Patterns of distribution and conservation status of freshwater fishes in South Africa

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The combined fish collection databases of the Albany Museum and the J.L.B. Smith Institute of Ichthyology are used to identify hotspots of endemism and threatened fish distributions in South Africa. Hotspots of fish species richness occur in the north-eastern lowveld sectors of South Africa and along the ecotone between the tropical/subtropical and temperate faunal zones. Hotspots of endemic fish richness occur within both the tropical and temperate faunal regions, notably in the Olifants River system, Western Cape and in areas of high relief such as the Cape Fold Mountains, the Amatola-Winterberg (Eastern Cape), and the Drakensberg Escarpment (Kwazulu/Natal-Eastern Transvaal). Threatened taxa are concentrated in the hotspots of endemic species richness which coincide largely with areas of major river conservation concern. There is limited scope for fish conservation within the ambit of formal (or informal) declared reserves, and the survival of the fauna depends on the success of river catchment conservation management. The value of museum collections in identifying areas of conservation concern for freshwater fishes is emphasized, and highlights the importance of well-preserved voucher specimens for biodiversity conservation.

Die gekombineerde visversamelingsdatabasisse van die Albany Museum en die J.L.B. Smith-Instituut vir Viskunde is gebruik om brandpunte van endemisme en die verspreidings van bedreigde vissoorte in Suid-Afrika te identifiseer. Brandpunte van visspesierykheid kom voor in die noord-oostelike laeveldstreek van Suid-Afrika asook in die ekosone tussen die tropiese/subtropiese en gematigde streke. Brandpunte van inheemse vissoortverspreiding kom voor in beide die tropiese en gematigde streke, veral in die Olifantsrivierstelsel (Weskaap) en in hooggeleë streke soos die Kaapse Plooiberge, die Amatola-Winterberge (Ooskaap), en die Drakensberg (Kwazulu/Natal-Oos Transvaal). Bedreigde spesies is hoofsaaklik gekonsentreer in die gebiede van endemiese visrykheid wat grootliks ooreenkom met die belangrikste rivierbewaringsgebiede. Daar is beperkte ruimte vir visbewaring binne die formele (of informele) verklaarde natuurreservate, en die oorlewing van die vislewe hang af van die suksesvolle bestuur van die rivieropvanggebiede. Die waarde van museumversamelings om bewaringsgebiede vir varswatervisse te identifiseer word hierdeur beklemtoon, asook die belangrikheid van goed gepreserveerde bewyseksemplare vir die bewaring van die biodiversiteit.

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The natural distribution of many animals and plants in South Africa is governed largely by the complexity of climate (Stuckenberg 1969). In the case of freshwater fishes, hydrographic and geomorphological history are equally important factors determining distribution patterns (Skelton 1994). Stuckenberg's (1969) Effective Temperature map (Figure 1) provides a measure of the influence of climate on distribution. The 16° ET isotherm is particularly useful for describing a reasonably good division between the distribution of the Zambezian and the southern temperate freshwater fish faunas (Skelton 1994). Freshwater dispersant fishes are entirely dependent on freshwater habitats for their existence and survival, and connections between freshwater bodies therefore are the only reliable means of natural dispersal.

The dependence of fishes on the aquatic environment renders them extremely vulnerable to human demands, uses and abuses of freshwater resources. South Africa is a predominantly dry country and its rivers and lakes are heavily used and impacted on as sources of freshwater for human needs (DWA 1986). As key integrals of landscape processes rivers and lakes are affected by practically every activity within the landscape (Davies, O'Keeffe & Snaddon 1993), and in South Africa, as elsewhere, anthropogenic impact on the landscape is extensive. Furthermore rivers are dynamic longitudinal systems so that impacts at one place are transmitted downstream for distances proportional to the scale and nature of the impact. This includes introduced aquatic organisms that often disperse widely throughout aquatic systems unless prevented by barriers from doing so. These are all vital considerations to the conservation of freshwater fishes.

The restriction of fishes to rivers and lakes both facilitates and complicates the monitoring of fish status and distribution. Rivers are discrete linear entities so that distribution records can be traced to particular points more easily than in open terrestrial systems. Most fishes are uncommon and need to be identified by trained biologists or taxonomists, and reliable distribution records require voucher specimens for scientific verification. Museum collections are therefore essential and usually the best means for determining distribution and conservation status of fishes.

The present objectives are to analyse fish distributions in South Africa, Lesotho and Swaziland, based on actual records in museum collections, in order to identify patterns of species richness and endemism that might focus and optimize efforts to conserve these organisms.

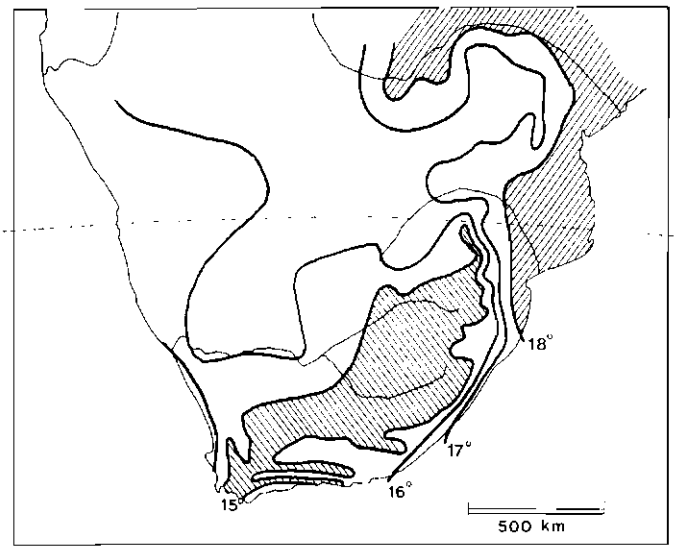

Figure 1 Effective Temperature isotherms in southern Africa (after Stuckenberg, 1969). Right slant shading indicates tropical area, left slant shading indicates temperate area.

Materials and methods

This study is restricted to indigenous freshwater dispersant fishes, i.e. primary and secondary freshwater fishes which are defined according to their tolerance (secondary) or intolerance (primary) of brackish water (Myers 1949). Excluded therefore are species of marine origin or affinity, and diadromous species such as anguillid eels. Alien species also are not considered.

The geographical scope of the study is restricted to the Republic of South Africa and the Kingdoms of Lesotho and Swaziland. For convenience the area encompassed by the three countries will be referred to as 'South Africa'. Reference to endemicity within this area is taken within a liberal framework of river basin catchments, i.e. a species is considered to be endemic to 'South Africa' if it occurs only within the borders of South Africa or is restricted to the river systems that partly or entirely occur within the borders of South Africa.

In South Africa freshwater fish collections are now concentrated in two Grahamstown museums, the J.L.B. Smith Institute of Ichthyology and the Albany Museum. For this study the freshwater fish collection records for South Africa of both museums have been combined to construct a GIS (Arc/Info) distribution database of records covering 727 quarter degree squares (QDS) (Figure 2). The scale of data analysis and map production was a quarter degree square (15' by 15') [see detailed methodology in Lombard (1995)].

The status of threatened species is based on the assessment given by Groombridge (1993) in the IUCN Red List of Threatened Animals. Non-endemic threatened species are taken from Skelton (1987).

Freshwater fishes in South Africa

There are 15 families, 29 genera and 94 indigenous freshwater fishes in South Africa (Table 1) and a further 18 alien species have been introduced and are established in the country's

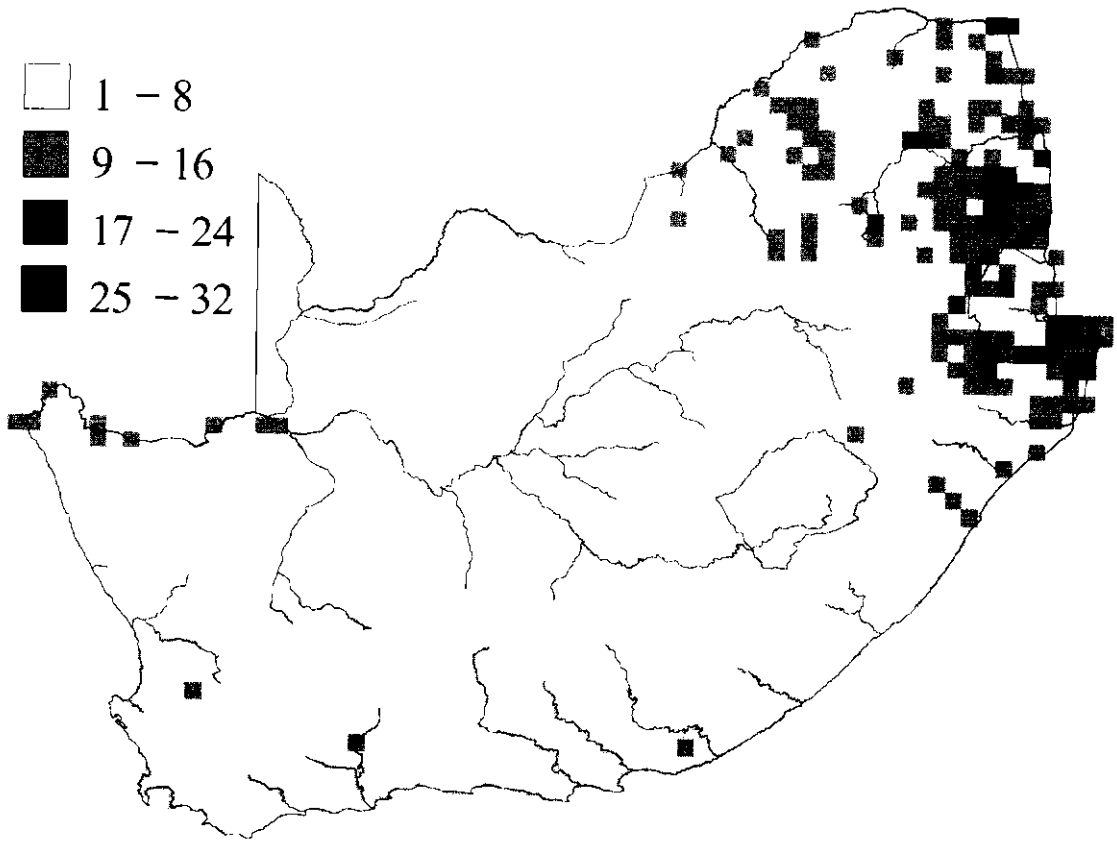

Figure 2 Indigenous fish species richness plotted from records in the fish collections of the J.L.B. Smith Institute of Ichthyology and the Albany Museum, Grahamstown.

Table 1 Indigenous freshwater fishes of South Africa, indicating faunal status, endemicity, conservation status. Abbreviations: Z = Zambezian; ST = southern temperate; E = endemic to South Africa; * = endemic to a single drainage basin, ** = endemic to less than three drainage basins; *** = endemic to several drainage basins; En = endangered; V = vulnerable; R = rare; S = safe; K = status not known sufficiently; SA = South Africa

Species	Fauna	Endemicity	Conservation
Protopterus annectens	Z		V/SA
Marcusenius macrolepidotus	Z		
Petrocephalus catostoma	Z		
Kneria auriculata	Z		R/SA
Barbus aeneus	ST	E*	
Barbus afrohamiltoni	Z		
Barbus amatolicus	ST	E**	
Barbus andrewi	ST	E**	En
Barbus annectens	Z		
Barbus anoplus	ST	E***	
Barbus argenteus	Z		
Barbus bifrenatus	Z		
Barbus brevipinnis	Z	E**	R
Barbus calidus	ST	E*	R
Barbus capensis	ST	E*	R
Barbus erubescens	ST	E*	E
Barbus eutaenia	Z		
Barbus gurneyi	ST	E***	
Barbus hospes	ST	E*	R
Barbus kimberleyensis	ST	E*	V
Barbus lineomaculatus	Z		
Barbus marequensis	Z		
Barbus mattozi	Z		
Barbus motebensis	ST	E**	K
Barbus natalensis	ST	E***	
Barbus neefi	Z		
Barbus pallidus	ST	E***	
Barbus paludinosus	Z		
Barbus polylepis	ST	E**	
Barbus radiatus	Z		
Barbus serra	ST	E*	V
Barbus toppini	Z		
Barbus treurensis	Z?	E*	V
Barbus trevelyani	ST	E**	En
Barbus trimaculatus	Z		
Barbus unitaeniatus	Z		
Barbus viviparus	Z		
Labeo capensis	ST	E*	
Labeo congoro	Z		
Labeo cylindricus	Z		
Labeo molybdinus	Z		
Labeo rosae	Z		
Labeo rubromaculatus	ST	E*	
Labeo ruddi	Z		
Labeo seeberi	ST	E*	En
Labeo umbratus	ST	E***	
Mesobola brevianalis	Z		

Table 1 Indigenous freshwater fishes of South Africa, indicating faunal status, endemicity, conservation status. Abbreviations: Z = Zambezian; ST = southern temperate; E = endemic to South Africa; * = endemic to a single drainage basin, ** = endemic to less than three drainage basins; *** = endemic to several drainage basins; En = endangered; V = vulnerable; R = rare; S = safe; K = status not known sufficiently; SA = South Africa (Continued)

Species	Fauna	Endemicity	Conservation
Opsaridium peringueyi	Z		V/SA
Pseudobarbus afer	ST	E***	R
Pseudobarbus asper	ST	E**	R
Pseudobarbus burchelli	ST	E**	R–S?
Pseudobarbus burgi	ST	E**	En
Pseudobarbus phlegethon	ST	E*	En
Pseudobarbus tenuis	ST	E**	V
Pseudobarbus quathlambae	ST	E*	En
Varicorhinus nelspruitensis	Z	E**	
Brycinus imberi	Z		
Brycinus lateralis	Z		R/SA
Hydrocynus vittatus	Z		
Micralestes acutidens	Z		
Austroglanis barnardi	ST	E*	En
Austroglanis gilli	ST	E*	R
Austroglanis sclateri	ST	E*	K/V
Schilbe intermedius	Z		
Amphilius natalensis	Z		
Amphilius uranoscopus	Z		
Clarias gariepinus	Z		
Clarias ngamensis	Z		
Clarias theodorae	Z		S/SA
Chiloglanis anoterus	Z	E**	
Chiloglanis bifurcus	Z	E*	V
Chiloglanis emarginatus	Z	E**	R/SA
Chiloglanis paratus	Z	E***	
Chiloglanis pretoriae	Z		
Chiloglanis swierstrai	Z	E***	K
Synodontis zambezensis	Z		
Galaxias zebratus	ST	E***	
Aplocheilichthys johnstoni	Z		
Aplocheilichthys katangae	Z		
Aplocheilichthys myaposae	Z	E***	
Nothobranchius orthonotus	Z		R/SA
Nothobranchius rachovii	Z		R/SA
Chetia brevis	Z	E*	R
Chetia flaviventris	Z	E*	
Oreochromis mossambicus	Z		
Oreochromis placidus	Z		V/SA
Pseudocrenilabrus philander	Z		
Serranochromis meridianus	Z	E**	R
Tilapia rendalli	Z		
Tilapia sparrmanii	Z		
Ctenopoma intermedium	Z		R/SA
Ctenopoma multispine	Z		
Sandelia bainsii	ST	E***	En
Sandelia capensis	ST	E***	

natural waters (Skelton 1993a). The indigenous species can be allocated to two natural biogeographical assemblages, a tropical or Zambezian fauna and a southern temperate fauna (Skelton 1994). The historical derivations of these two faunas are distinct, and although the faunas overlap geographically, it is convenient to describe each separately.

The Zambezian fauna extends throughout the Zambezi and historically associated drainage basins (Skelton 1994) and comprises 18 Afrotropical families and about 166 indigenous freshwater dispersant species. The dominant components of the fauna are cyprinids (52 species, 31%), cichlids (34 species, 21%) and siluroid catfishes (35 species, 21%). Within South Africa this fauna is distributed naturally as far south as the Orange River in the west and the Bushmans River (Eastern Cape) in the east, although the major subtraction zone on the east coast occurs around the St Lucia catchment in northeastern Natal (Skelton, Whitfield & James 1989). Sixty-one tropical indigenous species are recorded from South Africa, of which 13 (21%) are endemic to the Limpopo and/or the Incomati-Phongola catchments. Most of these endemic species have relatively narrow distribution ranges, in a few cases the species are restricted to a single tributary system (e.g. Treur River barb *Barbus treurensis* in the Blyde River; orange-fringed largemouth *Chetia brevis* in the Komati-Incomati and Incomati suckermouth *Chiloglanis bifurcus* in the Crocodile-Incomati River) (Table 1). In addition to the endemic species there are 15 or 16 species like the lungfish *Protopterus annectens*, the southern kneria *Kneria auriculata*, the spotted killifish *Nothobranchius orthonotus* and the rainbow killifish *Nothobranchius rachovii*, with marginal distributions in South Africa. However, most tropical species are fairly widely distributed beyond the borders of South Africa.

Only 12 (20%) Zambezian species are endemic to South Africa (Tables 1, 2). Five of these endemics are nevertheless confined to a single drainage system and a further four to only two systems. Some of the endemics are very restricted in range, e.g. *Barbus treurensis* is restricted to a single low order tributary (the Blyde River) of the Limpopo.

By comparison with the tropical fauna, the southern temperate fauna is small with only 33 species in four families. However, the entire fauna is endemic to South Africa (Table 2) and the conservation status of many species is therefore of particular concern. The temperate fauna is dominated by cyprinids (27 species, 81%) of which the majority are barbines (23 species, 85%) and there are four *Labeo* species (Table 1). The non-cyprinid component consists of three austroglanidid catfishes, a single species of *Galaxias* and two species of *Sandelia*. This fauna occurs in the coastal streams of the Cape and Natal, the Orange River system and the Highveld-Middleveld reaches of the Limpopo, Incomati and Phongola systems (Figure 3). Although a few species such as the chubbyhead barb (*Barbus anoplus*) and the moggel (*Labeo umbratus*) are fairly widespread, most southern temperate species have restricted distribution ranges. Local endemicity is therefore high (Table 2) and 45% (15 species) are restricted to a single river system, a further nine (27%) occur in fewer than five river systems, and another nine species (27%) occur in more than five river systems.

Table 2 Numbers and endemicity of indigenous freshwater fishes in South Africa

	Total		Temperate		Zambezian	
	N	%	*N*	%	*N*	%
Total No.	94	100	33	35	61	65
Endemic	45	48	33	100	12	20
Endemic*	19	20	15	45	4	7
Endemic**	33	35	24	73	9	15
Endemic***	12	13	9	27	3	5

*— single drainage system; **— <3 drainage systems; ***— >5 drainage systems

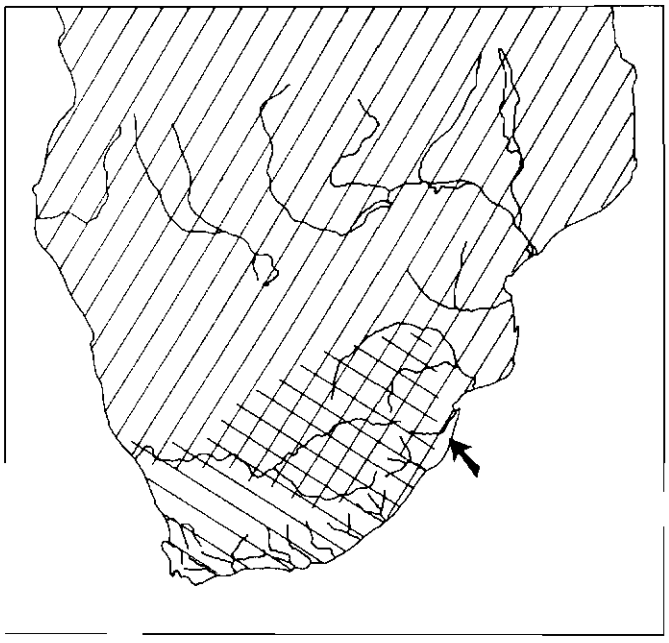

Figure 3 The distribution of tropical (Zambezian)(right slanting shading) and southern temperate (Cape) (left slanting shading) ichthyofaunae in southern Africa (after Skelton 1990). An arrow indicates the region where tropical species richness declines abruptly.

Distribution hotspots of species richness

The general distribution of the Zambezian and southern temperate faunas are shown in Figure 3. In the Transvaal interior the temperate fauna species are restricted to relatively higher altitude zones and tropical species to lower zones (Gaigher 1969, 1978). The relatively abrupt rise of the eastern (Drakensberg) escarpment restricts many tropical species to the coastal plain below about 300 m altitude. The high gradient streams of the escarpment provide a set of different hydrological conditions to the lowveld or coastal plain so that there are marked differences in the fish fauna between the two zones and species distributions are restricted accordingly. Similarly tropical fish species richness declines in accordance with the decrease in width of the coastal plain south of the St Lucia catchment in Natal (Bruton & Kok 1980; Skelton 1994).

These factors all feature in determining the general pattern of fish species richness (Figure 2). Although the scatter of collection records is uneven, especially in the Northern Cape, the Orange Free State and the former Transkei territory, the pattern shown in Figure 2 is not affected seriously. These are

areas where fish diversity is naturally low and evenly distributed and, apart from the former Transkei, the hydrographic network is less dense compared to that of the higher rainfall areas.

In Figure 2 fish species richness is measured on a scale of four units of eight species to a maximum of 32 species recorded per QDS. These units are too coarse to indicate hotspots in those areas where only the temperate fauna occurs because, apart from possibly the Olifants River (Western Cape), no more than five or six species are encountered in any particular system. Therefore endemic species richness shown in Figure 4 highlights more effectively the hotspots of the temperate faunal richness, as well as the distribution of the restricted species of the Zambezian fauna. The indigenous species richness map (Figure 2) exposes the faunal richness in the north-eastern sectors of the country (Kwazulu/Natal, Eastern Transvaal and Northern Transvaal) which emphasizes the importance of these areas for fish conservation.

There are three broad areas highlighted in the pattern of endemic fish species richness (Figure 4), namely the Cape Fold Mountain belt, the Orange River mainstream and the Eastern Transvaal-Kwazulu/Natal Drakensberg. Within these and other areas the hotspots of endemic species richness (Figure 4) include (1) the Olifants River (Western Cape), (2) the Eerste and Berg Rivers (Western Cape), (3) the Gourits-Keurbooms Rivers (Western Cape), (4) the Gamtoos-Swartkops-Sundays River areas (Eastern Cape), (5) the Great Fish River (Eastern Cape), (6) the Keiskamma River (Eastern Cape), (7) the Orange River mainstream, (8) tributaries of the Orange in Lesotho, (9) the Tugela headwaters (Kwazulu\Natal), (9) collectively the Eastern Transvaal escarpment from the Phongola to the Sabi and the Blyde River, and (10) the Witwatersrand-Magaliesberg areas. Most of these hotspots focus on areas of relatively high topographical relief, where conditions are most favourable for sustaining relict populations of fishes in streams and rivers through variable climatic periods. The rich fish fauna of the Olifants River (Western Cape) is partly a product of a major link with the Proto-Upper Orange-Vaal system that probably existed to at least the Mid-Miocene (Partridge & Maud 1987). This illustrates the importance of both historical circumstance and river system resilience over time for sustaining and building fish communities. The fragility of such long-isolated communities is shown clearly by the sudden and rapid decline that has occurred since the introduction of alien predators between 1890 and 1940.

Threatened fishes in South Africa

The conservation status of endemic and non-endemic freshwater fishes in South Africa is given in Table 1. Twenty-eight threatened endemic and nine non-endemic species are listed in the IUCN Red Data Book (Groombridge 1993). Threatened taxa represent 47% of the endemic species or 22% of all freshwater dispersant fishes in South Africa. For the endemics there are nine Endangered, six Vulnerable and 10 Rare species, one Indeterminate and three insufficiently known at present. The status of non-endemics applies only to their status within South Africa and there are two Vulnerable species and eight Rare species.

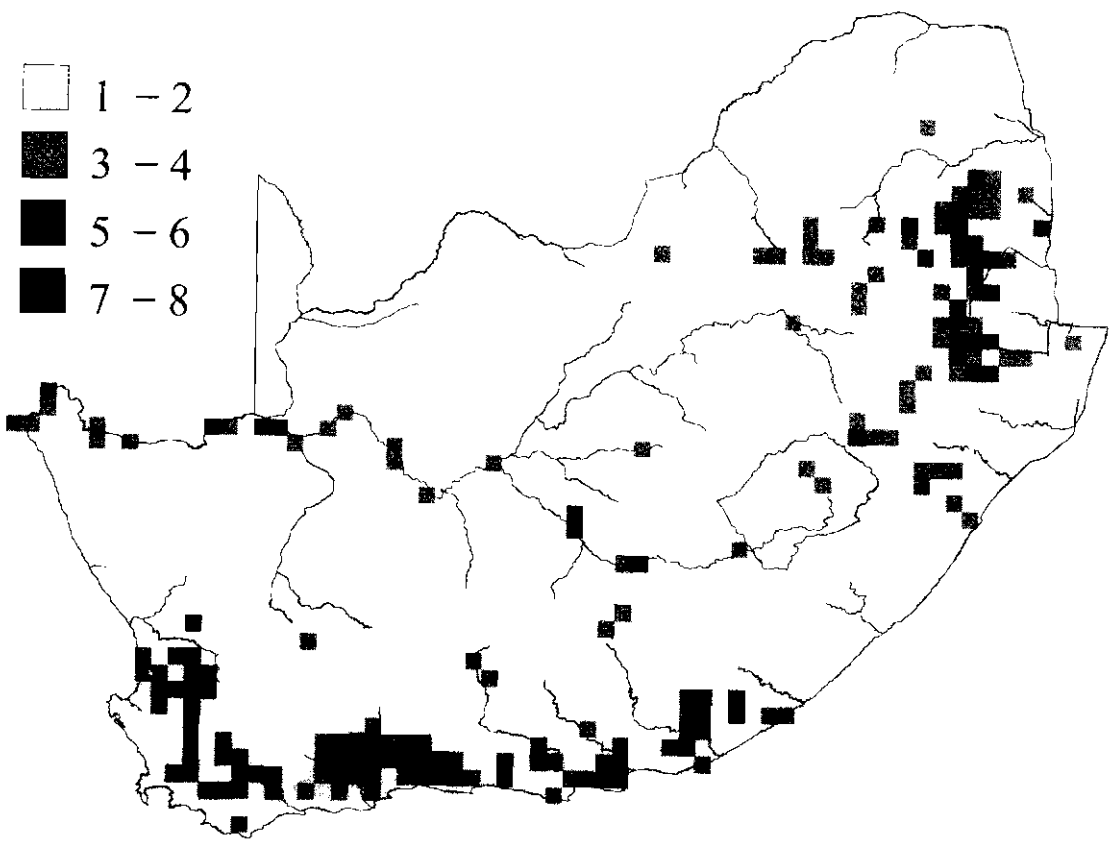

Figure 4 Endemic indigenous freshwater fish species richness plotted from records in the fish collections of the J.L.B. Smith Institute of Ichthyology and the Albany Museum, Grahamstown.

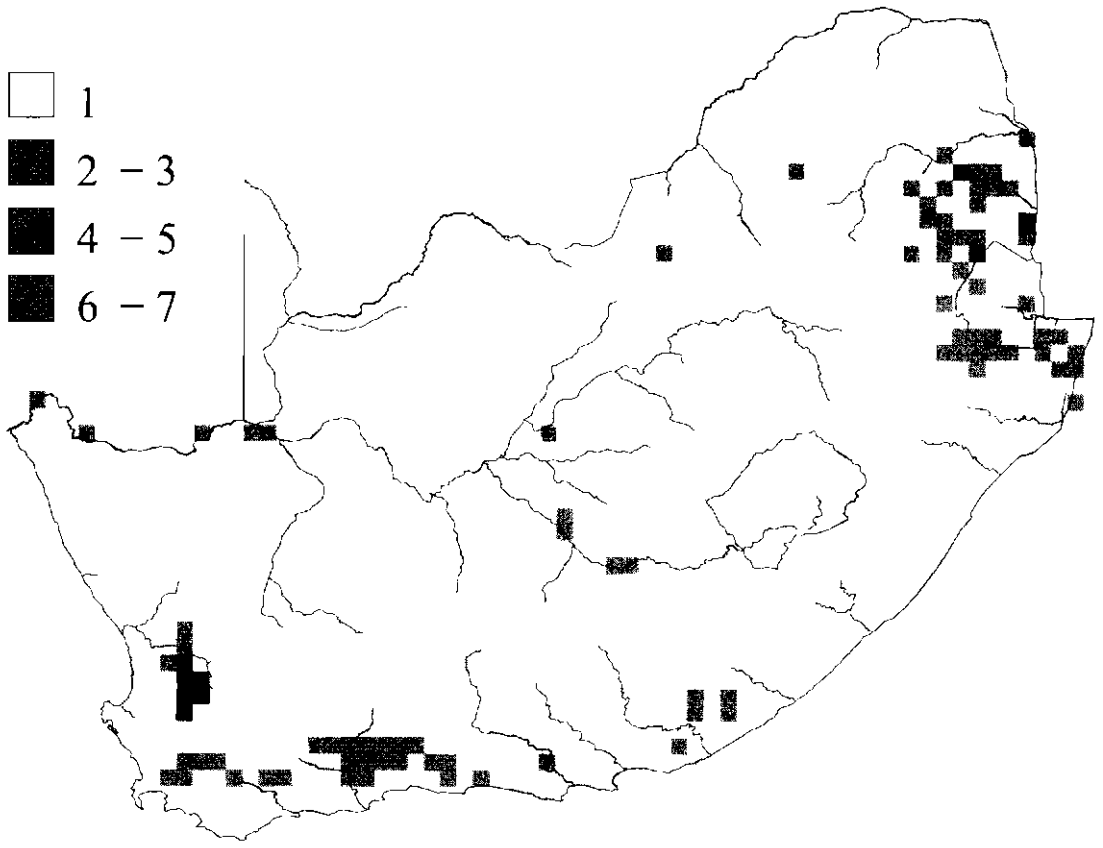

Figure 5 Endemic threatened freshwater fish species richness in South Africa plotted from records in the fish collections of the J.L.B. Smith Institute of Ichthyology and the Albany Museum, Grahamstown.

The distribution of threatened species (Figure 5) clearly emphasizes the trends of endemic species richness. The Olifants River (Western Cape) is the most notable hotspot of threatened fish species with between four and seven species per QDS in six QDS. In no other areas are more than three red data species found within the same QDS, and these areas are scattered widely: the Berg and Breede River systems (Western Cape), the Amatola-Winterberg area (Eastern Cape), Maputaland (northern Kwazulu/Natal), the escarpment and lowveld (Eastern Transvaal) and the Lower Orange River (Northern Cape). Aside from the Olifants River system the most important river systems for threatened fish species conservation are the Orange, the Great Fish, the Keiskamma and Buffalo, the Phongola, the Incomati and the Olifants-Limpopo.

Fish distribution and reserves

Protected natural areas vary in size, shape and representation to provide a combined coverage of less than 6% of the total area of South Africa (Siegfried 1989). A remarkably high proportion of the terrestrial vertebrate fauna and the vascular plant species are protected in these areas. Siegfried's (1989) analysis did not include fishes, but, given the coincidence of large-scale coverage of protected areas in the lowveld region of the Eastern Transvaal, Northern Transvaal and Kwazulu/Natal, as well as in the Cape Fold Mountain belt, with the natural indigenous fish species richness (Figure 2), a similarly high proportion of the fish fauna also occurs within reserve areas. The analysis of collections indicates that 78 (83%) of the 94 freshwater fish species in South Africa have been recorded at least once in formally protected areas. Most, if not all, of the Red Data Book species are also to be found in protected areas (Table 3). There is no room for complacency because reserves are a more complicated issue for fishes than for most other vertebrates (O'Keeffe, Davies, King & Skelton 1989).

Although protected areas do offer some protection to fishes through limited human access and catchment preservation, few reserves encompass entire catchments of significant size. Ideally a fish reserve should encompass the entire catchment of the water body concerned. The aquatic habitats in rivers are frequently impacted on by changes upstream or in the catchment beyond the boundaries of a reserve. The effectiveness of a reserve therefore depends on the extent of the catchment within the conserved area, and in the configuration of the reserve with respect to the catchment area. An effective fish reserve must secure the minimum water quantity and quality requirements for the entire community of species in the system. As far as possible natural hydrological cycles must be maintained and alien organisms, especially high-impact predators like bass and trout, need to be effectively excluded. The special need of free passage for migratory or diadromous species must also be satisfied. Small species in small communities may have fairly limited requirements but the larger species and larger communities have broader more diverse environmental requirements. Reserves placed higher in a catchment will be better protected and easier to manage than reserves further downstream. McDowall (1984) considered

Table 3 A selection of possible protected areas for threatened freshwater fishes in South Africa (including Lesotho and Swaziland). Abbreviations as given in Table 1. I = Indeterminate; NR = Nature reserve

Species	Status	Reserve/s
Austroglanis barnardi	E	Cedarberg Wilderness area
Barbus erubescens	E	Cedarberg Wilderness area
Labeo seeberi	E	Cedarberg Wilderness area, Matjiesrivier
Barbus trevelyani	E	Pirie Fisheries Station
Pseudobarbus burgi	E	Mont Rochelle NR; Assegaaibosch
Pseudobarbus phlegethon	E	Cedarberg Wilderness area; Beaverlac NR
Pseudobarbus quathlambae	E	Sehlabathebe National Park
Sandelia bainsii	E	Bloukrans Pool Reserve; Amalinda Fisheries Station
Barbus andrewi	V	Bontebok National Park
Barbus kimberleyensis	V	Augrabies Falls Nat. Park; Richtersveld Nat. Park
Barbus serra	V	Cedarberg Wilderness area
Barbus treurensis	V	In de Diepte Natural Heritage site
Chiloglanis bifurcus	V	Songimvelo Game Reserve; Ngodwana sanctuary
Austroglanis gilli	R	Cedarberg Wilderness area
Austroglanis sclateri	I(R)	Augrabies Falls Nat. Park; Richterveld Nat. Park
Barbus brevipinnis	R	Sabie-Sand Game Reserve; Songimvelo Game Reserve
Barbus capensis	R	Cedarberg Wilderness area
Barbus calidus	R	Cedarberg Wilderness area
Barbus hospes	R	Augrabies Falls Nat. Park; Richtersveld Nat. Park
Chetia brevis	R	Kruger National Park
Pseudobarbus afer	R	Baviaanskloof Wilderness area; Groendal Wilderness area; Suurberg Nat. Park; Loerie dam NR; Tsitsikamma Nat. Park; Whiskey Creek NR; Knysna Nat. Lake Area; (State Forests)
Pseudobarbus asper	R	Gamkapoort Nature Reserve
Pseudobarbus burchelli	R	Bontebok Nat. Park; Vrolikheid Nature Reserve; Marloth Nature Reserve
Pseudobarbus tenuis	R	Gamkapoort Nature Reserve
Serranochromis meridianus	R	Sabie-Sand Nature Reserve; Kruger Nat. Park; Sodwana Bay Nat. Park
Barbus motebensis	K	Magaliesberg Wilderness area
Chiloglanis swierstrai	K	Kruger Nat. Park; Sabie-Sand Nature Reserve
Non-endemic species		
Oreochromis placidus	V/SA	Sodwana Bay Nat Park; St Lucia Park
Protopterus annectens	V/SA	Kruger Nat. Park
Brycinus lateralis	R/SA	Mkuze Game Reserve; Hluhluwe Game Reserve; Umfolozi Game Reserve; St Lucia Park; Eastern Shores Nature Reserve;
Chiloglanis emarginatus	R/SA	Songimvelo Game Reserve
Clarias theodorae	R/SA	Kosi Bay Nature Reserve; Sodwana Nat. Park; St Lucia Park; Enseleni Nature Reserve
Ctenopoma intermedium	R/SA	St Lucia Park; Eastern Shores Nature Reserve
Kneria auriculata	R/SA	
Nothobranchius orthonotus	R/SA	Kruger National Park; Mkuze Game Res; Ndumu Game Reserve
Nothobranchius rachovii	R/SA	Kruger National Park
Opsaridium peringueyi	R/SA	Kruger National Park; Sabie-Sand Game Reserve; Lephalala Nature Reserve; Itala Nature Reserve

the following criteria as appropriate for fish reserves in New Zealand: naturalness of habitat; size of habitat; permanence of water; absence of exotic or alien species; absence of exploitation; and access to the sea.

At present South African rivers are heavily impacted on by human activities, to the point where even the largest downstream reserves, such as the Kruger National Park (KNP), can do little to guarantee the environmental security of downstream aquatic habitats (Deacon 1994). Even the most apparently pristine systems are not unaffected by human actions (Davies *et al.* 1993). Some local examples of fishes in protected areas will illustrate the strengths and weaknesses of the concept of formal protection within reserves for freshwater fishes.

The Blaauwkrantz Nature Reserve on the Bloukrans tributary of the Kowie River system near Grahamstown, Eastern Cape was created by the Algoa Regional Services Council to help conserve the endangered Eastern Cape rocky (*Sandelia bainsii*) (Cambray 1994a,b). The city of Grahamstown, including a large and rapidly expanding informal community, exists on the upper catchment of the Bloukrans River. Over the *ca* 20 km between the City and the reserve, the river is heavily exploited for irrigation by agriculture and is no longer perrenial but is reduced to a disconnected series of isolated pools for extended periods of time. Within the past few years the invasive South American water fern *Azolla filiculoides* has invaded the river and at times completely covers the isolated pools. As a result of these threats, and in spite of co-ordinated effort by the local community to remove the water fern from the habitat of the fish species, the population of *S. bainsii* is now severely threatened with extinction in the system (Cambray 1994a,b).

In spite of its large size the Kruger National Park (KNP) offers little sanctuary to riverine fish species mainly because it cuts across downstream sections of river catchments and these habitats are subject to upstream perturbations (Deacon 1994). Although the natural resilience of tropical fish communities is generally high, a fact well supported by Chutter & Heath's (1993) study of the fishes of the Letaba River during low flows, the fish communities of KNP rivers have declined

in recent years (Russell & Rogers 1989; Deacon 1994). However, in spite of these limitations the KNP does have some positive prospects for the conservation of threatened species, especially those of temporary water bodies or lotic species that survive in offstream reservoirs (Gaigher 1978; Pienaar 1978; Skelton 1987). In a similar situation the Mkuze Game Reserve also provides effective sanctuary for the rainpool-dwelling spotted killifish (*Nothobranchius orthonotus*). In the past even such sanctuaries were violated by the authorities spraying pools for mosquito control.

Several mountain catchment reserves are well sited upstream but fail to provide safe sanctuary for indigenous fishes because of the presence of introduced alien predators. The Sehlabathebe National Park in Lesotho is a good example of this. The endangered Drakensberg minnow *Pseudobarbus quathlambae*, feared at one stage to be extinct, was rediscovered in the Tsoelikane River in 1971 (Pike & Tedder 1973). The Sehlabathebe National Park, proclaimed in 1973, includes the entire catchment basin of the Tsoelikane River but the minnow remains threatened by the presence of introduced rainbow trout (*Oncorhynchus mykiss*). Other threats include habitat deterioration by sedimentation from various sources such as road building, the collapse of small reservoirs, and overgrazing by domestic stock, all within the National Park (Skelton 1987; Cambray & Meyer 1988).

The Blindekloof River in the Groendal Wilderness Area near Uitenhage, Eastern Cape is as near to pristine as could be expected, except for the presence of largemouth bass (*Micropterus salmoides*), which has devastated indigenous fish populations in the invaded lower reaches of the stream (Skelton 1993b). Thus, in the absence of a suitable natural downstream barrier to prevent the entry of alien invasive organisms, many otherwise ideal sanctuaries are ineffective for conserving indigenous fishes.

The effectiveness of downstream barriers can be critical for the survival of a species. The Treur River barb (*Barbus treurensis*) survives only because trout and bass were prevented from invading the Blyde River above a waterfall (Pott 1981). The species has been reintroduced to waterfall protected sanctuaries on the private property of Mondi Forests and have been declared Natural Heritage Sites (Pott 1981; Anonymous 1994a).

The threatened (Vulnerable) Incomati suckermouth *Chiloglanis bifurcus* is naturally restricted to a section of the Crocodile-Incomati River system between the altitudes of 900 and 1200 m, and to the Lomati tributary of the same system (Skelton 1987; Heymans 1987). The Crocodile River and its major tributary the Elands River, where this species occurs, are both seriously affected by regulation from impoundments, pollution from a paper mill, afforestation and other agricultural developments (Skelton 1987; Kleynhans, Schulz, Engelbrecht & Rousseau 1992). A serious pollution event in 1989 affected over 40 km of the river including 38% of *C. bifurcus* habitat, and even two years later the fish fauna had not recovered (Kleynhans *et al.* 1992; James 1992). As a result of this disaster, a tributary to the Elands, the Ngodwana River, was selected as a possible sanctuary for the species and was stocked in 1993. The Ngodwana River is a perennial stream with suitable riffle-pool habitats for the Incomati suckermouth but its catchment is extensively planted with pines, and there is a downstream dam, stocked with largemouth bass (*Micropterus salmoides*) and other fishes, shortly above its confluence with the Elands River. A few gravel roads service the valley. The stream is not invaded yet by alien fish species and a small weir has been built in the river a few hundred metres above the inflow to the dam to serve as a bass barrier. Although the sanctuary is presently secure at least two future threats are the likely decrease in river flow as a result of increased forestation of the upper valley slopes and the prospect of a new road to be built through the valley.

From all the above examples we conclude that it is extremely difficult to conserve fishes through the route of formal reserves and for the long term it is necessary to focus on the broader issue of holistic river catchment conservation. Reserves assume an important role in the conservation of threatened species within the context of the irreversability of extinction. However, measures of this nature must be seen for what they are and that 'Nature conservation is but one of a number of aims which concentrate on maintaining ecological functioning for multiple uses. The maintenance of biotic diversity, often seen as an aim of conservation, is really a consequence of effective conservation' (O'Keeffe 1989: 256).

Hotspots of fish diversity and reserves — possibilities and prospects in South Africa

An ideal reserve system that would incorporate all indigenous freshwater fish species in South Africa is shown in Figure 6. The QDSs shown were selected by an iterative reserve selection algorithm [see detailed methodology in Lombard (1995)] and only indicate the general area of the required reserves. These hypothetical reserves are predictably distributed in a pattern that is generally (but not specifically) consistent with the pattern of endemic species richness (Figure 4) and endemic threatened species richness (Figure 5). Many of the iterative reserves coincide with existing protected areas and, in the light of problems with formal reserves and fish conservation discussed above, the question is therefore raised as to whether or not the information can be applied constructively to conserving fish biodiversity in South Africa.

The answer is positive if the process helps to focus attention on areas of maximum concern and effect for conservation. For example the Olifants River (Western Cape) is the pre-eminent hotspot of both endemic fish richness and of endemic threatened fish richness. At least two iterative reserves occur on the system and the system is therefore a prime area for conservation attention. The Olifants River has been the focus of nature conservation concern for several decades now (Scott 1982; Skelton 1987; Gore, King & Hamman 1991). There are several protected areas in the Olifants catchment including the Cedarberg Wilderness Area and the recently aquired Matjiesrivier reserve (Anonymous 1994b) but such protected areas will not nearly solve the problem of conserving the freshwater fishes of the system. The reason for this is that the major threats to the fishes of this system are not only introduced alien predators (especially bass *Micropterus salmoides* and *M. dolomieu*), but also the demand for agricultural water and water pollution (Scott 1982; Gore *et al.* 1991). The majority of the endemic freshwater fishes of the Olifants River have survived the impact of introduced bass only in streams where natural barriers have prevented the invasion of

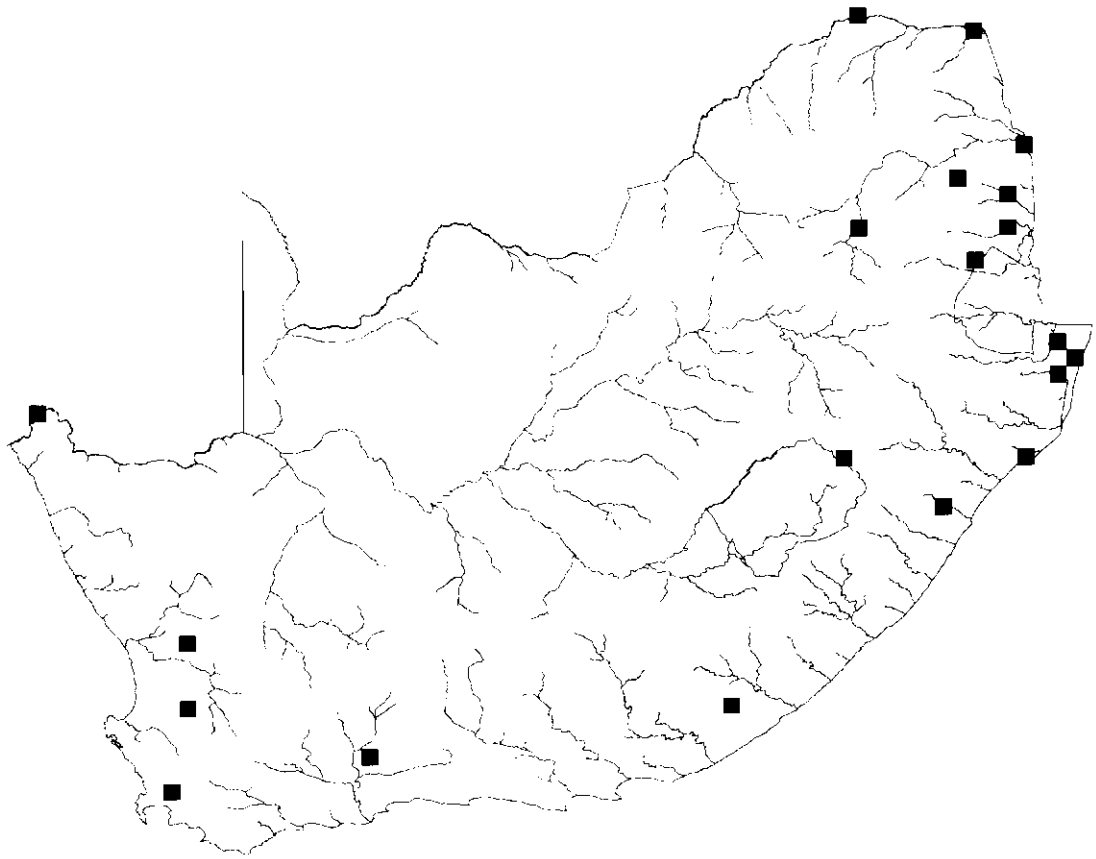

Figure 6 Iterative reserves of indigenous fish species in South Africa, plotted from records in the fish collections of the J.L.B.Smith Institute of Ichthyology and the Albany Museum, Grahamstown.

the aliens (PHS pers. obs.). Therefore, the long-term survival of the fish fauna of this system will depend to a large extent on the endurance of such natural riverine sanctuaries more than on the formal declaration of protected areas. Declaring natural riverine sanctuaries as formal reserves would, of course, assist the long-term viability of such sanctuaries.

The problem of downstream siting of formal reserves remains a major problem for lentic fish conservation, especially in the case of high biodiversity (e.g. in the Kruger National Park), or specialized endemics (e.g. for Namaqua barb *Barbus hospes* confined to the Orange River below Augrabies Falls). In these cases it is imperative that sound holistic, ecosystem conservation is practised and enforced (O'Keeffe 1989; O'Keeffe *et al.* 1989; Davies *et al.* 1993). In some cases, where human use is closely integrated with the riverine environment, conservation measures could include the recognition of the river as a biosphere reserve or sanctuary, where human activities are relatively restricted. This concept is now being developed for the densely populated Phongola River floodplain in Maputaland (G. Merron, pers. comm.), where the fish community is an important part of the floodplain ecology.

Conclusions — the value of museum collections for conservation

Drinkrow, Cherry & Siegfried (1994) emphasize the valuable role that natural history collections can play in preserving biodiversity in South Africa. The present analysis of fish distribution and hotspots of richness would not have been possible without the extensive museum collections on which it is based. At this stage the analysis is incomplete, as several historically important collections are not yet included in the database. Chronological issues have not been addressed which is important in terms of fish conservation because the hotspots as revealed by the analysis are those exposed from decades of sampling. There is increasing evidence of the decline in range of many species and their presence in any particular quadrant does not necessarily mean the species is still to be found in that area. A pertinent example is given by the distribution map of southern barred minnow *Opsaridium peringueyi* where early (pre-1912) records of the species in the Pienaars and Hennops Rivers around Pretoria (Figure 7) have not been re-collected from there since that time. The nearest recent record is the literature reference by Kleynhans & Hoffman (1992) to a threatened population from the Phalala River in the Waterberg. Without the museum records analysis would not reflect the true historical distribution range of the species.

Many requests for researchers and conservationists to lodge voucher specimens from their studies in museums are made (e.g. Cambray 1990; Cambray & De Moor 1994). Voucher specimens are a prerequisite for the validation of scientific biological research, and yet few biologists bother themselves with the elementary basic procedure. Museum collections have always been part and parcel of systematic research but now, as both the pace of environmental degradation and the need to conserve biodiversity increases, so does the value and utility of museum collections also increase.

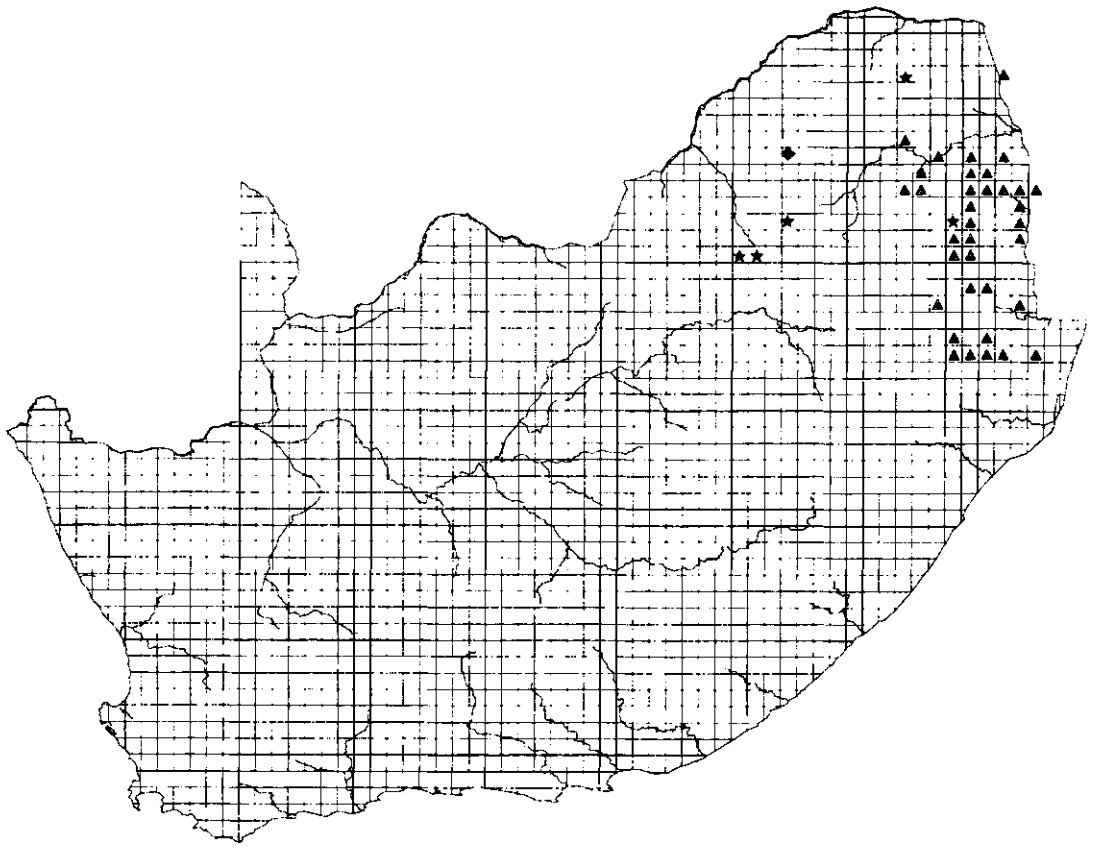

Figure 7 The distribution of *Opsaridium peringueyi* (Gilchrist & Thompson 1913) in South Africa plotted from records in the fish collections in the J.L.B. Smith Institute of Ichthyology and the Albany Museum, Grahamstown (triangles). Stars indicate records in the Transvaal Museum collection; the diamond indicates literature record after Kleynhans & Hoffman 1992.

Museum records are often the only evidence of the biota of changed or destroyed ecosystems. Modern computer technology such as GIS only increases the research potential and value of museum collections as is demonstrated in this paper. Our study also demonstrates the value of combining data from different collections and is the start of a programme aimed to produce a dynamic atlas of fish distribution in southern Africa that will be used to further the biogeographic analysis and conservation of the fauna. It is sobering to consider how much better the data base would be if all researchers and collectors of samples had simply lodged them in a museum. We would prefer not to be left with Tompkins' (1991:203) dictum: 'The objects in museums preserve for us a source of life from which we need to nourish ourselves when the resources that would normally supply us have run dry.

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