblage structure over the study period. Axis 1 accounted for 52.2 % of the total variability, with differentiation predominantly between sites in the eastern (sites 1 to 4) and western (sites 5 to 9) reaches of the study area. *Austroglanis sclateri* were recorded only in the eastern reach of the study area (Table 2), whereas *B. paludinosus* ( $F(1.7) = 5.612$ ,  $P < 0.05$ ) and *P. philander* ( $F(1.7) = 16.554$ ,  $P < 0.01$ ) were significantly more abundant at sites 5 to 9. Axis 2 of this

ordination (27.2 % of the variability) distinguished predominantly between open channel sites in the western reaches of the study area. The high extent to which different fish species were present at all sites in the western reach (Table 2) suggests that spatial variability of sample sites was due primarily to differences in the relative abundances of species rather than species being confined to specific parts of the river system. Site 5 was characterised by high abundances of *P. philander*, *L. capensis* and *T. sparrmanii*, whereas sites 6 and 9 were characterised by relatively high abundances of *B. paludinosus*.

Significant relationships between axis 1 scores and the microhabitat variables V1 ( $r^2 = 0.46$ ,  $P < 0.05$ ) and V2 ( $r^2 = 0.44$ ,  $P < 0.05$ ) indicates that flow velocity was important in determining assemblage structure. Significant correlation between flow velocity (V1 and V2) and other microhabitat variables (Table 1), particularly depth (D1 and D2) and cover (C2 and C4), suggest that these aspects of the aquatic environment were also important determinants of fish assemblage structure. No significant relationships between axis 2 scores and microhabitat variables were detected.

No significant relationship between the diversity of fish assemblages and the aquatic environment could be detected ( $r^2 = 0.20$ ,  $P > 0.05$ ) when all sample sites were included in the regression. The lack of correlation was due, in part, to the comparatively high diversity of species collected at site 3 despite the uniformity of depth (mostly > 100 cm), cover (largely absent), and flow (mostly 0–0.333 m/s) and hence low environmental diversity. As outlined above, the environmental characteristics of site 3 differed substantially from other sites within the study area. Removal of site 3 from the regression did yield a significant correlation between

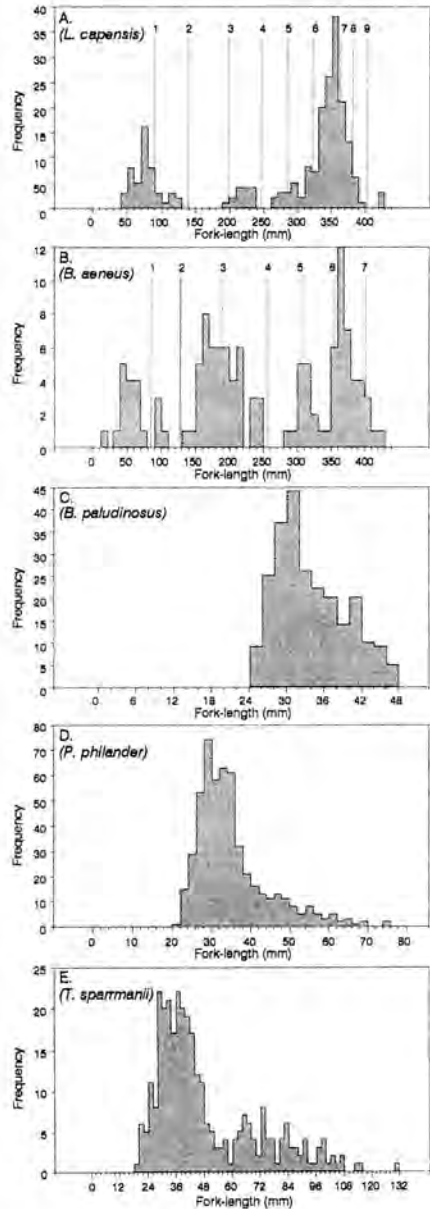


Figure 4. Fork-length frequency distribution of five abundant fish species. Dashed lines represent the mean length at age (years) for *L. capensis* (Figure 4a) and *B. aeneus* (Figure 4b) modified from Mulder (1973b) and Mulder (1973a) respectively.

the diversity of fish assemblages and the aquatic environment ( $r^2 = 0.51$ ,  $P < 0.05$ ).

The length frequency distribution of the large cyprinids *L. capensis* (Fig. 4a) and *B. aeneus* (Fig. 4b) illustrate the presence of both sub-adults and adults of varying ages, indicating successful recruitment in most years. Although there is no data on age and corresponding lengths for other abundant species in the Vaal River, the high proportion of small individuals of *B. paludinosus* (Fig. 4c), *P. philander* (Fig. 4d) and *T. sparrmanii* (Fig. 4e) also indicate successful recruitment of these species.

Comparisons between of the length-mass relationships of the four large cyprinids *B. aeneus* (Fig. 5a), *B. kimberleyensis* (Fig. 5b), *L. capensis* (Fig. 5c) and *L. umbratus* (Fig. 5d) as determined in this study, and throughout the Vaal River in June 1969 (Mulder 1973a, 1973b), indicate declines in the physical condition of fish. The mass of *P. philander* specimens (> 50 mm FL) were lower than equivalent sized fish collected in the Inkomati river system (unpublished data) in Mpumalanga Province, South Africa (Fig. 5e) further illustrating poor physical condition of fish in the Vaal River. Alternatively, the mass of *L. capensis* (> 200 mm FL) in the Vaal River were higher than equivalent sized fish in the Caledon River (Baird & Fourie 1978), a tributary of the Orange River in the Orange Free State, South Africa (Fig. 5c). This suggests more favourable environmental conditions for this species in the Vaal River component of the Orange-Vaal system.

## Discussion

Several differences in the species complement compared to previous studies

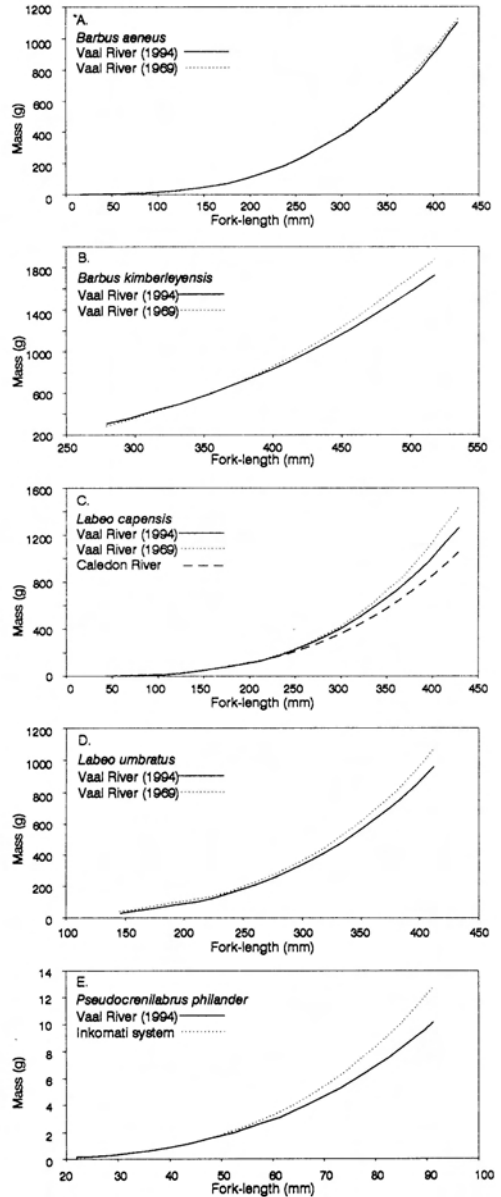


Fig. 5. Length-mass relationship of five abundant fish species. Data defined as Vaal 1994 from this study, Vaal 1969 for *B. aeneus* and *B. kimberleyensis* modified from Mulder (1973a), Vaal 1969 for *L. capensis* and *L. umbratus* modified from Mulder (1973b), Caledon for *L. capensis* modified from Baird & Fourie (1978) and Inkomati for *P. philander* from unpublished data.



were evident. The high abundance of *B. paludinosus* was at variance with the findings of Benade (1993), who collected few specimens in the lower Vaal. *Barbus paludinosus* predominantly inhabits quiet, well-vegetated waters in lakes, swamps and marshes, or marginal areas of larger rivers and slow flowing streams (Skelton & Cambray 1981; Cambray 1984; Skelton 1993). Low flow velocities and the abundance of aquatic plants, particularly at sample sites in the western reaches of the study area, appear to favour *B. paludinosus*, evidenced by their abundance, and the high proportion of younger individuals.

The comparatively high abundance of *A. sclateri* in the Vaalbos National Park also contrasts with the findings of previous surveys in the Orange-Vaal system (Skelton & Cambray 1981; Benade 1993) where this Red Data (Rare) species (Skelton 1987) was reported to be uncommon. For example, Benade (1993) noted that in 1986 only six *A. sclateri* were collected from approximately 12 tons of fish sampled in the Barkly West region (cf. Fig. 1). Similarly, eight surveys undertaken in the lower Vaal and Orange rivers between July 1985 and April 1989 yielded only six specimens (Benade 1993). *Austroglanis sclateri* occurs predominantly in rocky areas with flowing water (Skelton & Cambray 1981; Cambray 1984; Jackson *et al.* 1983). Skelton (1987) maintains that localised destruction of this habitat by alluvial mining poses a threat to *A. sclateri*. Intensive mining along the eastern reaches of the Vaalbos National Park, however, has resulted in the artificial creation of numerous small stony runs and rapids in a section of the Vaal River where flow reductions and sedimentation have undoubtedly disturbed much of the natural habitat of *A. sclateri*. The high abundance of *A. sclateri* in areas where disturbance to the stream environment through alluvial mining has been most intensive suggests, contrary to the opinion of

Skelton (1987), that mining may have, in the long-term, increased the local availability of the preferred habitat of this species.

Two species, *Barbus anoplus* and *Cyprinus carpio*, have previously been recorded in the lower Vaal River (Benade 1993; Skelton 1993), though were not collected in this survey. *Barbus anoplus* has previously been found to be abundant in the marginal areas of large impoundments in the Orange-Vaal system (Cambray *et al.* 1978; Cambray & Hahndiek 1980), though densities in the mainstream are reported as being low (Skelton & Cambray 1981; Cambray 1984; Benade 1993). It is frequently associated with submerged aquatic plants (Skelton 1993), and despite the high abundance of this form of cover in the western reaches of the study area, *B. anoplus* appears to remain a scarce species.

Although *C. carpio* was not collected in these surveys, anglers reports indicate that it does occur in the study area. Standard fish sampling equipment appears to be inefficient for sampling *C. carpio* (Benade 1993), and low numbers in surveys in the Orange-Vaal system (Cambray 1984; Skelton & Cambray 1981; Benade 1993) may not accurately reflect the abundance of this species.

Similar to previous studies of fish assemblages in the Vaal River (Mulder 1973a, 1973b; Benade 1993) *P. philander* and *T. sparrmanii*, which are tolerant of a wide range of environmental conditions but nevertheless favour quiet or standing waters with submerged or emergent vegetation (Skelton & Cambray 1981, Skelton 1993), were widespread and abundant. Large cyprinids (*B. aeneus*, *B. kimberleyensis*, *L. capensis*, *L. umbratus*) and *C. gariepinus* continued to be widespread, with *L. capensis* the most abundant species. The low abundance of *B. trimaculatus* supports Benade's (1993) assessment of the vulnerability of this species in the Vaal River.

A relationship between the diversity of fish assemblages and the aquatic environment has previously been demonstrated for both aquatic invertebrates (Allan 1975; Harman 1972) and fish (Gorman & Karr 1978; Schlosser 1982, 1985; Capone & Kuschlan 1991; Pusey *et al.* 1993, 1995). This relationship was also evident in the Vaal River, with the micro-habitat variables flow velocity, cover and depth strongly associated with assemblage structure. The association between fish assemblage diversity and flow velocity (Pusey *et al.* 1995), depth (Schlosser 1987) and cover (Pusey *et al.* 1993, 1995) has also been demonstrated elsewhere. Physical and chemical changes in the aquatic environment may cause significant changes in the structure of fish assemblages (Pusey *et al.* 1993). The absence of appreciable changes in the species complement between surveys undertaken in 1985-1989 (Benade 1993) and 1994-1995 (this study) indicates stability of fish assemblages and hence the absence of short-term changes in the suitability of environmental conditions for fish. Declines in the condition of fish, however, do suggest changes in the aquatic environment that are either long-term in nature, or are of insufficient magnitude over the short-term to have significantly affected recruitment success. A variety of extrinsic factors such as food availability, and degree of parasitisation, can affect the condition of fish (Le Cren 1951). Although it was not the objective of this study to identify reasons for changes in the condition of fish species, it is reasonable to conclude that declining water quality, severe water regulation, sedimentation, and increases in the distribution and abundance of emergent macrophytes are contributory factors.

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### References

- ALLAN, J.D. 1975. The distributional ecology and diversity of benthic insects in Cement Creek, Colorado. *Ecology* 56: 1040-1053.
- BAIRD, D.P. & S. FOURIE. 1978. The length/mass relationship and condition of *Labeo capensis* in the Caledon River. *Journal of the Limnological Society of Southern Africa* 4 (1): 53-58.
- BENADE, C.B. 1993. Studies on fish populations in the regulated Orange River system within the borders of the Cape Province. MSc. thesis, University of the Orange Free State, Bloemfontein.
- BOVEE, K.D. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. Instream flow information paper 12. U.S.D.I. Fish and Wildlife Service, Office of Biological Services. FWS/OBS-82/26. 248pp.
- BRAUNE, E. & K.H. ROGERS. 1987. *The Vaal River catchment: Problems and research needs*. Pretoria: Council for Scientific and Industrial Research (South African National Scientific Programmes report; no. 143).
- BRUWER, C.A., H.R. VAN VLIET, D.P. SARTORY & P.L. KEMPSTER. 1985. An assessment of water related problems of the Vaal River between Barrage and Douglas Weir. Pretoria: Department of Water Affairs. (Technical report; no 121).
- CAMBRAJ, J.A. 1984. Fish populations in the Middle and Lower Orange River, with special reference to the effects of stream regulation. *Journal of the Limnological Society of southern Africa* 10(2): 37-49.
- CAMBRAJ, J.A., HAHNDIEK, S. & Q. HAHNDIEK. 1978. The juvenile fish populations in the marginal areas of the Hendrik Verwoerd Dam. *Journal of the Limnological Society of Southern Africa* 4(1): 21-33.
- CAMBRAJ, J.A. & Q. HAHNDIEK. 1980. The juvenile and minnow fish populations in the marginal areas of the PK le Roux impoundment, Orange River, South Africa. Unpublished research report. Department of Nature and Environmental Conservation. CPA, Cape Town.
- CAPONE, T.A. & J.A. KUSCHLAN. 1991. Fish community structure in dry-season stream pools. *Ecology* 72: 983-992.
- DEPARTMENT OF WATER AFFAIRS. 1985. Draft report on the management of South African water resources. Pretoria: Department of Water Affairs.

- GAIGHER, I.G., HAMMAN, K.C.D. & S.C. THORNE. 1980. Possible adaptive significance of sex ratio and sexual differences in size at maturity in the Orange River Labeo, *Labeo capensis*. *Journal of the Limnological Society of southern Africa* 6: 5-38.
- GAIGHER, I.G., HAMMAN, K.C.D. & S.C. THORNE. 1981. Relative fish population density changes in the P.K. le Roux Dam during the first three years of inundation. *Journal of the Limnological Society of southern Africa* 7: 37-41.
- GAUCH, H.G. 1982. *Multivariate analysis in community ecology*. Cambridge: Cambridge University Press.
- GORMAN, O.T. & J.R. KARR. 1978. Habitat structure and stream fish communities. *Ecology* 59: 507-515.
- HAMMAN, K.C.H. 1980. Post-impoundment trends in the fish populations of the Hendrik Verwoerd Dam, South Africa. *Journal of the Limnological Society of southern Africa* 6: 101-108.
- HARMAN, W. 1972. Benthic substrates: their effect on freshwater mollusca. *Ecology* 53: 271-277.
- JACKSON, P.B.N., D.H. ECCLES & K.C.D. HAMMAN. 1983. The choice of efficiency in sampling gear. Pp.132-152. In: ALLANSON, B.R. & P.B.N. JACKSON (eds.), *Limnology and fisheries potential of Lake le Roux*. Pretoria: Council for Scientific and Industrial Research (South African National Scientific Programmes report; no. 77).
- JUBB, R.A. 1972. The Hendrik Verwoerd Dam and Orange River fishes. *Piscator* 84: 22-26.
- KRIEL, J.P. 1972. The role of the Hendrik Verwoerd Dam in the Orange River Project. *Civil Engineer South Africa* 14(2): 51-61.
- LE CREN, E.D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecology* 20: 201 - 209.
- LOMBARD, A.T. 1995. The problems with multi-species conservation: do hotspots, ideal reserves and existing reserves coincide? *South African Journal of Zoology* 30(3): 145-163.
- MAGURRAN, A.E. 1988. *Ecological diversity and its measurement*. Cambridge: University Press.
- MULDER, P.F.S. 1973a. Aspects of the ecology of *Barbus kimberleyensis* and *Barbus holubi* in the Vaal River. *Zoologica Africana* 8: 1-14.
- MULDER, P.F.S. 1973b. Aspects of the ecology of *Labeo umbratus* and *Labeo capensis* in the Vaal River. *Zoologica Africana* 8: 15-24.
- PUSEY, B.J., ARTHINGTON, A.H. & M.G. READ. 1993. Spatial and temporal variation in fish assemblage structure in the Mary River, south-eastern Queensland: the influence of habitat structure. *Environmental Biology of Fishes* 37: 355-380.
- PUSEY, B.J., ARTHINGTON, A.H. & M.G. READ. 1995. Species richness and spatial variation in fish assemblage structure in two rivers of the Wet Tropics of northern Queensland, Australia. *Environmental Biology of Fishes* 42: 181-199.
- RAUBENHEIMER, A.J., D.C. MIDGELEY AND W.J.H. VREY. 1985. *Verlag van die Komitee van Ondersoek insake Watervoorsiening vir die Vaalriviergebied*. Pretoria: Departement Waterwese.
- REBELO, A.G. & W.R. SIEGFRIED. 1992. Where should nature reserves be located in the Cape floristic region, South Africa? Models for the spatial configuration of a reserve network aimed at maximizing the protection of floral diversity. *Conservation Biology* 6: 243-252.
- SCHLOSSER, I.J. 1982. Fish community structure and function along two habitat gradients in a head-water stream. *Ecological Monograph* 52: 395-414.
- SCHLOSSER, I.J. 1985. Flow regime, juvenile abundance and the assemblage structure of stream fishes. *Ecology* 66: 1484-1490.
- SCHLOSSER, I.J. 1987. A conceptual framework for fish communities in small warmwater streams. Pp. 17-24. In: W.J. MATTHEWS & D.C. HEINS (eds.), *Community and Evolutionary Ecology of North American Stream Fishes*. Norman: University of Oklahoma Press.
- SIEGFRIED, W.R. 1989. Preservation of species in southern African nature reserves. In: HUNTLEY, B.J. (ed.), *Biotic Diversity in southern Africa: Concepts and Conservation*, Oxford University Press, Cape Town. 186-201.
- SKELTON, P.H. 1986. Fish of the Orange-Vaal system. Pp. 143-161. In: B.R. DAVIES & K.F. WALKER (eds.), *The Ecology of River Systems*. Dordrecht: Dr Junk Publishers.
- SKELTON, P.H. 1987. *South African Red Data Book - Fishes*. Pretoria: Council for Scientific and Industrial Research (South African National Scientific Programmes report; no. 137).
- SKELTON, P.H. 1993. *A complete guide to the freshwater fishes of southern Africa*. Southern Book Publishers, Halfway House.
- SKELTON, P.H. 1990. The conservation and status of threatened fishes in southern Africa. *Journal of Fish Biology* 37 (Supplement A): 87-95
- SKELTON, P.H. and J.A. CAMBRAY. 1981. The freshwater fishes of the Middle and Lower Orange River. *Koedoe* 24: 51-66.
- SKELTON, P.H., J.A. CAMBRAY, A. LOMBARD & G.A. BENN. 1995. Patterns of distribution and conservation status of freshwater fish in South Africa. *South African Journal of Zoology* 30(3): 71-81.
- STSC. 1989. Statgraphics Version 4.0. Statistical Graphics Corporation.
- VAN SCHOOR, D.A. 1968. Survey of the fishes in the Orange and Vaal Rivers from Aliwal North to Douglas. *News Bulletin of the Zoological Society of southern Africa* 9: 8-9.