TECHNICAL REPORT ON THE STATE OF YELLOWFISHES IN SOUTH AFRICA 2007

Report to the
Water Research Commission
by
The Yellowfish Working Group

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EXECUTIVE SUMMARY

The Executive Committee of South Africa's national Yellowfish Working Group (YWG) recommended in 2006 that a status report be compiled for the nine "yellowfishes" that are the focus of the Group's activities. These species include six true yellowfishes (*Labeobarbus* spp.) and three large *Barbus* species (*B. andrewi*, *B. rapax* and *B. serra*) that closely resemble yellowfishes. The Committee further recommended that two reports be produced: a popular report for the layman (e.g. anglers, riparian land-owners) and a technical report, aimed at scientists and conservation staff, that would provide comprehensive and updated information on the status of the nine species. Funding was needed to produce such reports, and the Water Research Commission approved an application, managed by the Federation of Southern African Flyfishers (FOSAF), in 2006. The popular report was released at the annual conference of the YWG in April 2007.

Why is it necessary to produce a national status report on yellowfishes? There are several compelling reasons. First, the yellowfishes are, arguably, the most popular indigenous freshwater fishes caught by anglers across the country, and hence support valuable and growing recreational and subsistence fisheries. Second, yellowfishes are valuable indicators of aquatic ecosystem health, as they require rivers and dams that have diverse habitat, good water quality and few or no alien fishes and plants. They thrive in rivers that have a near natural flow regime. Being charismatic to anglers and good ecological indicators, they are possibly our best flagship species for aquatic ecosystems. Third, three of the nine species are threatened, including two that are endangered (Berg-Breede whitefish *Barbus andrewi* Barnard, 1937 and Clanwilliam sawfin *Barbus serra* Peters, 1864). Finally, several yellowfish species have been translocated by inter-basin water transfer schemes (IBWTS) and through stockings into new waters where they are now invasive and likely to become an ecological problem.

The technical report comprises 11 chapters, with an introduction followed by nine species accounts and a final chapter on invasive alien yellowfishes in South Africa. Ichthyologists and conservation officials who have a sound knowledge of the biology, ecology and management of yellowfishes in southern Africa have written the various chapters. The report concludes with an appendix containing the most comprehensive list of yellowfish reference material available.

The introductory chapter on yellowfishes highlights that they are widely distributed and endemic to Africa and constitute a lineage of about 80 large cyprinid fish species with several well-defined traits and characteristics. The taxonomy of southern African yellowfishes is rather confusing and has, over the years, changed considerably with 30 species being described in the early 1900s. Today, only six South African species are considered valid.

The most outstanding feature of the African yellowfish lineage is the very high number (about 150 – a hexaploid or six-fold condition) of cell chromosomes. Most other African cyprinids have around 50 chromosomes (the normal or diploid state) in each cell. Southern Africa has two groups of yellowfish, described as large-scale and small-scale forms. Of the six true yellowfish species described in this report, five are small-scaled and one large-scaled. At present the relationship between these groups is uncertain, because forms also exist elsewhere in Africa.

The physical features of yellowfishes include their relatively large size, fusiform bodies, parallel striations on scales, and short-based fins that include a dorsal fin with a simple (i.e. not serrated) usually bony and spiny anterior ray. Yellowfishes show little sexual dimorphism with both sexes in many species tending to turn deep brazen gold or yellow when breeding, and they develop small pimple-like nuptial tubercles on the head and sometimes all over the body.

There are three other large barbine cyprinids in southern Africa that are covered in this report, but these are not true yellowfish. None of these other species have 150 chromosomes, and they also differ in several essential morphological features. *Barbus andrewi* and *B. serra* are tetraploid cyprinids with about 100 chromosomes, a feature which is shared with the Western Cape's redfin minnows and all European *Barbus*. They have a serrated dorsal fin spine and the head shape with its pointed snout differs from that of the yellowfishes. These two species seem to be more closely related to some of the smaller redfin minnows than to yellowfish. The papermouth *Barbus rapax* Steindachner, 1894 also has a serrated dorsal fin spine but is a "diploid" species with 50 chromosomes and is related to other African barbs. The chapters on the nine species are divided into sections on distribution and conservation status, status of habitats, biology and ecology, threats, conservation management and yellowfish utilisation.

An assessment of the conservation status shows that three of the nine species are threatened. The conservation status of South African fishes was revised in 2006 using the most recent IUCN criteria. The three threatened species include two Endangered species, namely *B. andrewi* and *B. serra*, and one Vulnerable species, the Clanwilliam yellowfish *Labeobarbus capensis* (A. Smith, 1841). *Barbus andrewi* is the first "yellowfish" to have become locally extinct in an entire river system; notably in the Berg River System in the mid 1990s due to a combination of threats. The Orange-Vaal largemouth yellowfish *Labeobarbus kimberleyensis* (Gilchrist & Thompson, 1913) has been listed as Near Threatened, because of flow modifications and impaired water quality in parts of its distribution range.

The natural distribution of the nine species varies markedly, with some species restricted to a single river system, whereas others are widely distributed across several river systems and provinces. The current distribution of the three threatened species has become even more restricted, due to major declines in distribution range as a consequence of local extirpation by invasive alien predatory fishes. The most naturally restricted species are those of the Western Cape, namely *B. serra* and *L. capensis*, which are endemic to the Olifants-Doring River System and *B. andrewi* which is only found in the Berg and Breede River systems. At present, healthy recruiting populations of each species occupy less than 20 percent of their original distribution range. *Barbus andrewi*, is even more restricted, due to the severe impacts of invasive alien fishes, with healthy recruiting populations only present in a few dams in the Breede catchment. The species became extinct in the Berg River in the 1990s. Two other yellowfishes (*Labeobarbus aeneus* [Burchell, 1822] and *L. kimberleyensis*) are also naturally restricted to a single river system, the Orange-Vaal, but are widespread across a huge area because this extremely large catchment covers more than half of South Africa. The former species has also been translocated extensively across South Africa, due to IBWTS and stocking programmes several decades ago. The remaining yellowfish species and *B. rapax* are found in many river systems and, like *L. aeneus* and *L. kimberleyensis*, are widespread and still relatively abundant.

The biology and ecology of the nine species reveals that they are primarily river dwellers, with a preference for large rivers with diverse habitat, natural fast flows and good water quality. However, all species are relatively adaptable and appear to thrive in impoundments, provided that spawning habitat is available in the dam or inflowing rivers. The chapter on northern smallscale yellowfish *Labeobarbus polylepis* Boulenger, 1907 shows that some species have fairly specific life history and spawning requirements. This has important implications for the design and operation of dams in rivers with indigenous yellowfish populations. Another common feature of the nine 'yellowfishes' is that they are slow growing and long-lived. The slow growth rate, especially of Western Cape species, makes juveniles particularly vulnerable to predation by faster growing alien fishes such as smallmouth bass *Micropterus dolomieu* (Lacepède, 1802). Trophy yellowfishes are probably between 10 and 20 years old and, in order to reach that size, anglers need to release captured fishes, even large specimens.

It is clear that there still are substantial gaps in our knowledge of the nine 'yellowfishes' – for some species such as *B. andrewi* there is a general lack of scientific knowledge whereas with others we do not know enough of specific matters such as spawning requirements, age and growth, diet, and detailed habitat requirements.

Threats to yellowfishes are numerous and varied. The most threatened species are all in the Western and Northern Cape – namely *B. andrewi* in the Berg and Breede River systems and *B. serra* and *L. capensis* in the Olifants-Doring River System. These fishes have experienced huge declines in their distribution ranges and population densities since the 1930s – invasive alien fishes have been the major cause of this decline but water abstraction from rivers, in-stream dams, and to a lesser extent, invasive alien plants and water pollution have all contributed significantly.

The other six species, although more widespread and abundant, are also under growing pressure from man-made impacts. For the northern and eastern species, the key threats are deteriorating water quality (often due to poorly managed or inadequate water-treatment works), illegal harvesting by subsistence fishers (primarily by netting) and IBWTS which have translocated yellowfishes into new areas causing new ecological problems, including the potential for hybridisation with locally occurring yellowfishes. *Barbus rapax* and *L. kimberleyensis*, in particular, are severely affected. In addition, several sub-populations of the remaining species are in decline. Until we have a clear understanding of the intraspecific genetic differences of each species, we cannot afford to lose yellowfish populations in any river, as they may be genetically unique. Many conservationists have expressed particular concern that as yellowfishes become increasingly popular with anglers and riparian landowners, they will be illegally introduced into new waters and cause ecological damage. The chapter on alien yellowfishes highlights the various yellowfish translocations that have taken place, mostly through IBWTS and officially sanctioned stockings several decades ago. Introduced yellow-fishes have usually thrived in their new waters and, being large omnivores, may have disturbed the local ecology significantly. Little research has taken place to quantify this phenomenon or the possible hybridisation with native populations.

The growing interest in yellowfishes, led by the concerted efforts of the YWG, has had major positive spin-offs for river conservation through the establishment of dedicated yellowfish conservancies. The Orange-Vaal River Yellowfish Conservation and Management Association, established in 1996, have 749 members and manage the river from Vaal Dam to Bloemhof Dam, a river distance of nearly 700 km. A similar conservancy has been set up on the Elands River in Mpumalanga below Waterval-Boven. In the Western Cape, the Greater Cederberg Biodiversity Corridor, has been recently established as part of the Cape Action for People and the Environment (CAPE) to improve conservation of the wider Cederberg area, including the critically important Olifants-Doring River System. Angling groups have enthusiastically embraced efforts to improve management of yellowfishes and associated habitat. These include FOSAF, Fly Castaways, Cape Piscatorial Society and the bait and artificial-lure angling sectors. Angling groups are pressurising government to harmonise legislation affecting yellowfishes so that there are no differences across provincial boundaries. Latest proposals include a no-keep catch approach to *B. andrewi*, *B. serra*, *L capensis* and *L. kimberleyensis* and a daily catch limit of two fish per day of 30 to 50 cm for the more common species. Anglers also want a national freshwater fishing licence, the income from which will be used to improve management of inland fisheries across the country.

Key concerns relating to yellowfish management are the inadequate resources allocated to freshwater fish conservation and river health management across the country – some provincial conservation authorities do not even have a dedicated freshwater aquatic scientist. Most conservation authorities employ less than three persons, surely too few for the requirements of sound river and fishery management. The Department of Water Affairs and Forestry also has major capacity constraints at present; these may be overcome once Catchment Management Agencies are fully operational. The lack of adequate funding for freshwater fish monitoring and research work is also a major concern. This issue could be overcome through a dedicated national freshwater angling fund.

Angling for yellowfish will continue to grow in popularity and, with adequate resources and skills devoted to their management, these fishes can sustain very valuable recreational and subsistence fisheries across South Africa. Sound management depends on good information that is based on facts and the input of experts. It is hoped that current and future stakeholders in yellowfish management will read and be guided by the contents of this report.

ACKNOWLEDGEMENTS

The work of the members of the Yellowfish Working Group (YWG) and the Federation of Flyfishing of South Africa (FOSAF) is appreciated.

In particular, we acknowledge the contributions of the individual authors who contributed their time and energy to producing this report.

AN INTRODUCTION TO AFRICAN YELLOWFISH AND TO THIS REPORT

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ABSTRACT

Africa's yellowfishes (*Labeobarbus*) and large minnows (*Barbus*) are important economic and cultural resources. Utilisation of yellowfishes in particular has continued since man's early history as indicated by numerous and varied archeological records. The taxonomy of the yellowfishes is somewhat complicated due to their variable features, widespread distributions and in some instances broad ecological ranges. Today six yellowfishes and three sawfin minnows are recognised from South Africa and these are loosely referred to as the "nine yellowfishes". The characteristics of the yellowfishes as a group are summarized and a table lists all the known yellowfish species in Africa. We describe briefly the key differences between the yellowfishes and southern sawfin groups as well as the relationships of these fishes and the evolution of the species in a southern African context. The origin of the Yellowfish Working Group is mentioned and the structure of the chapters following is outlined.

Introduction

Africa's large barbine cyprinid species are striking creatures, well known and valued for their beauty and as a food source ever since humans first fished in African freshwaters. Most are migratory, running up rivers to spawn in upper-catchment gravel beds and indigenous peoples all over the continent have exploited them particularly during such spawning 'runs'. The archaeological record, including rock art, historical middens and hieroglyphics from ancient Egypt are all evidence of this long-standing relationship (Figures 1 and 2, Bloemfontein Museum, 2007).

Yellowfishes (*Labeobarbus*) are endemic to Africa and constitute a lineage of about 80 large cyprinid fish species (Appendix 1) with some well-defined traits and characteristics. They occur in all the larger rivers in sub-Saharan Africa, including the Nile, Niger, Congo and Zambezi and in the Great Rift and other Lakes of East Africa, south to KwaZulu-Natal in the east and the Orange and Clanwilliam Olifants Rivers in the west. A few species have been transported to rivers beyond their natural range, notably the Orange-Vaal smallmouth yellowfish *Labeobarbus aeneus* (Burchell, 1822), to coastal drainages from the Great Kei to the Gourits (Bell-Cross and Minshull, 1998; De Moor and Bruton, 1996; Skelton, 2001; Swartz, this volume).

Taxonomic notes

The type species (the first described) for the genus is *Labeobarbus nedgia* described by Rüppell in 1835 from Lake Tana in Ethiopia (Figure 3). This was later synonymised with the widespread nilotic species *Barbus intermedius* (Rüppell, 1835). However, a series of papers by Nagelkerke and Sibbing (Nagelkerke and Sibbing 1997, Nagelkerke and Sibbing 1998, Nagelkerke and Sibbing 2000) resurrected the genus *Labeobarbus*, recognised *L. nedgia* as a valid and endemic species to Lake Tana and described more fully the spectacular radiation of yellowfishes in Lake Tana.

***Labeobarbus nedgia*, Rüppell 1835.**

Original reference: Neuer Nachtrag von Beschreibungen und Abbildungen neuer Fische, im Nil entdeckt. Mus. Senckenberg, Abhandl. Beschr. Naturg. v. 2 (no. 1): 1-28.
Type locality: Goraza, Lake Tana, Ethiopia.
Holotype: SMF 2619 (unique).
Family: Cyprinidae.
Distribution: Lake Tana, Ethiopia.
Habitat: freshwater.

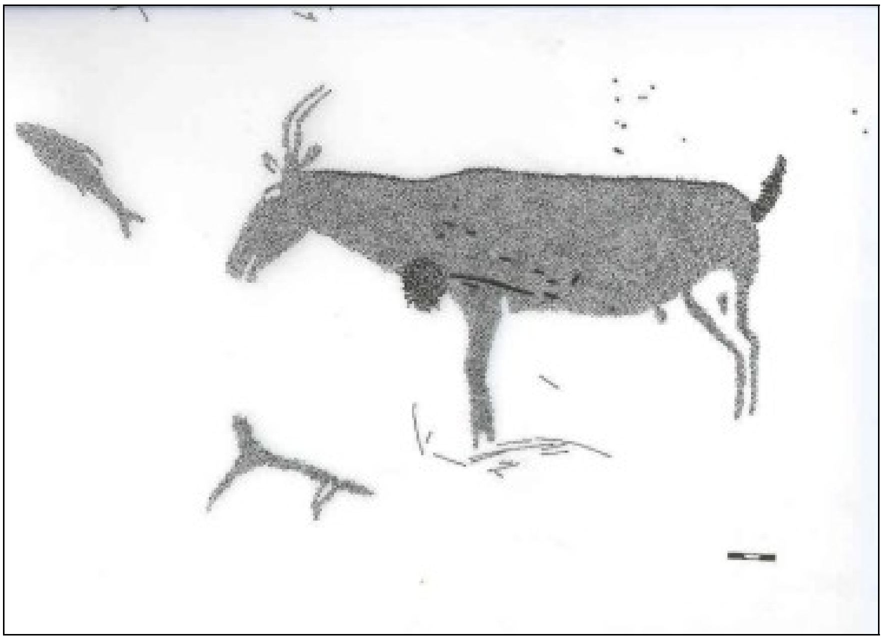

Figure 1: Bushman rock art from the Koffiefontein (De Beers) Diamond Mine showing a yellowfish (http://www.nasmus.co.za/rockart/news.HTM#yellowfish).

Figure 2: Subsistence fishermen on the upper Orange River system in Lesotho.

The taxonomy of southern African yellowfishes is rather confusing and has, over the years, changed considerably. In Gilchrist and Thompson's (1913) pioneering "Freshwater Fishes of

South Africa", some 30 yellowfishes are described. Many of the species recognised by Gilchrist and Thompson are now considered to be forms of a much smaller number of species. Today only seven species are considered valid (Appendix 2)(Skelton, 2001; Catalog of fishes, 2007). Much of the taxonomic confusion has arisen due to the variable morphological features exhibited by several species of yellowfishes particularly mouth and lip forms.

or

Figure 3: The type species for the genus *Labeobarbus, Labeobarbus nedgia* from Lake Tana, Ethiopia (photo by Leo Nagelkerke).

Yellowfish characteristics and biology

The most outstanding feature of the African yellowfish lineage is the very high number (about 150) of cell chromosomes – a fact only recently discovered (Oellerman and Skelton, 1990; Golubtsov and Krysanov, 1993; Naran et al., 2007) (Figure 4). The great majority of cyprinid fishes have around 50 chromosomes (the normal or diploid state) in each cell, there are also a number of species with around 100 chromosomes (a tetraploid or four-fold condition), and even fewer, including yellowfishes, with 150, i.e. hexaploid or six-fold condition (Golubtsov and Krysanov, 1993; Naran et al., 2006).

The physical features of yellowfishes include their relatively large size (i.e. adults grow beyond 150 mm SL), with the larger species attaining a length of up to a metre or so and as much as 20 to 30 kg mass (Banister, 1973; Banister and Clarke, 1980; Berrebi et al., 1996; Gilchrist and Thompson, 1913; Jubb, 1967; Skelton, 2001). Yellowfish are strong bodied and most are spindle-shaped; only a few are stout and relatively deep bodied. Their fins are short-based (with relatively few rays) and the dorsal fin has a simple (i.e. not serrated) usually bony and spiny anterior ray. In some species, the anterior dorsal rays are extended; in adults the anal fin also has longer anterior rays giving it a characteristic trapezoidal shape. They show little sexual dimorphism (females are plumper in breeding condition), both sexes in many species tending to turn deep brazen gold or yellow when breeding, and they develop small pimple-like nuptial tubercles on the head and sometimes all over the body (Figure 5). The scales are strong and well developed with numerous parallel striations, and there is a lateral line running from head to tail. The mouth is mostly sub-terminal with variable lips (Figures 6a, 6b): from large fleshy lips (called rubberlips, when the fish is adapted to grubbing between pebbles and cobbles) to thin, straight, keratinized lips (also known as “varicorhinus” or razor-lipped mouth) a form that is used to scrape and chisel food from rocks and other hard surfaces (Crass, 1964; Jubb, 1967; Skelton, 2001). As with all cyprinids there are no jaw teeth, but they have strong pharyngeal teeth in three rows, that are also varied in form from heavy rounded (molariform) crushing teeth, to slender and hooked teeth. Hooked and pointed pharyngeal teeth are suited to raking soft food from the mouth to the intestine (cyprinids do not have a stomach); heavy rounded teeth crush hard foods such as molluscs or hard seeds. The digestive tract is longer than the length of the fish, sometimes as much as three or four times that length. They are mostly generalized feeders, taking whatever food is available at the time, feeding in quiet or running waters, from the surface, the mid-water column or off the substrate. There are a few specialized predatory species, with larger terminal mouth forms, but these predators are a minority in the lineage.

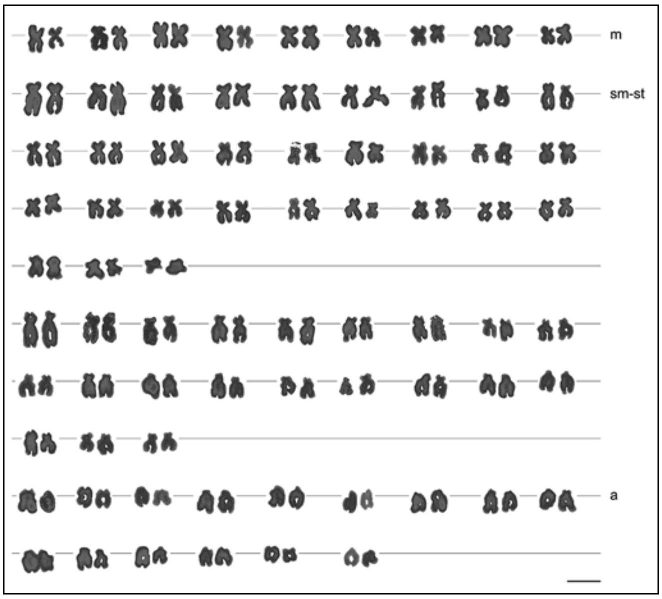

Figure 4: A karyotype from a *Labeobarbus polylepis* showing 75 pairs of chromosomes (m= metacentric, sm=sub-metacentric, st=sub-telocentric and a=acrocentric all relating to the position of the centromere) (Naran et al., 2007).

Typically yellowfish are large river or lake dwellers, and move into smaller rivers and tributaries to breed. Being strong swimmers they thrive in flowing habitats, in pools below cascades and rapids, even in thundering gorges – and in places they are known appropriately as ‘gorgefish”. Yellowfish generally breed in flowing water over rocky or gravel habitats following the onset of the rainy season (Brooks, 1950; Cambray et al., 1997; Harrison, 1977; Roux 2006; Roux, this volume). Ripe adults congregate downstream of suitable spawning sites until ready to spawn. This occurs when groups of ripe male fishes move into the site and are then joined by individual females who are attended to closely and pressured by the males, the ova being released and fertilized over the gravel or rocky bed. Breeding activity may extend over several days, and after spawning the adults return downstream. The eggs hatch and the larvae and young fish move downstream into nursery areas where they form cohort schools in the shallows.

Figure 5: A mature *Labeobarbus polylepis* from the Elands River, Mpumalanga showing nuptial tubercles on head and body (photograph by Melissa Brand).

Figure 6a: Two mouth forms in *Labeobarbus marequensis* from the Phongolo River system in Swaziland: upper – chisel mouth form, lower - normal mouth form.

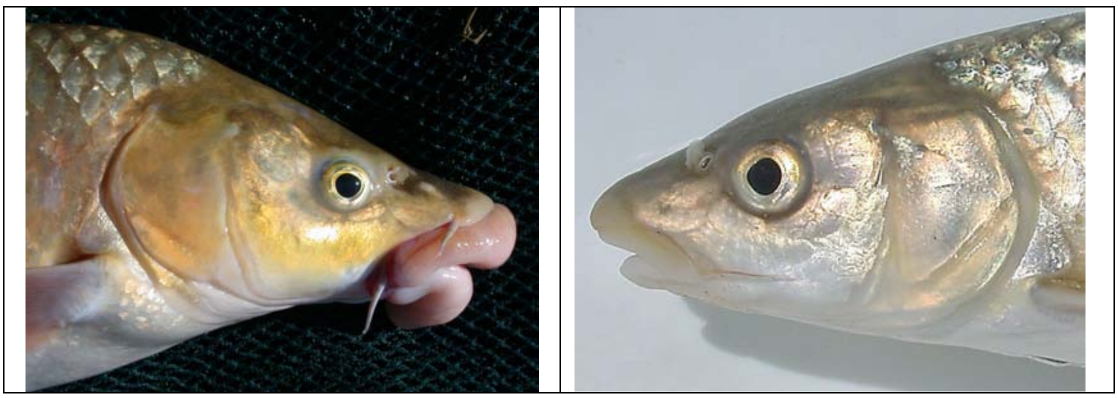

Figure 6b: Two mouth forms in *Labeobarbus aeneus* from the Orange River: left – rubberlip form, right normal mouth form.

Winter spawning of Bushveld smallscale yellowfish *Labeobarbus polylepis* Boulenger, 1907 has been recorded during a mild winter in the Ngwempisi River in Swaziland (personal observation). There is the potential for major disruptions to breeding patterns if such mild winter conditions are combined with unsynchronised water releases from dams.

The evolutionary and phylogenetic relationships of yellowfishes are not well known. The lineage is widespread in Africa and has been present in the rivers and lakes of the continent for a long period of time. The fossil record is poor and the earliest records come from the mid-Miocene of East Africa. A better indicator of the age of the lineage may be estimated in the time of last connection between now independent river systems where related species occur. For example, the presence of related yellowfish in the Clanwilliam Olifants and the upper Orange-Vaal rivers is part of the evidence indicating these systems were once connected, and geologists estimated the last linkage was during the early Miocene some 20 million years ago.

The evolutionary drivers for yellowfishes may be derived from considering the nature of the species in a system when more than one species is present. One example comes from a species flock in Lake Tana, the source of the Blue Nile in the Ethiopian Highlands (Nagelkerke and Sibbing, 1997). The 15 or so yellowfish (*Labeobarbus*) species in the lake diverge in terms of head morphology, feeding structures and body shape, and also around the breeding (spawning) times and places. Some of the species run up the affluent rivers to spawn whilst others remain in the lake and spawn along the shores. *Labeobarbus intermedius* is considered the generalised riverine species, probably little changed from the ancestral form from which this flock has evolved, and is common and widespread in the Nile and other rivers of North East Africa.

This situation is very similar to the differences in biology and ecology as described for *L. aeneus* and the Orange-Vaal largemouth yellowfish *L. kimberleyensis* (Gilchrist & Thompson, 1913). *Labeobarbus aeneus* is a more generalized form with variable characteristics in terms of mouth form and body shape. *Labeobarbus kimberleyensis* is essentially a predator with a far more consistent body and mouth form. The two species breed at slightly different stages in the annual hydrographic cycle – the smallmouth earlier in the rainy season, the largemouth later (Mulder, 1973; Tómasson, 1984).

In Southern Africa there are two groups of yellowfish, here simply described as large-scale and small-scale forms. At present the relationship between these groups is uncertain because elsewhere in Africa both large and small-scale forms also exist. The two large-scale yellowfish species are Lowveld largescale yellowfish *L. marequensis* (A. Smith, 1841) from the lowveld rivers (Phongolo to Limpopo and further north) and upper Zambezi yellowfish *L. codringtonii* (Boulenger, 1908) from the upper Zambezi, Okavango and Kunene. The small-scale group is endemic to the Orange-Vaal and surrounding rivers. Evolutionary and phylogenetic relationships between the species are still being established but the current concept is that the Orange-Vaal basin was once more extensive than it is today and was where the common ancestor existed. The surrounding rivers gradually captured parts of the Orange-Vaal drainage and with each capture some of the common ancestral population was separated and eventually speciated (evolved in isolation) from that ancestor (Skelton, 1986; 1988). Within the Orange-Vaal itself components of the population were partially or completely isolated through habitat preference and feeding biology. These components also over time diverged to the point of not interbreeding and therefore speciated into the largemouth and smallmouth species. The recent genetic analyses of these fishes indicate that they are extremely closely related and that there has either been introgression, or incomplete separation (Bloomer and Naran, 2007; Bloomer et al., 2007). At this stage we can only speculate, but it may well be that the environmental pressures in the Orange-Vaal system as a result of construction of dams and weirs, and the extensive abstraction of water, and other habitat destruction through pollution and other interventions have so affected the riverine environment that the two species can no longer function independently and are, therefore, interbreeding and hybridising.

Whitefish, Sawfin and Papermouth are not True Yellowfishes

There are several other large (reaching longer than 150 mm SL) barbine cyprinids in southern Africa, but these are not yellowfish. None of these other species have 150 chromosomes, and they also differ in several essential morphological features (Figure 7). The Berg-Breede whitefish *Barbus andrewi* Barnard, 1937 and Clanwilliam sawfin *Barbus serra* Peters, 1864 both have about 100 chromosomes and are therefore tetraploid species. Their dorsal fin spine is serrated, their scales have radial striations and their head shape is different, the snout is generally more tubular and pointed. These two species seem to be more closely related to some of the smaller redfin minnows than to yellowfish. The papermouth *Barbus rapax* Steindachner, 1894 from the Limpopo catchment, also with a serrated dorsal fin spine and radial striated scales is a "diploid" species with 50 chromosomes, related to other African barbs and is not closely related to the yellowfish or southern tetraploid sawfin lineages.

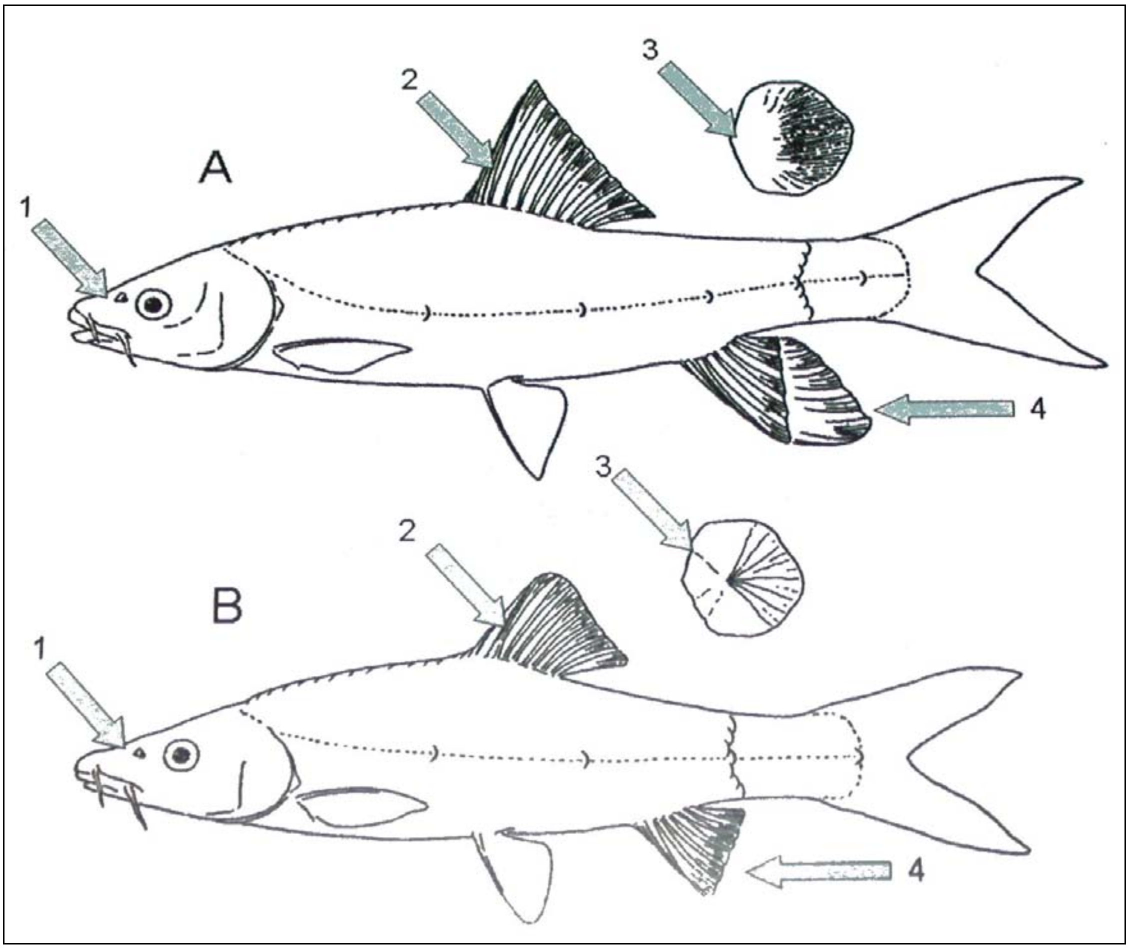

Figure 7: Some differences between (A) yellowfish (*Labeobarbus spp.*) and (B) other large barbine cyprinids (B) such as the Berg-Breede whitefish, *Barbus andrewi.* 1. Head shape including snout, longer in B. 2 Form of the dorsal fin ray simple and spinous in A, serrated in B. 3 Striations on the scales, parallel in A, radiate in B. 4 Shape of anal fin in adult fishes, extended in A, not extended in B.

The Yellowfish Working Group and Associated Products

The Yellowfish Working Group (YWG) developed from the 1994 Federation of Southern African Fly Fishers (FOSAF) conference (Mincher, 2007). The YWG's mission was to use yellowfishes as flagships for conservation of the aquatic environment in South Africa. Today the YWG and its programmes around yellowfish and riverine conservation are a highlight in southern African freshwater conservation. The education of freshwater anglers in varied aspects of aquatic biology, taxonomy and conservation has occurred through newsletters, annual conferences and interactions with scientific programmes. The report, *State of Yellowfishes in South Africa 2007* (Wolhuter and Impson, 2007), a scientific study examining Orange-Vaal yellowfish biodiversity and conservation issues (Bloomer et al., 2007) and this technical report are each major contributions to promoting our valuable indigenous fishes and improving sound management of South Africa's aquatic environments.

Chapters of the technical report

This technical report contains chapters by relevant specialists (provincial conservation scientists and research scientists) on the six South African yellowfishes and the three South African large sawfins (loosely referred to as the nine 'yellowfishes'). The chapters are structured as follows.

- Title
- Author and contact details
- Abstract
- Introduction
- Conservation status of species
- Status of habitat
- Biology and Ecology
- Threats
- Conservation measures to conserve yellowfish resource
- Value of yellowfish resource to anglers and subsistence fishers
- Concluding remarks
- References

Additionally a chapter on yellowfishes as alien species is also included. This chapter explains why some yellowfish species were translocated outside their natural distribution range and describes the negative ecological impacts of alien yellowfishes. Finally, a yellowfish bibliography has been compiled. The chapters summarise current scientific and conservation knowledge for each species/topic and hopefully will serve as an important reference source for future research and conservation programmes.

Acknowledgements

We thank the following people for allowing the use of images: Daksha Naran - *L. polylepis* karyotype, Leo Nagelkerke and Nand Sibbing - photograph of *L. nedgia*, Melissa Brand - photograph of *L. polylepis* with tubercles and Ms Shiona Moodley (Bloemfontein Museum) - image of rock art from the Koffiefontein Cave. Dean Impson is thanked for reviewing the draft of this paper.

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Appendix 1: The Yellowfishes (*Labeobarbus*) of Africa.

***Labeobarbus* Species**	**Author/date**	**Distribution**	**Size notes**
L. aeneus	(Burchell, 1822)	Orange-Vaal	240 mm SL
L. acutirostris	(Bini, 1940)	Lake Tana	410 mm FL
L. allaudi	(Pellegrin, 1909)	Eastern Ruwenzori's	198 mm SL
L. altianalis	(Boulenger, 1900)	Nile, Great Lakes	3 sub-species
L. altidorsalis	(Boulenger, 1908)	Kafue River	360 mm TL
L. aspius	(Boulenger, 1912)	Lebuzi River, Congo	420 mm TL
L. batesii	(Boulenger, 1903)	Chad, Cameroon	435 mm TL
L. brevicauda	(Keilhack 1908)		
L. brevicephalus	(Nagelkerke & Sibbing, 1997)	Lake Tana	317 mm SL
L. brevispinnis	(Holly, 1927)	CWA, Cameroon	230 mm TL
L. bynni	(Forsskål, 1775)	Nile, west Africa	820 mm TL
L. capensis	(Smith 1841)	Olifants River, Cape	987 mm TL
L. cardozi	(Boulenger, 1912)	Congo	530 mm SL
L. caudovittatus	(Boulenger, 1902)	Congo	800 mm SL
L. codringtonii	(Boulenger 1908)	Upper Zambezi	235 mm TL
L. compinei	(Sauvage, 1879)	Ogowe	730 mm TL
L. crassibarbis	(Nagelkerke & Sibbing 1997)	Lake Tana	505 mm FL
L. dainellii	(Bini, 1940)	L. Tana	490 mm FL
L. ethiopicus	(Zolezzi, 1939)	Lake Zwai, Ethiopia	258 mm SL
L. eurystomus	(Keilhack, 1908)	Lake Malawi	465 mm SL
L. ganganensis	(Vinciguerra, 1895)	Juba, Wata, Somalia	176 mm SL
L. gestetneri	(Banister & Bailey, 1979)	Congo, Upemba	249 mm SL
L. girardi	(Boulenger, 1910)	Lucalla River, Angola	300 mm SL
L. gorguari	(Rüppell, 1836)	Lake Tana	532 mm FL
L. gorgorensis	(Bini, 1940)	Lake Tana	618 mm FL
L. gruveli	(Pellegrin, 1911)	Guinea	280 mm TL
L. gulielmi	(Boulenger, 1910)	Quanza R., Angola	150 mm TL?
L. habereri	(Steindachner, 1912)	Ja River, Congo	162 mm TL
L. huloti	(Banister, 1976)	Lake Albert	282 mm SL
L. humphri	(Banister, 1976)	North Kivu, Rwanda-Burundi	214 mm SL
L. intermedius	(Rüppell, 1836)	Nile, East Africa	489 mm SL
L. iturii	(Holly, 1929)	Congo	399 mm TL
L. johnstonii	(Boulenger 1907)	Lake Malawi	320 nn SL
L. jubbi	(Poll, 1967)	Upper Kasai, Congo	225 mm TL
L. kinberleyensis	(Gilchrist & Thompson, 1913)	Orange-Vaal	825 mm FL
L. lagoensis	(Günther, 1868)	Lagos, Nigeria	255 mm FL
L. litamba	(Keilhack 1908)		
L. longifilis	(Pellegrin, 1935)	Congo, Kivu	320 mm TL
L. longissimus	(Nagelkerke & Sibbing, 1997)	Lake Tana	610 mm FL
L. lucius	(Boulenger, 1910)	Lucalla River, Angola	230 mm TL
L. macroceps	(Fowler, 1936)	Congo	320 mm TL
L. macrolepis	(Pfeffer, 1889)	Malagarazi-Ruaha, E. Africa	343 mm TL
L. macrophthalmus	(Bini, 1940)	Lake Tana	
L. malacanthus	(Pappenheim, 1911)	Equatorial Guinea	150 mm TL?
L. marequensis	(Smith, 1841)	Zambezi-Phongolo	440 mm TL
L. mariae	(Holly, 1929)	Athi-Tana, E. Africa	342 mm TL
L. mawambi	(Pappenheim, 1914)	Ituri, Congo	150 mm TL?
L. mawambiensis	(Steindachner, 1911)	Congo	150 mm TL?
L. mbami	(Holly, 1927)	Cameroon	196 mm TL?
L. megastoma	(Nagelkerke & Sibbing, 1997)	Lake Tana	824 mm FL
L. microbarbis	(David & Poll, 1937)	Lake Luhondo, Rwanda	216 mm TL
L. miriabilis	(Pappenheim & Boulenger, 1914)	Ituri, Congo	353 mm TL
L. mungoensis	(Trewavas, 1974)	W. Cameroon	179 mm SL

L. naningsi	(De Beaufort, 1932)	Congo, Angola	320 mm TL
L. natalensis	(Castelnau, 1861)	Kwazulu-Natal, SE Africa	325 mm TL
L. nedgia	Rüppell, 1836	Lake Tana	707 mm FL Type species
L. osseensis	(Nagelkerke & Sibbing, 1997)	Lake Tana	264 mm SL
L. oxyrhynchus	(Pfeffer, 1889)	Athi-Tana, East Africa	369 mm TL
L. pagestecheri	(Fischer, 1884)	Kilimanjaro, East Africa	315 mm SL
L. paucisquamatus	(Pellegrin, 1935)	Congo	248 mm SL
L. petitjeani	(Daget, 1962)	Upper Niger, West Africa	160 mm SL
L. platydorsus	(Nagelkerke & Sibbing, 1997)	Lake Tana	635 mm FL
L. platyrhinus	(Boulenger, 1900)	Lake Tanganyika	347 mm TL
L. polylepis	(Boulenger, 1907)	Limpopo-Phongolo, SE Africa	585 mm TL
L. progenys	(Boulenger, 1903)	Cameroon	180 mm TL
L. rhinophorus	(Boulenger, 1910)	Lucalla River, Angola	150 mm TL
L. rocadasi	(Boulenger, 1910)	Lucalla-Quanza, Angola	350 mm TL
L. roylii	(Boulenger, 1912)	Chiloango, Congo	490 mm TL
L. wurtzi	(Daget, 1963)	Guinea, Volta, West Africa	256 mm SL
L. sacratus	(Daget, 1963)	West Africa	290 mm TL
L. somerini	(Boulenger, 1911)	Ruwenzori's, central Africa	360 mm SL
L. stappersii	(Boulenger, 1915)	Luapula-Mweru, Congo	594 mm SL
L. surkis	(Rüppell, 1836)	Lake Tana	
L. trachypterus	(Boulenger, 1915)	Luapula-Mweru, Congo	239 mm SL
L. tropidolepis	(Boulenger, 1900)	Lake Tanganyika	750 mm SL
L. truttiformis	(Nagelkerke & Sibbing, 1997)	Lake Tana	442 mm FL
L. tsanensis	(Nagelkerke & Sibbing, 1997)	Lake Tana	394 mm FL
L. parawaldroni	(Leveque, Thys & Traore, 1987)	Côte d'Ivoire, West Africa	230 mm SL

Appendix 2: Recognised Southern African Yellowfish (*Labeobarbus*) and Large *Barbus* Species and Synonomies (Catalog of Fishes, 2007).

Yellowfishes - *Labeobarbus* Rüppell, 1835

Labeobarbus *aeneus*, (Burchell 1822).
Cyprinus aeneus, Burchell 1822. Zak R.
Barbus gilchristi, Boulenger 1911. Kraai R.
Barbus holubi, Steindachner 1894. Modder R.
Barbus mentalis, Gilchrist & Thompson 1913. Kimberly.

Labeobarbus marequensis, Smith 1841.
Barbus brucii, Boulenger 1907. Groot Olifant R.
Varicorhinus brucii, Boulenger 1907. Klein Olifant R.
Barbus cookei, Gilchrist & Thompson 1913. Crocodile R.
Barbus dwaarsensis, Gilchrist & Thompson 1913. Dwaars R.
Barbus fairbairnii, Boulenger 1908. Gorge below Victoria Falls, Zambezi R.,
Barbus gunningi, Gilchrist & Thompson 1913. Thabina R., Prenaara R.
Barbus (Dangila) inermis, Peters 1852. Lower Zambezi R., Mozambique.
Barbus (Cheilobarbus) marequensis, Smith 1841. Interior of South Africa.
Varicorhinus nasutus, Gilchrist & Thompson 1911. Gorge below Victoria Falls,
Barbus rhodesianus, Boulenger 1902. Near Mazoë, Zimbabwe.
Barbus sabiensis, Gilchrist & Thompson 1913. Sabi R., Magalies R.
Barbus sector, Boulenger 1907. Groot Olifant R., Transvaal, South Africa.
Barbus swierstrae, Gilchrist & Thompson 1913. Thabina R., Dwars R.,
Barbus victoriae, Boulenger 1908 - Gorge below Victoria Falls
Labeobarbus zambezensis, Peters 1852 - Zambezi R. at Tette, Mozambique.

Labeobarbus capensis (Smith, 1841).
Barbus (Cheilobarbus) capensis, Smith 1841. Olifants River,

Labeobarbus natalensis, Castelnau 1861.
Labeobarbus aureus, Cope 1867. Umvoti, Natal,
Barbus bowkeri, Boulenger 1902. Durban [Port Natal], South Africa. *Barbus dendrotrachelus*, Fowler 1934. Paulpietersburg Dam.
Barbus grouti, Fowler 1934. Umsinduzi R., Natal.
Barbus lobochilus, Boulenger 1911. Natal, South Africa.
Barbus marleyi, Fowler 1934. Sinclair, Broadmoor, Natal.
Barbus mfongosi, Gilchrist & Thompson 1913. M'Fongosi, Zululand, *Barbus natalensis*, Castelnau 1861. Tugela R., Natal.
Barbus robinsoni, Gilchrist & Thompson 1913. Natal.
Barbus stigmaticus, Fowler 1934. Mahai R.
Barbus tugelensis, Fowler 1934. Tugela R.
Barbus zuluensis, Gilchrist & Thompson 1913. M'Fongosi R.

Labeobarbus polylepis (Boulenger 1907).
Barbus polylepis, Boulenger 1907. Klein Olifant R.

Labeobarbus codringtonii (Boulenger 1908).
Barbus chilotes, Boulenger 1908. Maramba R., Zambezi.
Barbus codringtonii, Boulenger 1908. Zambesi R. above Victoria Falls.
Barbus hypostomatus, Pellegrin 1936. Okavango R., Angola.

Labeobarbus kimberleyensis (Gilchrist & Thompson 1913).
Barbus kimberleyensis, Gilchrist & Thompson 1913. Kimberley.
Barbus pienaarii, Fitzsimons 1949. Vaal R.

Temperate, tetraploid sawfins - *Barbus*

Barbus serra Peters 1864.
Barbus serra, Peters 1864. Cape of Good Hope, South Africa.

Barbus andrewi, Barnard 1937.
Barbus andrewi, Barnard 1937. Berg River., sw. Cape.

<u>Tropical, diploid sawfins - *Barbus*</u>

Barbus rapax, Steindachner 1894

Barbus rapax, Steindachner 1894. Limpopo R., Transvaal.

Barbus mattozi Guimarães 1884.

Barbus mattozi, Guimarães 1884. Coroca R., Angola.
Barbus sauvagei, Pellegrin 1912. South-central region of South Africa.
Barbus serrula, Gilchrist & Thompson 1913. Pienaars R., Pretoria.

STATUS OF THE CLANWILLIAM YELLOWFISH *LABEOBARBUS CAPENSIS* (A. SMITH, 1841)

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ABSTRACT

The Clanwilliam yellowfish *Labeobarbus capensis* (A. Smith, 1841) has undergone major declines in its distribution range and abundance since the 1930s. Invasive fishes (primarily bass, *Micropterus* spp.), habitat degradation due to over-abstraction, in-stream dams, river canalisation and the inappropriate use of fertilisers and pesticides are the principal causes of this decline. Clanwilliam yellowfish are currently listed as Vulnerable by the IUCN and viable recruiting populations are restricted to main stem and tributary reaches where invasions have not yet taken place and disturbances are minimal. Several recent conservation and water resource management measures hold substantial promise for the future of the species, including the establishment of the Greater Cederberg Biodiversity Corridor, the development of a freshwater conservation plan for the Olifants-Doring Water Management Area, the formation of a Catchment Management Agency and planned eradication of alien fishes from designated rivers. Current obstacles include insufficient capacities for river and fish management at the Department of Water Affairs and Forestry and CapeNature, low levels of awareness amongst landowners and anglers, and unsustainable levels of abstraction throughout the catchment. The continuing spread of invasive alien fishes, including new illegal introductions such as carp *Cyprinus carpio* Linnaeus, 1758, and the difficulty in eradicating alien fishes are serious obstacles to improving the conservation status of *L. capensis*.

Introduction

The Clanwilliam yellowfish *Labeobarbus capensis* (A. Smith, 1841) is endemic to the Olifants-Doring River system (ODRS), a national "hotspot" for freshwater fish diversity (Skelton et al., 1995) and arguably our most important river system for freshwater fish conservation (Impson et al., 2002). Of its 10 indigenous fish species, eight are endemic and all endemic species are threatened. Two other large endemic cyprinids occur in this system, the Clanwilliam sawfin *Barbus serra* Peters, 1864 (Paxton, this volume) and the Clanwilliam sandfish *Labeo seeberi* Gilchrist & Thompson 1911. *Labeobarbus capensis* is the largest indigenous freshwater fish in the Cape Floristic Region (CFR) attaining almost 11 kg in weight and is probably South Africa's second largest yellowfish species, after the Orange-Vaal largemouth yellowfish, *Labeobarbus kimberleyensis* (Gilchrist & Thompson, 1913). Once widespread and abundant in the ODRS (Harrison, 1963), *L. capensis* is now classified as Vulnerable with healthy sub-populations currently restricted to the upper reaches of the Olifants River and several perennial tributaries (IUCN, 2007).

Labeobarbus capensis is the flagship freshwater fish of the 19 species currently recognized in the CFR and has received the most conservation focus in terms of awareness, research, monitoring, culture and stocking programmes. This report describes our current knowledge of this relatively well-known yellowfish species and highlights research and management recommendations that are needed to improve its conservation status in future.

Taxonomic History

Barbus (Cheilobarbus) capensis, A. Smith, 1841. Olifants River, w. coast of South Africa. Holotype (unique): BMNH 1845.7.3.99 (dry).

Status and Distribution

Labeobarbus capensis is restricted to the ODRS (Figure 1). The system has varied geology and rainfall, contributing to acidic perennial rivers in the wetter west and alkaline seasonal rivers in the drier east. Anecdotal reports indicated very large numbers of *L. capensis* were naturally present in suitable habitat across the system (Figure 2) before the introduction of *Micropterus dolomieu* (Lacepède, 1802) to the middle Olifants in the 1940s (Barnard, 1938; Harrison, 1938; Wells, 1949).

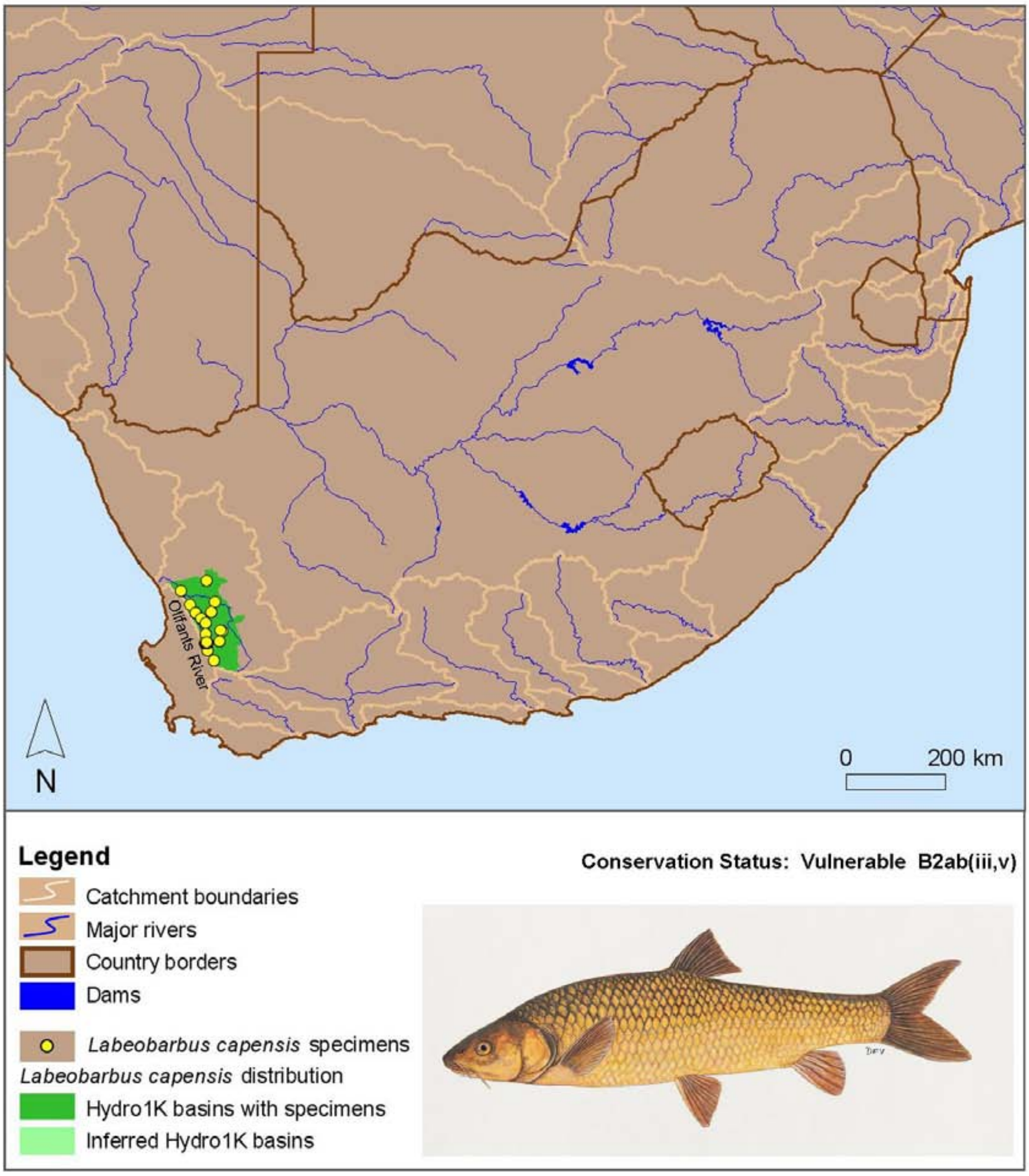

Figure 1: Distribution of *Labeobarbus capensis*, based on voucher records (prepared by Willem Coetzer, SAIAB).

Van Rensburg (1966) noted that adult *L. capensis* were still found in reasonable numbers in the Olifants main stem. However, Gaigher's (1973) survey, less than 10 years later at eight stations from Keerom to Vredendal on the main stem, showed that the species had almost disappeared below Keerom, apart from a small sub-population in Bulshoek Dam. Additional surveys by provincial conservation staff in 1979, 1980, 1981 and 1982 (Scott, 1982) and by Bills (1999) documented further declines in the conservation status and abundance of *L. capensis* and other endemic fishes. Paxton et al. (2002) undertook a detailed survey of the Olifants and Doring main stems in 2001 and found that although *L. capensis* was the most widespread of the large endemic cyprinids, overall abundances were low and it was almost absent in the Olifants River below Keerom. Currently, healthy numbers of recruiting fishes of *L. capensis* are fount only in areas free of alien fishes (Scott, 1982; Bills, 1999; Paxton et al., 2002), probably less than 10% of its original distribution range (Figure 3). *Labeobarbus capensis* is classified as Vulnerable under B2a(ii)b(iii,v) (IUCN, 2007), as the current population has a greatly reduced distribution range and is experiencing a continued slow decline because of declining habitat quality and range expansions of invasive alien fishes (IUCN, 2007). Threats are also perceived to be widespread and effectively affecting all populations simultaneously.

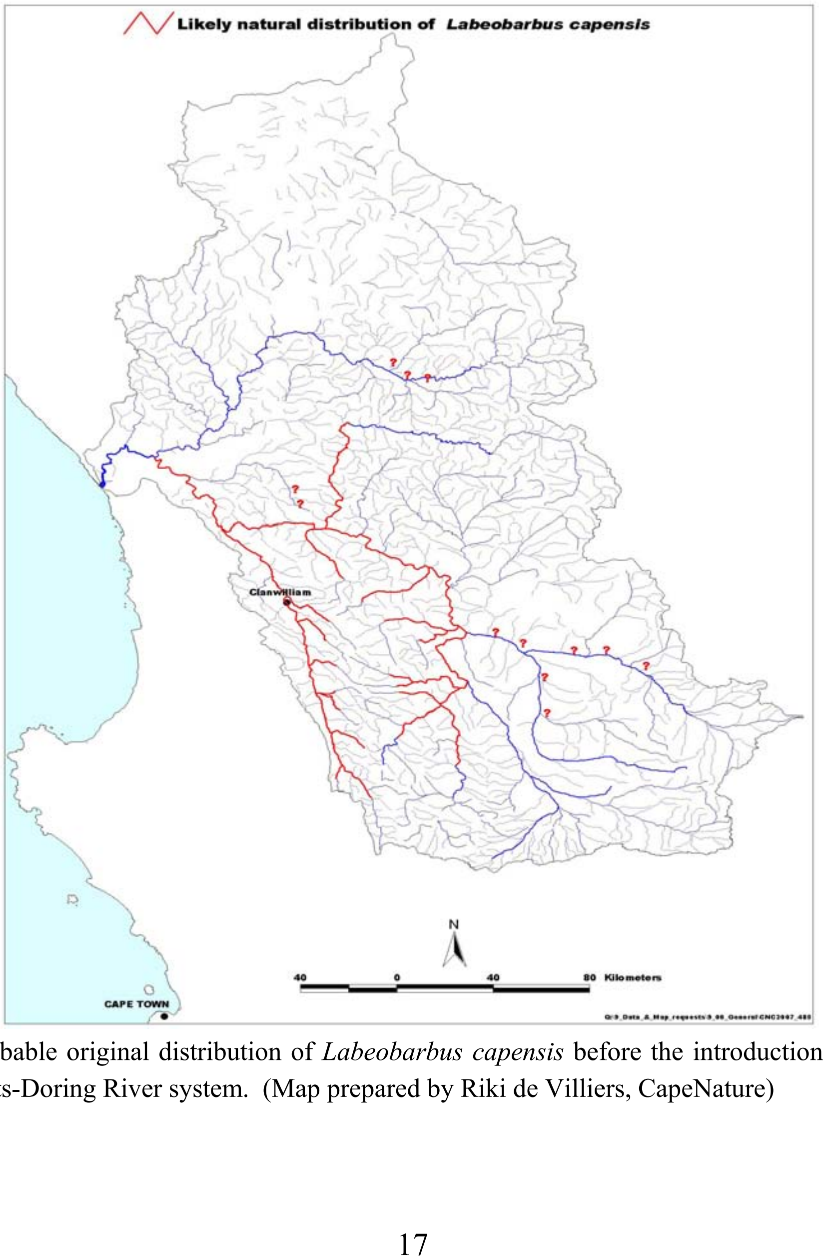

Figure 2: Probable original distribution of *Labeobarbus capensis* before the introduction of alien fishes into the Olifants-Doring River system. (Map prepared by Riki de Villiers, CapeNature)

The Department of Water Affairs and Forestry (DWAF) recognises six important management sub-areas within the Olifants-Doring River system. Amongst these, the Upper and Lower Olifants, the Doring and Kouebokkeveld are most important in terms of Clanwilliam yellowfish distribution. The current status and distribution of Clanwilliam yellowfish will be considered below in the context of each of these management sub-areas.

Upper Olifants

The Upper Olifants Management Sub-area extends from the headwaters of the Olifants River in the Agter Witzenberg to the Clanwilliam Dam. This sub-area is perhaps the most important for *L. capensis* as it has the highest density of fishes and comprises rivers with excellent habitat. It includes the spectacular and near pristine Olifants River gorge which starts at Visgat in the Agter Witzenberg plateau and extends to Keerom, nearly 30 km downstream.

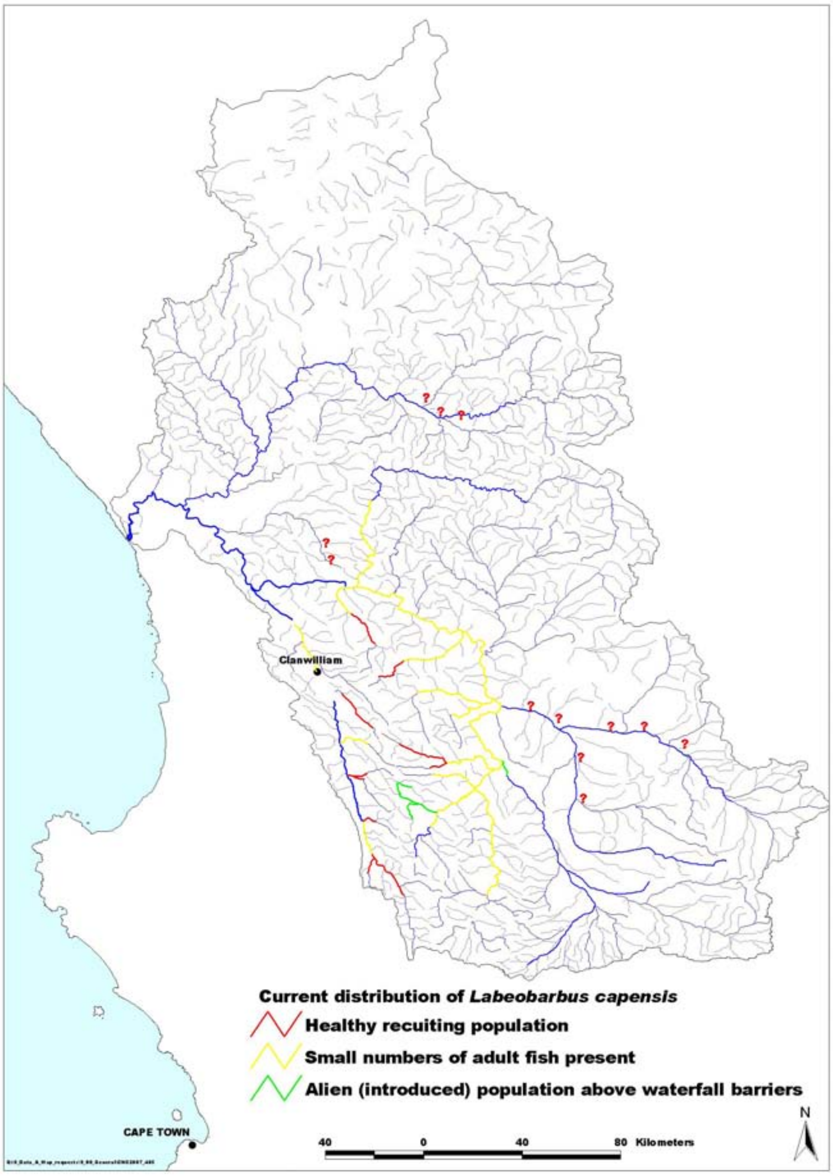

Figure 3: Present distribution of *Labeobarbus capensis*. Healthy sub-populations are shown in red. Areas with small numbers of adult fishes (yellow) are infested with alien fishes. (Map prepared by Riki de Villiers, CapeNature)

The gorge, with its excellent habitat and water quality, is a key area for freshwater fish conservation in the ODRS (Hamman et al., 1991), as it has large and healthy populations of *L. capensis* and *B. serra*. Densities are highest at the top end of the gorge and decline steadily from the middle to the bottom as densities of smallmouth bass increase concomitantly. Recent surveys by Paxton et al. (2002) indicate that *L. capensis* has almost disappeared from the main stem between Keerom and Clanwilliam Dam, a distance of over 80 km. This sub-area, however, includes several perennial tributaries that have good recruiting sub-populations of *L. capensis* – the Boskloof, Noordhoeks, Ratels, Rondegat and Thee Rivers. Although the gorge appears near pristine, it is sited below the Agter Witzenberg plateau which is heavily farmed and has several off-stream dams, that are stocked with salmonids and possibly bass. Further reductions of flow and water quality will impact on the gorge, and may assist the spread of alien fishes such as *M. dolomieu* up the gorge.

Lower Olifants

The Lower Olifants Management Sub-area extends from the Clanwilliam Dam to the mouth of the Olifants River. This area was originally famous for recreational angling for *L. capensis*, with the biggest specimens found in the larger and more nutrient-rich pools located here. The Clanwilliam Hotel actively promoted angling for this species with captions as follows: "Countless millions up to 20 lbs". Anecdotal reports indicate that the Clanwilliam and Bulshoek Dams constructed in 1926 and 1933 respectively had a major negative effect on this species, by stopping upstream migrations, regulating river flow and providing a refuge for *Micropterus* spp. and bluegill sunfish *Lepomis macrochirus* Rafinesque, 1819.

Apart from an area immediately downstream of Clanwilliam Dam where a sizeable population of *L. capensis* exists (King et al., 1998), recent surveys by Paxton et al. (2002) show that very few Clanwilliam yellowfish are found in the lower Olifants. Alien fishes such as *M. dolomieu*, *L. macrochirus* and banded tilapia *Tilapia sparrmanii* A. Smith, 1840 dominate this area, including new illegal arrivals such as carp *Cyprinus carpio* Linnaeus, 1758 and Mozambique tilapia *Oreochromis mossambicus* (Peters 1852).

Kouebokkeveld

The Kouebokkeveld Management Sub-area, situated in the Doring River catchment, includes the headwaters of the Riet and Groot Rivers in the south and extends to the confluence of the Groot River with the dry Doring in the north.

This area, especially the greater Cederberg component, provides the bulk of the Doring River's winter and spring flows. Important perennial tributaries in this sub-area are the Groot, Matjies, Riet and Twee Rivers. Historical reports on distribution limits and densities of *L. capensis* are lacking, but the abundance of good habitat in these rivers indicates that yellowfish were widespread and plentiful before bass became dominant. The Kouebokkeveld plateau, where most of these rivers arise, probably lacked yellowfish due to natural in-stream barriers, and they were never found above the lower of the three large waterfalls on the Twee River.

Healthy numbers of *L. capensis* are presently found in the Matjies River upstream of its confluence with the Krom River (Paxton, in preparation). There are now also many in the Twee River, above the bottom waterfall, thanks to an ill-advised introduction of *L. capensis* into the middle reaches of this river by the Cape Department of Nature Conservation in the mid-1980s (Hamman et al., 1988). This river has its own endemic fish, the Twee River redfin *Barbus erubescens* Skelton, 1974, which is now critically endangered due to habitat degradation and the effects of introduced fishes, including predatory and competitive impacts from *L. capensis* and the Cape kurper *Sandelia capensis* (Cuvier, 1831) (Impson et al., 2007).

Doring River

The Doring River sub-area extends from the confluence of the dry Doring River and the Groot River in the south to the confluence of the Doring and Olifants Rivers near Klawer in the north and includes the tributaries entering from the Cederberg and Karoo.

This sub-area includes that portion of the main stem of the Doring River that is characterised by permanent water (usually isolated pools in the dry season), the Biedouw, Brandewyn and Tra Tra tributaries that drain the wetter sandy soils of the Cederberg and also the Oorlogskloof-Koebee and Tankwa Rivers draining the drier more clayey soils of the Karoo. We know from recent surveys that *L. capensis* must have been present in large numbers before bass invaded the Doring River, likely from the original stockings in the Olifants River.

The Doring River still has *L. capensis* throughout its course, but only low numbers of adult fish. There are very few fish under 300 mm TL in size, suggesting the successful recruitment has not taken place for several years (Impson, 1999; Menck, 2001; Paxton et al., 2002). Tributaries with good numbers of *L. capensis* are the upper Biedouw and Brandewyn rivers and the Koebee River. The status of *L. capensis* in the Tankwa River needs to be assessed urgently. This river has sizeable pools in its middle reaches before it enters Oudebaskraal Dam, a 2-million m^3 privately owned dam, which has also never been properly surveyed.

Biology and Ecology

The taxonomy of the species is described in Skelton (2001). Adult *L. capensis* are light brown with golden-yellow fins, males becoming golden yellow during the breeding season (Figure 4).

Figure 4: Adult *Labeobarbus capensis* in an aquarium.

Juveniles are silvery with irregular dark blotches or vertical bars on the sides (Jubb, 1965) (Figure 5). They frequently co-exist with *B. serra,* the latter being readily distinguished by its serrated dorsal fin spine, radial striations, olive-green colour and smaller adult size.

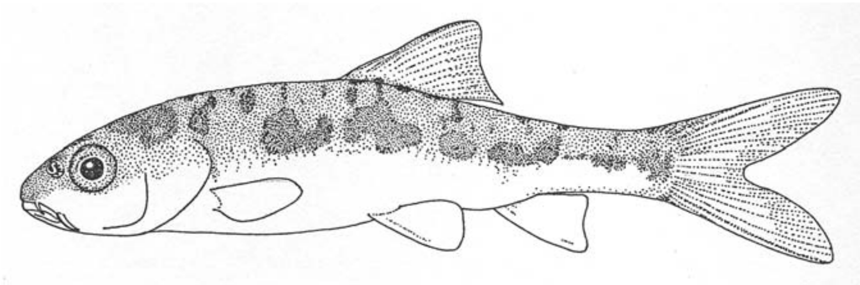

Figure 5: Colour pattern of juvenile *Labeobarbus capensis* from the Olifant River gorge (source, SAIAB).

The Clanwilliam yellowfish is an adaptable species, inhabiting rivers of variable size and water quality. Paxton (in preparation) studied the species in the Driehoeks River of the Cederberg where water temperatures varied seasonally between 5.5ºC and 26ºC; water conductivity ranged from 24 uS/cm to 28 uS/cm and pH was between 5.6 and 6.2. His study included the Doring River, which receives substantial flow from alkaline seasonal Karoo rivers; here pH ranged from 7.4 to 8.7 and conductivity from 90.3 uS/cm to 1425 uS/cm.

Adult *L. capensis* prefer relatively fast flowing water of variable depth (Gore et al., 1991). Sub-adults are frequently found in riffles, with juveniles smaller than 4 cm generally inhabiting backwaters and slow-flowing shallow riffles. In seasonal rivers like the Doring, deep permanent pools with good cover provided by rocky reefs or palmiet *Prionium serratum* are an important refuge during the hot dry summers.

Adults are omnivorous, feeding primarily on aquatic macro-invertebrates and algae (Van Rensburg, 1966). Paxton (in press) found them to be drift feeders in the warmer months in the Driehoeks River. Juveniles feed on small aquatic invertebrates. Age and growth studies of scales by Van Rensburg (1966) indicate that *L. capensis* is relatively slow growing, with one-, five-, and 10-year old specimens attaining 8.7 cm, 34 cm and 49.4 cm respectively. Anglers have caught specimens in excess of 90 cm and these could easily be more than 20 years old.

The reproductive style of *L. capensis* is that of an open sub-stratum spawner (A.1.) and the guild lithophils (A.1.3.), which are rock and gravel spawners with benthic free embryos (Cambray, 1999). *Labeobarbus capensis* breeds in late spring to summer when water temperatures reach 19ºC and are stable or rising. Small schools of adults migrate upstream to spawn in riffles and glides that are 0.3 to 0.6 m deep, with flow rates of 0.6 to 1.3 m/s (King et al., 1998). Gonad development increases sharply in September, with ripe-running fish recorded from November to February (Van Rensburg, 1966).

Cambray (1999) recorded that eggs are non-adhesive, falling between gravel and cobble on the spawning bed; free embyos are photophobic remaining in the same habitat as the eggs for 10 to 12 days at 22ºC. *Labeobarbus capensis* is a repeat spawner over several days, as well as a multiple spawner throughout the four-month reproductive season (Cambray et al., 1997). Size and age at maturity are not known and are probably dependent on the size and nutrient content of the river in which they are resident. The species has been observed spawning in farm dams in shallow rocky bays.

Threats

The major threat to the species has been the predatory impact of invasive alien fish species, especially *M. dolomieu* (Van Rensburg, 1966; Gaigher et al., 1980; Skelton, 1987) and to a lesser extent *L. macrochirus*, largemouth bass *Micropterus salmoides* (Lacepède, 1802) and spotted bass *Micropterus punctalatus* (Rafinesque, 1819). *Labeobarbus capensis* also competes with *Tilapia sparrmanii*, *L. macrochirus* and *M. dolomieu* for food resources. The first alien fish introduced into the ODRS were brown trout *Salmo trutta* Linnaeus, 1758 and rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792) between 1900 and 1910 (Harrison, 1938), followed by *M. dolomieu*, *M. punctalatus* and *M. salmoides* in the 1930s and 1940s (Wells, 1949). *Lepomis macrochirus* and *T. sparrmanii* were later introduced as fodder fish for bass when it became apparent that bass had eliminated the smaller cyprinids in invaded river areas. These were legal introductions, undertaken or supported by the Inland Fisheries Department of the Cape Provincial Administration. Alien fishes now dominate the mainstreams of the Olifants and Doring Rivers as well as the lower reaches of many tributaries. The species above are not the only fish invaders – illegal introductions in the last decade include *C. carpio* and sharptooth catfish *Clarias gariepinus* (Burchell, 1822). Information from anglers indicates that these species are now flourishing in the middle and lower reaches of the Olifants River.

Habitat degradation is another substantial threat (Skelton, 1987) as the Olifants River valley and the Kouebokkeveld are intensively farmed for citrus, deciduous fruits and grapes. These are heavy users of water and pesticides during the dry warmer months (Bills, 1999) when rivers are naturally low. Due to legislative deficiencies in the previous water act, riparian landowners could abstract the entire summer base flow to feed off-stream dams, causing small perennial rivers to stop flowing with major negative ecological impacts. Two large in-stream dams on the Olifants River, Bulshoek Dam built in 1919 and Clanwilliam Dam built in 1932, are barriers to upstream migrations of large cyprinids in the system, as well as serving as refuges for alien fishes during severe winter flooding (Paxton et al., 2002; Paxton in preparation). The effect of the dams on upstream spawning migrations has been catastrophic. Historical accounts describe thousands of yellowfish massed below Bulshoek Dam in the spring of 1938 (Harrison, 1977). These days *L. capensis* is a rarity in the Olifants River below Bulshoek Dam (Paxton et al., 2002). The dams have also fragmented yellowfish stocks (Cambray, 1999) with unpredictable long-term genetic consequences. The lower reaches of many tributaries have been bulldozed and canalised for flood protection purposes. The excess use of fertilisers and pesticides (many copper-based) by intensive agricultural practices also poses a substantial threat to indigenous fishes (Bills, 1999).

Trends in the decline of this species between 1930 and 2005, and the reasons why, are described in detail by Paxton et al. (2002).

Conservation Measures to Conserve the Yellowfish Resource

Legislation

Labeobarbus capensis has been listed as endangered by the provincial Nature Conservation Ordinance making catch and release compulsory. It is also listed as a “Vulnerable” species in the National Environmental Management: Biodiversity Act (2006), providing it with additional legal protection under the regulations protecting indigenous species.

Hatcheries and stockings

The Clanwilliam Yellowfish Station was established in 1976 by the former Cape Department of Nature and Environmental Conservation (CDNEC) to culture *L. capensis*, then regarded as the most threatened indigenous fish species, for re-stocking the catchment (CDNEC, 1978/79). The project was named “Operation Yellowfish” and received substantial resources from the CDNEC (Anon, 1979). The hatchery was however not a long-term success as it was situated below Clanwilliam Dam from which water for the town and hatchery is drawn from the bottom of the dam. In summer the poor quality of this water led to continual outbreaks of disease in young yellowfish at the hatchery which ceased operating in 1996. The station was, however, instrumental in distributing thousands of *L. capensis* to farm dams and to tributaries (CDNEC, 1981/82), some of which were outside the natural range of the species. For example, in the mid 1980s, *L. capensis* was introduced above waterfall barriers on the Twee River, home to the critically endangered Twee River redfin, in a misguided attempt to conserve the species. Another stocking above a natural barrier on the Boontjies River at Bushmanskloof Nature Reserve in the late 1990s was more carefully assessed (Impson and Tharme, 1998). Such introductions remain a contentious conservation issue (Tharme and Anderson, 1999). Stocking of *L. capensis* between 1979 and 1995 has been fairly extensive across the ODRS, and it is likely that natural genetic diversity has been compromised by such actions.

These days, CapeNature personnel only stock dams from nearby rivers in the same catchment. This is a major philosophical shift in the approach to stocking indigenous fishes in the province and has been applauded by ichthyologists. For genetic reasons rivers are no longer stocked and also because it is a pointless exercise introducing small yellowfish into waters infested with bass.

Protected areas and conservation programmes

The ODRS is characterised by several large protected areas – in 2004, Cape Action for People and the Environment (CAPE) established a flagship conservation area, the Greater Cederberg Biodiversity Corridor. Likewise, the Cederberg Wilderness, Matjies and Oorlogskloof Nature Reserves include rivers that contain populations of *L. capensis*. However, these “protected” rivers provide no protection for *L. capensis* if alien fishes have invaded them. Alien fish need to be eradicated from priority rivers within reserves through the construction of in-stream barriers and the application of piscicides above these.

Important rivers for freshwater fish conservation in the ODRS have been identified through a comprehensive analysis (see Impson et al., 1999; Nel et al., 2006).

Apart from the “Clanwilliam sanctuary” immediately below Clanwilliam Dam, that today enjoys negligible status and receives little management, no conservancies have been established specifically for *L. capensis*.

Some conservancies such as the Ratels River Conservancy and the Matjies River Conservancy have been established, however, to better protect rivers and their catchments. The stewardship component of the Greater Cederberg Biodiversity Corridor will include freshwaters from 2007. The intention will be to focus on privately owned land that straddles certain rivers that are to be given priority in the conservation effort.

Eradication of alien fishes from priority rivers

The Table Mountain Fund approved a project, completed in 2006, to quantify the predatory impact of alien fishes and identify priority rivers from which these fishes should be eradicated (Impson, 2007). This project enabled CAPE to develop a dedicated pilot project to eradicate invasive alien fishes from priority rivers in the CFR, including two rivers in the GCBC that contain *L. capensis* – the Krom and Rondegat Rivers. An Environmental Impact Assessment will be undertaken as part of this project in 2007 and, if positive, will permit alien fishes to be eradicated in designated rivers in 2008 (Impson, 2007). Clearing alien fishes from the Krom and Rondegat rivers will provide about 15 and 10 km respectively of alien-free habitat for *L. capensis* and other threatened fishes, which should improve significantly the conservation status of several species.

Improved management of water resources

A Catchment Management Agency for the Olifants-Doring Water Management Area was established in 2005, but is not yet fully operational. Once properly staffed and funded (likely in 2008), the CMA will improve river management in the ODRS. The CMA will be guided in its actions by a series of recently released reports, namely the *Olifants-Doring State of River Report* (DWAF, 2005) and a *Conservation Assessment of Freshwater Biodiversity in the Olifants/Doorn Water Management Area* (Nel et al., 2006). The determination and implementation of the Environmental Reserve is another key requirement. A Comprehensive Reserve has been determined for the ODRS, which has confirmed that no large in-stream dams can be built on the Doring River. An environmental impact assessment is being undertaken to evaluate the effect of raising Clanwilliam Dam by between 5 and 15 m. One of the reasons for raising the wall is to allow environmental flow releases which should benefit the Clanwilliam yellowfish sanctuary below the wall. Cambray (1999) noted that properly managed water releases from Clanwilliam Dam could be used to trigger spawning of *L. capensis* and lead to higher recruitment levels in this area.

Monitoring and Research Needs

The ODRS is provincially acknowledged to be the most important river system for fish conservation. Hence, it has received the bulk of CapeNature's monitoring effort, with detailed surveys done by Van Rensburg (1966), Gaigher (1973) and Impson and Thorne (1994/95). The South African Institute of Aquatic Biodiversity (Bills, 1999) and the University of Cape Town (Paxton et al., 2002) have also undertaken comprehensive fish surveys of the system. This has assisted in identifying important rivers for freshwater fish conservation (Impson et al., 1999; Nel et al., 2006).

The last detailed survey was in 1999; clearly another system-wide survey is urgently needed, especially with angler information indicating that *C. carpio* and *C. gariepinus*, both highly invasive and destructive species, have now been introduced into these fragile waters.
Labeobarbus capensis has been relatively well studied compared to other yellowfishes, with studies on distribution (Paxton et al., 2002), reproduction and diet (Van Rensburg, 1966; Cambray et al., 1997; King et al., 1998) and culture requirements (Bok and Immelmann, 1988). Woodford et al. (2005) quantified the predatory effects of *M. dolomieu* in a Cederberg stream containing *L. capensis*.

The most critical research gaps are:

- The impacts invasive alien fishes have on indigenous fishes in the ODRS, including *L. capensis*.
- Whether *L. capensis* and *B. serra* spawn in different areas and at different temperatures? Important spawning areas should be mapped and receive greater protection.
- Angler awareness of *L. capensis*. Is this increasing, is it positive and are their ethical differences between the different angling disciplines? Anglers can also help a lot with distribution records by taking appropriate photographs and recording locality data.
- Whether farm dams stocked with *L. capensis* represent a viable part of a conservation strategy to conserve the species?
- Whether smaller rivers such as the Noordhoeks and Ratels have resident but perhaps stunted sub-populations of *L. capensis*, or do adults migrate from larger rivers into smaller tributaries to spawn? Telemetry and other tagging work are needed to ascertain this.

Value of the Yellowfish Resource to Recreational Anglers and Subsistence Fishers

Historically, Clanwilliam yellowfish provided excellent sport for anglers, and being good eating were a popular and important source of protein for farmers and their employees. Several articles in *Piscator*, journal of the Cape Piscatorial Society, bear proof of the value of the recreational angling in the mid 1900s. Consider an advertisement for the Hotel Clanwilliam in 1948 that read: “Countless millions up to 20 lb in weight... The Olifants teems with yellowfish...” In 1947, the angler Brooks (1950) describes several visits to the Olifants in autumn which “…provided the sport of my life – never less than seven yellowfish each day from 3 lb. to 5 lb., and on one occasion 19”.

At present, *L. capensis* cannot support a high value and popular recreational fishery because it is either too scarce or else is fairly abundant only in relatively inaccessible areas. Since the late 1970s, CapeNature has stocked Clanwilliam yellowfish into farm dams and a few rivers with the intention of creating sanctuaries and improving angling for the species. The establishment of the Western Cape Yellowfish Working Group in 2006 is an encouraging sign of angler commitment to these efforts.

Education and awareness of key stakeholder groups such as anglers and the conservation-orientated public is a critical need (Impson et al., 2002) and has received considerable attention via a range of popular articles by Immelman (1989), Impson (1999, 2001, 2004), Marr et al.

(2005) and others. Display aquaria at the Two Oceans Aquarium, Cape Town; the Rooibos Tea Board, Clanwilliam; and at the regional offices of the GCBC in Porterville have been stocked with *L. capensis*. Fish stockings can also be a powerful awareness tool – land-owners with potentially valuable yellowfish waters are interested in deriving an income from recreational angling for *L. capensis* and *B. serra*, whereas more conservation-focused land-owners want to create sanctuaries for threatened fish species. One such example is the Ratels River Conservancy, situated near the Olifants River gorge in the Groot Winterhoek mountains – here members want to make the catchment a priority yellowfish zone, through improved conservation of the Ratels River and by removing alien fishes from dams in the catchment and stocking these with Clanwilliam yellowfish and sawfin instead. The Ratels River is the closest destination in the ODRS for Cape Town anglers.

Stakeholders interested in yellowfish conservation in the Olifants-Doring catchment will have to work very hard to increase numbers of *L. capensis*, especially in local rivers. An ambitious project aimed at removing alien fish from priority streams in the system has been started and is supported by the Western Cape Bass Anglers Association and the Cape Piscatorial Society (Impson, 2007). These organisations realise that the removal of alien fishes from these small streams will not affect bass and trout fishing in the Western Cape as these streams are hardly ever fished.

Labeobarbus capensis was, and in certain areas remains, an important catch to subsistence fishermen. It is a large and highly palatable fish. Farm labourers frequently fish for the species, and have been discouraged from killing them by conservation staff and riparian landowners. The killing of *L. capensis* in rivers and public dams is illegal.

Conclusion

For a flagship species, the current status of *L. capensis* is of extreme concern. Monitoring and researching the decline into extinction of this once abundant and widespread species is not the only management effort needed. We know what specific interventions are required to better conserve *L. capensis*. To improve its conservation status, several key challenges need to be met, namely:

- Creating river sanctuaries of the most important river areas, through expansion of formally protected areas, establishment of stewardship agreements and the creation of additional conservancies. These rivers must be kept free of alien fishes and have a near natural catchment, riparian zone and flow regime.
- Eradication of alien fishes from priority rivers. These rivers have excellent habitat and several are within protected areas. Their only drawback is the presence of alien fishes – by removing these we can significantly increase the overall population size of indigenous fishes, including *L. capensis*. Eradication of alien fishes is an essential tool to improving the conservation status of many CFR species.
- More aquatic ecologists are needed at CapeNature and DWAF, especially within the ODRS.
- Improved awareness amongst the general public in the ODRS regarding indigenous fish and river issues.

These challenges are currently receiving attention. Conservation actions need to be carefully assessed before being implemented. Past actions, mainly stocking, may have resulted in a genetically homogenous population of *L. capensis,* and an invasive and ecologically harmful stock of the species in the upper Twee River.

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STATUS OF THE KWAZULU-NATAL YELLOWFISH *LABEOBARBUS NATALENSIS* (CASTELNAU, 1861)

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ABSTRACT

The KwaZulu-Natal yellowfish *Labeobarbus natalensis* (Castelnau, 1861) is a popular angling fish amongst sport and subsistence anglers alike. It is the most ubiquitous freshwater fish in the province and occurs in a wide range of habitats extending from the coastal lowlands to the foothills of the Drakensberg. Although fairly tolerant of man-induced habitat change, the greatest threat facing this species is increased water abstraction and chronic pollution associated with urban areas such as Durban and Pietermaritzburg. Further threats are the potential for interspecific hybridisation with translocated Orange-Vaal smallmouth yellowfish *Labeobarbus aeneus* (Burchell, 1822) that are now resident in the upper Thukela catchment. Intraspecific hybridization may also occur when genetically distinct *L. natalensis* from different river systems are mixed through inter-basin water transfers or through direct stocking for angling purposes. Recent research has indicated that considerable genetic variation exists between several geographically isolated populations. Illegal netting using gill nets that target spawning fish is a growing concern. Although not as widely popularised as the Orange-Vaal yellowfish species, interest is growing progressively in KwaZulu-Natal in capturing this fish on both fly and spinning tackle. Several angling outlets now stock dedicated tackle and flies for this species. Anglers, landowners and municipal authorities need to be educated about conservation issues affecting this widespread and valuable species. Current obstacles to improving management for this species and its habitat include insufficient capacity for integrated catchment management, low levels of awareness amongst landowners and anglers, and the lack of environmental flows released from larger in-stream dams.

Introduction

The KwaZulu-Natal yellowfish *Labeobarbus natalensis* (Castelnau, 1861), locally known as the scaly, is a common endemic species in KwaZulu-Natal (KZN), occurring from the coastal lowlands to an altitude of 1500 m or more. It occurs widely across the province from the Mtamvuna River, the border between Eastern Cape and KZN, to the Mkuze River in the north-east. *Labeobarbus natalensis* occurs in a wide range of habitats from pools and rapids of clear streams to deep turbid waters of larger rivers and impoundments. Its omnivorous diet and tolerance to varying flow and water quality has enabled it to thrive in flow-regulated rivers as well as moderately polluted waters. It also grows to a large size and is widespread in the province, making it a popular recreational and subsistence angling species.

This report describes our current knowledge of this valuable and well-known yellowfish species and provides management actions and recommendations for the future conservation of the species.

Taxonomic History

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Barbus stigmaticus, Fowler 1934. Mahai R., South Africa, elev. 5000 ft. Holotype: ANSP 54932. Paratypes: ANSP 54928-30 (3), USNM 103114 [ex ANSP 54931] (1).
Barbus tugelensis, Fowler 1934. Tugela R., Natal, South Africa. Holotype: ANSP 54916.
Barbus zuluensis, Gilchrist & Thompson 1913. M'Fongosi R., Zululand, South Africa. Holotype (unique): SAM 10745 [now at AMG].

Distribution and Status

Labeobarbus natalensis is probably KZN's most widespread and common indigenous fish species (Figure 1) and current stocks in all large systems could be considered to be reasonably exploitable without endangering the species. Most rivers and their in-stream dams have healthy stocks. People have fished for *L. natalensis* for thousands of years. Mazel (1989) found *L. natalensis* bones that were 4400 years old in previously inhabited rock shelters in the northern part of the Thukela basin indicating the use of these fish by early man.

It is listed as Least Concern in the IUCN Red Data assessment for southern Africa (IUCN, 2007) due to its widespread distribution within KwaZulu Natal, high abundance and no major threats to its overall survival.

This species occurs in all the major rivers south of the Phongolo River to the Mtamvuna River and in hundreds of small tributaries from the coast inland to altitudes in excess of 1600 m. Waterfalls have prevented access to the upper parts of some rivers, noticeably the Mzimkhulu and Ingwangwana, which both flow for more than 80 km before scalies are to be found in them. A vertical drop of only a few meters is generally sufficient to keep *L. natalensis* from ascending a fall and colonising the stream above.

It is absent in the Phongolo catchment in the north where it is replaced by the Bushveld smallscale yellowfish *Labeobarbus polylepis* Boulenger, 1907 and Lowveld largescale yellowfish *Labeobarbus marequensis* (A. Smith, 1841) (Crass 1964).

The KZN yellowfish has been recorded in approximately half of the formally protected conservation areas of Ezemvelo KwaZulu-Natal Wildlife (EKZNW) (Coke, 1991) (Table 1). Many of these reserves have permanent *L. natalensis* populations and, by virtue of providing ecologically healthy catchments and riverine habitat, play an important role in conserving the species.

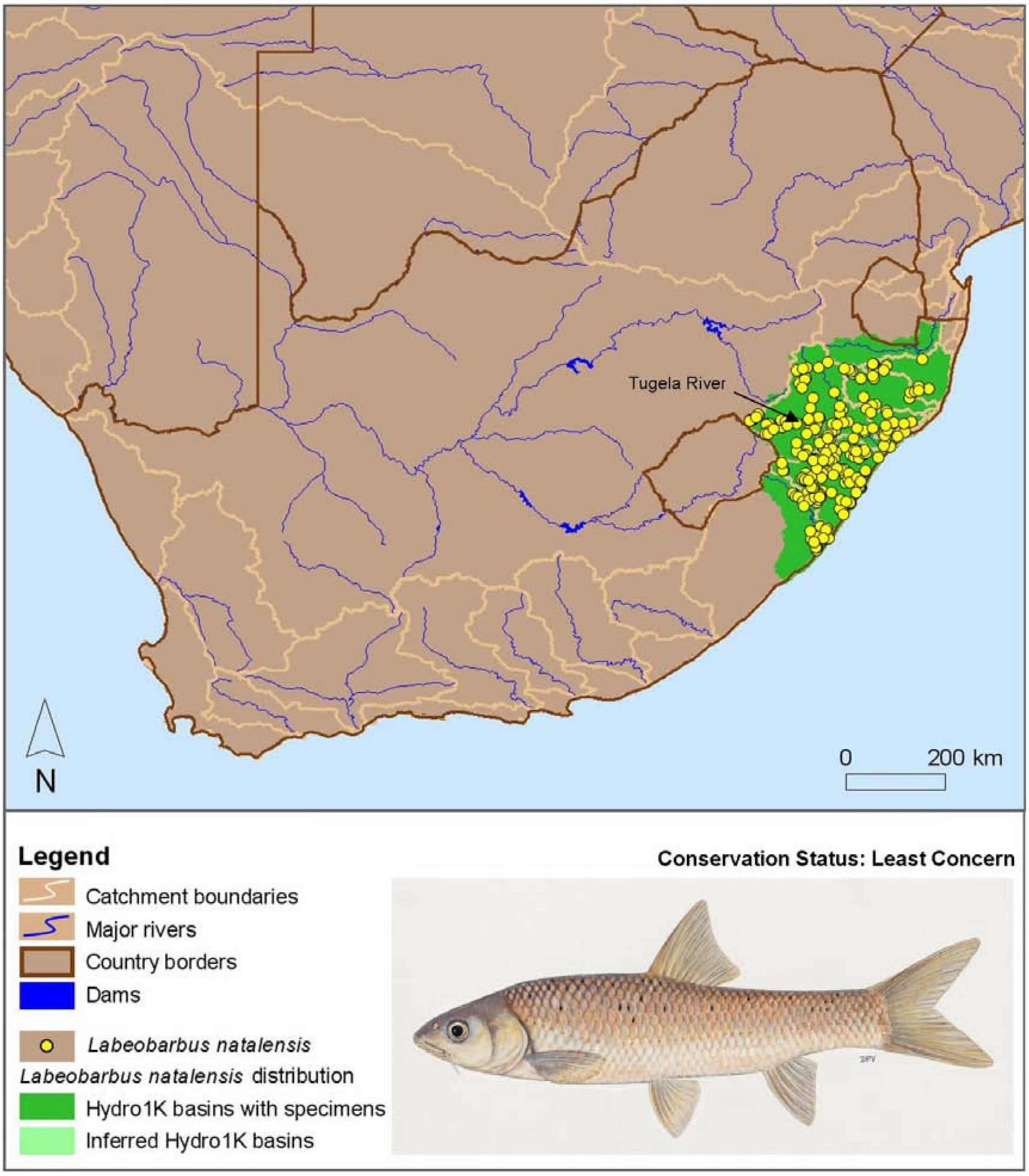

Figure 1: Distribution of *Labeobarbus natalensis*, based on voucher records (prepared by Willem Coetzer, SAIAB).

Status of habitat

KwaZulu-Natal is fortunate from a national yellowfish perspective to have a relatively high rainfall and a large number of river systems, several of which are unregulated or "free-flowing" (i.e. no large in-stream dams) (Figure 2). Most rivers have not been over-abstracted for agricultural purposes and are in a reasonable ecological condition with acceptable habitat, flow variability and water quality. Free flowing rivers that have good water quality should have high numbers of *L. natalensis* as these most closely meet the life history requirements of this riverine migratory species. The many rivers, some with large catchments such as the Thukela, provide EKZNW with a range of options for managing and conserving *L. natalensis* and its associated habitat.

Table 1: Nature Reserves in KwaZulu-Natal in which *Labeobarbus natalensis* has been recorded.

NATURE RESERVE	RIVER SYSTEM	PERMANENT OR SEASONAL POPULATION (U=Unknown)
Cathedral Peak Nature Reserve	Mlambonja River	S
Chelmsford Dam Nature Reserve	iNgagane River	P
Hluhluwe Game Reserve	Hluhluwe, Nzimane, Kwa-Ndimbili and Zimbokodweni rivers	P
Umfolozi Game Reserve	Black Imfolozi River	P
Impendle Nature Reserve	Sithunjwana River	U
Krantzkloof Nature Reserve	Molweni River	P
Kenneth Stainbank Nature Reserve	Mhlatuzana River	P
Lotheni Nature Reserve	Lotheni River	S
Midmar Dam Nature Reserve	uMgeni River	P
Moor Park Nature Reserve	Bushmans River	S
Mbunbazi Nature Reserve	Vungu River	U
Oribi Gorge Nature Reserve	Mzimkhulwana River	P
Royal Natal National Park	Thukela River	S
Spioenkop Dam Nature Reserve	Thukela River	P
Mtamvuna Nature Reserve	Mtamvuna River	P
Mkuze Game Reserve	Mkuze River	P
Ubombo Mountain Nature Reserve	Mfundeni River	P
Vergelegen Nature Reserve	Mkomazi River	S
Vernon Crookes Nature Reserve	eMhlango River	P
Wagendrift Dam Nature Reserve	Bushmans River	P
Weenen Game Reserve	Bushmans River	P

The rivers under the greatest threat are those that supply water to Durban and Pietermaritzburg. These rivers were surveyed as part of a recent State of River report (DWAF, 2004).

The uMgeni and neighbouring catchments comprise a region of widely varying land uses, ranging from conserved natural areas, to areas of intense urban and industrial development, forestry and agriculture. The uMgeni is a highly regulated river with three large in-stream dams, namely Midmar, Albert Falls and Nagle Dams. eThekweni District Municipality (City of Durban), with a population of 3.5 million people, has more than 200 river bio-monitoring sites and spends more than R1 million each year monitoring its river systems.

Biology and Ecology

Morphology

Labeobarbus natalensis has a fusiform (torpedo-shaped) body, is a strong swimmer and attains a total length (TL) of 640 mm and a mass of more than 4.6 kg (Figure 3). Body shape and numerous other morphological features show considerable variation both within populations and across their wide geographical range. This is in part why so many synonyms exist (see taxonomic history section above).

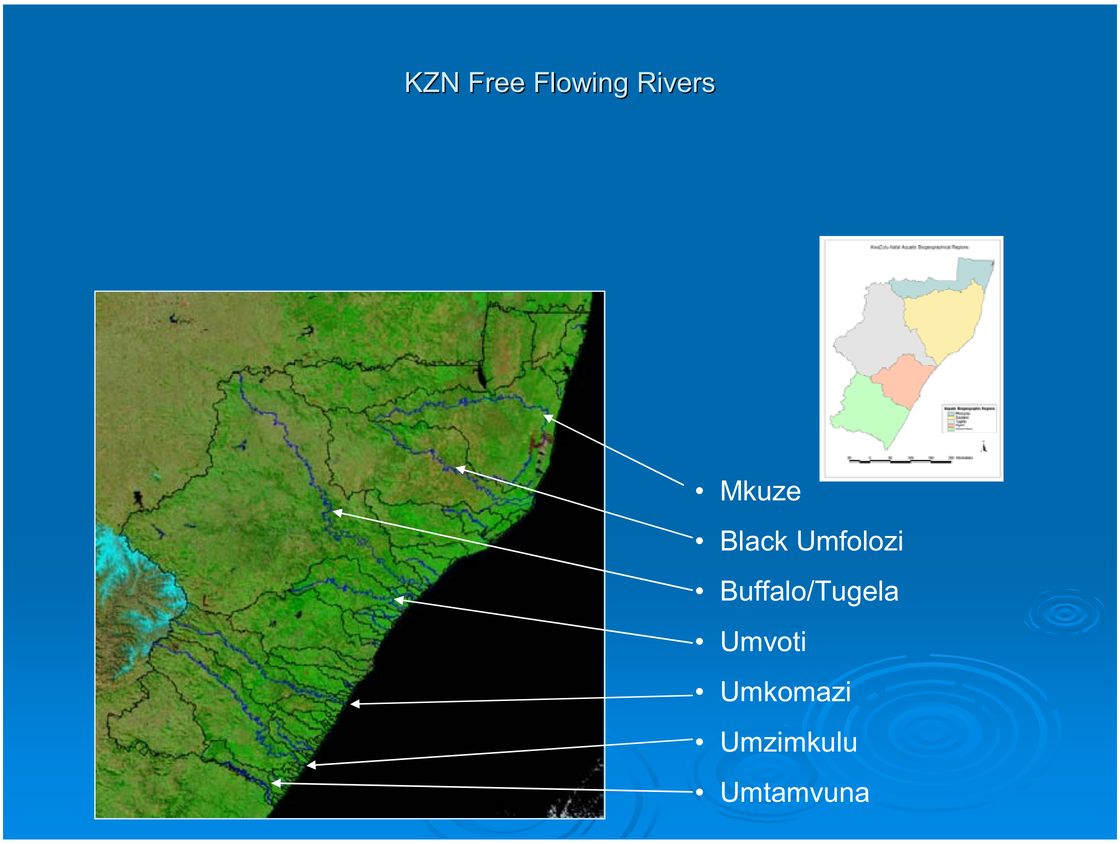

Figure 2: Free flowing or unregulated rivers in KwaZulu-Natal. Insert shows the five Water Management Areas in the province.

The shape of the body varies from one individual to another; specimens from the upper parts of rivers are usually elongate with a depth less than head length, whereas in the lower waters, one finds more thick-set, hump-backed fish with a depth at least equal to head length.

The mouth is extremely variable ranging from a straight scraping form to enlarged 'rubber lips" and the well-developed barbels are as long or greater than orbit diameter (Skelton 2001). The anterior pair is usually about as long as the eye diameter and the posterior pair slightly longer. The last dorsal spine, which originates almost directly above the base of the ventral fin, is thin and flexible in fish from headwater streams but thick and rigid from fish from the lower waters. Dorsal fin height is usually correlated with dorsal fin spine thickness. The fin base is fairly short with eight or nine branched rays. Scales along the lateral line may be as few as 31 or as many as 43, but are generally from 35 to 39. Caudal peduncle scales are normally 16, with a range of 14 to 18 (Crass, 1964).

The colour of *L. natalensis* tends to be variable, depending on water clarity and body condition. Fry are silvery with irregular dark markings; juveniles lose their dark marks but remain silvery. Adults are olive above with bronze sides and a cream ventral surface.

Figure 3: Large adult *Labeobarbus natalensis*. (photo, Turner Wilkinson).

Habitat requirements

The species is found in a wide variety of habitats from pools and rapids of clear streams to deep turbid waters of larger rivers and impoundments. Juveniles form large schools in shallow marginal habitats. *L. natalensis* tends to move upstream in summer, probably for spawning and feeding purposes, and retreats downstream in winter to seek warmer water and big deep pools. These pools offer better shelter from predators such as cormorants and otters.

Like other members of the genus *Labeobarbus*, this species has a distinct tendency to remain in schools although individual fish may take up a particular station for feeding.

Young *L. natalensis* collect in schools along the margins of pools or shallow backwaters. Even when they have grown and moved into the main river they continue to congregate in groups which keep together while seeking food, and move as a single unit when danger threatens (Crass, 1964).

In the clear waters of Nagle Dam, schools have been observed each consisting of individuals of a remarkably uniform size, large fish in one school and small ones in another. *Labeobarbus natalensis* is remarkable for its adaptability to different kinds of water and a wide range of temperatures. A preference for warmth is indicated by the behaviour of young fish that frequent shallow backwaters where the temperatures may be as high as 32ºC on a summer afternoon. Wherever a tributary stream enters the main river, *L. natalensis* collects in shoals if the stream is warmer than the river.

Feeding

Labeobarbus natalensis is omnivorous feeding on algae, detritus and aquatic invertebrates (Skelton, 2001). It is adaptable and feeds on what is abundant and available. Juveniles inhabit rapids and stony pools and feed chiefly on midge larvae and mayfly nymphs. Adults are very fond of eating crabs (Crass, 1964).

Breeding

Wright and Coke (1975a, 1975b) investigated natural spawning, artificial propagation, and some biological aspects of *L. natalensis*. This section summarises aspects of their work and also includes information provided by C. Wright (personal communication).

Scalies seem to overwinter in in-stream dams or large pools in the middle and lower reaches of rivers. In late August and September, adult fish (mainly females) gather at the inlets of dams to begin upstream migrations. Upstream migrations occur when the rains begin at the end of spring. Large shoals of *L. natalensis* move upstream, mainly at night, and when they reach a cataract or waterfall dozens of individuals can be seen jumping in an attempt to clear the obstruction. Fish moving upstream are not all mature, so the migrations cannot be described solely as spawning runs. In the absence of impassable waterfalls, both adult and juvenile fish penetrate as far as the headwaters of many streams in summer.

The breeding season peaks in October-November when the water temperature reaches 22ºC following good seasonal rains. Spawning occurs in both day- and night-time in suitable habitat in the river. Spawning adults average between 600 g and 2 kg with males on average being considerably smaller than females. Large numbers of males attend to the spawning females, often outnumbering them by as much as 10 to 1 so that a great deal of random fertilization takes place. Gravid females carry eggs at different stages of development indicating that multiple spawning takes place. Under natural conditions, scalies select algae-free spawning beds in riffles with spawning taking place predominantly at water temperatures of over 19ºC. Females select coarse gravel beds in well-aerated shallow sections of the river. Here they quiver and shake as they deposit eggs into the gravel bed. These eggs are very sticky and attach readily to the substrate.

After 3 to 4 days the fertilized eggs hatch into transparent larvae which then burrow head down further into the gravel. The presence of light appears to be a major factor contributing to the downward burrowing activity of larvae, suggesting negative phototropism. The larvae have a small yolk sac and spend approximately 10 days developing further in the confined safety of the gravel. As the larvae develop towards the post-larval stage an air bubble develops in the body causing them to adopt a more head-up position. The young fry then start wriggling and swimming up after spending approximately three weeks in the gravel. Two weeks after the free-swimming stage had been reached the first signs of active feeding became apparent under hatchery conditions.

When water temperatures fall in autumn, scalies become less active and their general absence from the upper parts of the rivers in winter indicates that they move downstream at this time. Fry have been observed at different times of the year, from spring through autumn, but examination of the mature fish indicates that the peak spawning period is in late spring to early summer. Eggs are about 2 mm in diameter and a female over 1.35 kg may carry more than 20,000. A body length of 125 or 150 mm TL is commonly reached after the first year of life and males generally mature as yearlings although females do not develop ova until their second year. The smallest mature males were 10.7 cm but no female less than 14.5 cm has been found with developed ovaries.

Threats

Currently the greatest threats are river regulation, catchment transformation and water pollution. *Labeobarbus natalensis* populations seem to be on the decline. Anglers report smaller catches and attribute it to water pollution, invasion of rivers by alien fish species, such as carp *Cyprinus carpio* Linnaeus, 1758 and bass *Micropterus* spp., and to predation by increasing numbers of fish-eating birds. Poor land-management, especially intensive agriculture such as sugar-cane farming and excessive livestock densities in Tribal Trust Lands are cause for increasing concern. This leads to soil erosion which in turn causes the silting-up of spawning gravels and even whole pools. Over the last 15 years, prominent scaly angler Wally Schroeder has witnessed the loss of rocky areas, clean gravels and deep pools in the Thukela River due to siltation. The 1984 Cyclone Demoina floods and the September 1987 floods scoured out many pools and cleaned the gravel beds, but within a couple of years, these had been silted up again. Large in-stream dams in the Thukela catchment have decreased flood flows and the cleansing effect they have on fish habitats (Coke, 1999).

The uMgeni catchment area, which supplies water to Durban and Pietermaritzburg, is under particular threat due to the rapidly growing demand for water. Urbanization in the lower reaches of the river has led to an increase in contaminated runoff and faecal pollution. The uMgeni River is also heavily regulated by in-stream dams, resulting in downstream flow reduction and the degradation of downstream water quality, habitat and biotic integrity (DWAF, 2006). The 2025 baseline scenario of water supply from the Mvoti-Mzimkhulu Water Management Area predicts a shortfall of 422 million m^3 whereas the high scenario predicts a deficit of 789 million m^3 (DWAF, 2004).

Thirty-two rivers were recently sampled during a 2006 River Health Programme (RHP) survey in the Durban Metro area (Graham, 2006).

Fifteen or 47 percent of these rivers are known to have had populations of *L. natalensis* in the past. Eleven of the rivers still supported *L. natalensis* at the time of sampling. Sampling error, and potentially increased pollution, was the most likely cause for the absence of this species in the Palmiet, Lovu, Msimbazi and Msinyati rivers. These fish surveys suggest that *L. natalensis* is capable of surviving in a wide range of conditions. Polluted rivers, with a poor to fair ecostatus, however had on average fewer and more stunted fish. The Msunduze River, which flows through Pietermaritzburg, had several massive fish kills in 2006 due to an accumulation of waste products in the river and the concomitant depletion of dissolved oxygen in the water. With 70 percent of municipal wastewater treatment plants in KZN currently rated as being non-compliant, there are real reasons for concern. Deformed *L. natalensis* up to 1 kg are often found where water pollution is evident (W. Schroeder, personal communication). Also evident are mouth and fin deformities, crooked backs and even healed wounds with the ribs of some fish sticking right out of the body (Coke, 1999). Virtually every year in spring, considerable numbers of *L. natalensis* with *Saprolegnia* infections are found in polluted rivers. This fungus now occurs permanently in our waters (Oldewage and Van As, 1987) and readily infects weakened fish that have survived cold winters in poor-quality water (Coke, 1997).

Other key threats are hybridisation and displacement of the species due to the introduction of alien species from the Thukela-Vaal Interbasin Water Transfer (IBT) scheme. The Orange-Vaal smallmouth yellowfish *Labeobarbus aeneus* (Burchell, 1822) and Orange River mudfish *Labeo capensis* (A. Smith, 1841) are on record as having entered KZN in this manner (Figure 4). Records date back to samples collected by Mike Coke in 1991. *Labeobarbus aeneus* has the potential of naturalising in the Thukela primary catchment as well as hybridising with the endemic *L. natalensis*. However, a river survey of the upper Thukela River in November 2005 failed to locate any morphologically distinct specimens (Karssing, 2006a). The Orange-Vaal largemouth yellowfish *Labeobarbus* ki*mberleyensis* (Gilchrist & Thompson, 1913) is also present in Sterkfontein Dam and could enter the upper Thukela catchment via the same route as *L. aeneus*. If this large predatory yellowfish invades the Thukela River system, it could have devastating ecological consequences. Preliminary genetic work carried out by Prof. Paulette Bloomer of Pretoria University on specimens taken from the Mzimkhulu, Mkuze, Sterkspruit, Bushmans and the Thukela Rivers suggest that *L. natalensis* is genetically distinct from *L. aeneus*. Owing to geographical isolation, *L. natalensis* from different river systems in KZN also shows considerable genetic variation. However, little variation was detected among populations inhabiting the Thukela River.

A further IBT of concern is Mearn's Weir that transfers water and probably also aquatic organisms, including *L. natalensis*, from the Mooi River (a tributary of the Thukela) into the uMgeni catchment (Coke, 1995). Mearn's Weir, which is situated below the confluence of the Mooi and Little Mooi Rivers, is used as the main water storage facility. The pumped water from this weir is released into the Mpofana River, a tributary of the Lions River, from where it flows into the uMgeni River and on to Midmar Dam.

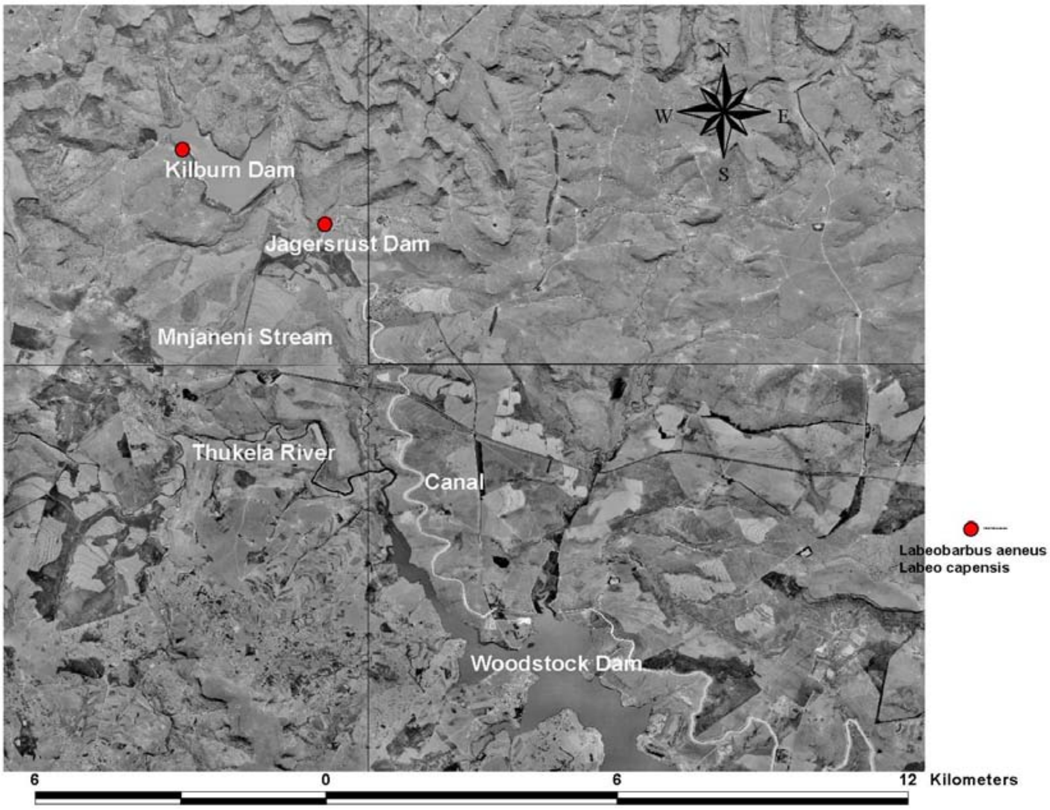

Figure 4: Site records for translocated *Labeobarbus aeneus* and *Labeo capensis* in the headwaters of the Thukela catchment. The Thukela-Sterkfontein Dam Water Transfer Scheme made the translocation possible.

Ironically, the increased popularity of *L. natalensis* as an angling fish could result in it being moved outside of its natural range and becoming invasive in other provinces and river systems. Similarly, anglers and landowners could stock neighbouring yellowfish species illegally into dams within the natural range of the KZN yellowfish. *Labeobarbus natalensis* is on record in having been moved above waterfalls in the Mzimkhulu and Thukela Rivers (De Moor and Bruton, 1988). The infestation of alien plants in the riparian zone and predation and competition by alien fishes are small but constant threats.

Both *L. polylepis* and *L. marequensis* have historically been moved outside their natural range in KZN. These are isolated records dating back to 1971 and 1972 when Mr Tom Pike collected specimens of both species from the Bloemveld Dam, Vryheid in the Imfolozi River system. A field survey in 2005 in Umfolozi Game Reserve failed to locate any specimens of either species. At this stage, it is not known, despite carrying out field inspections, whether any of these alien yellowfish species have established viable populations in KZN or whether they may have hybridised with indigenous species.

Measures to Conserve the Yellowfish Resource

Protected areas and conservancies

As part of the systematic conservation planning process currently being undertaken by EKZNW, representative sections of river systems in the province will be identified for protection with the aim of conserving their biodiversity. Accordingly, Dickens et al. (2004) have developed a preliminary biophysical classification and map of these systems for EKZNW. In addition, Dr N. Rivers-Moore, Dr P. Goodman and M. Nkosi of EKZNW are developing a systematic conservation plan for aquatic ecosystems. The current state of these aquatic resources was indexed by the degree of land transformation in the catchments, as well as an estimate of the number of impoundments weighted by the amount of water impounded. Free-flowing rivers in the province have been identified as part of this process. Such rivers hold the greatest potential for conserving biodiversity in the face of climate change and ongoing anthropogenic pressure on freshwater aquatic resources.

To date no formal conservancies have been established in KZN directly around the yellowfish angling resource. The angling potential of yellowfish has however been recognised amongst private game reserves and lodges on the Mkomazi River and more recently the Bushmans River. Umgeni Valley Nature Reserve (WESSA) in Howick offers some excellent public yellowfish fishing.

Hatcheries and stockings

Attempts to spawn *L. natalensis* at the Natal Parks Board Nagle Dam Fish Hatchery in 1992 met with scant success (Pike, 1993). Historically, scalies were artificially introduced into the upper Pholela and Little Mooi Rivers above waterfalls that formerly restricted their distribution. The origin of the stocked fish is another concern as they may have been from another river system to the one being stocked. If they are alien to the system they could have moved downstream and interbred with the native strain of *L. natalensis*. Scalies were also translocated from the Msunduze River at Pietermaritzburg to a dam at Marandellas, Zimbabwe from where they subsequently invaded the upper reaches of the Save River. No current culture of *L. natalensis* is being undertaken and none is foreseen or recommended.

Preliminary research has confirmed that that there is considerable genetic variation between geographically isolated populations of *L. natalensis* within the province. To protect the genetic integrity of yellowfish species, the national committee of the Yellowfish Working Group (YWG) has recommended that if yellowfish are to be stocked into dams they should be sourced from within the same catchment in which the dam is located and only stocked under supervision of the provincial conservation agency.

Education and awareness

Fly fishing for the *L. natalensis* is increasing in popularity, although considerable public ignorance still exists in terms of locating suitable angling venues and adopting appropriate angling techniques. It is expected that fly fishing for the species will continue to grow as the cost of trout fishing and fuel prices increases. The Natal chapter of the YWG has contributed towards the awareness of the KZN yellowfish as a desirable quarry through popular articles written for *The Quill*, a newsletter distributed widely in the Natal Midlands.

Legislation

The minimum requirement to ensure sustainable harvesting of the species is potentially a daily bag limit of two fish between 30 cm and 50 cm and restricting the capture method to rod and line. This is in line with what has been recommended by the national YWG for non-threatened yellowfishes. However, the current daily limit in the Ordinance is 10 fish with a minimum length of 20 cm. Provincial conservation authorities, in collaboration with stakeholders and interested and affected parties, have a meaningful role to play in changing legislation and ensuring compliance. In this regard EKZNW has recently reconstituted its Fresh Water Fishing Liaison Committee which now serves as a valuable platform for the public participation process.

Monitoring and research needs

Given that *L. natalensis* is not yet threatened, the River Health programme is seen as the best tool for monitoring the status of the species. EKZNW staff has also contributed samples for genetic studies and routinely submit voucher specimens to museums collected during field surveys. A key monitoring requirement is more frequent fish surveys of rivers where the potential for yellowfish competition and hybridisation is greatest. These rivers are the upper Thukela, Imfolozi and uMgeni.

The YWG has identified two key research needs:

- A detailed study to determine genetic and morphological structuring of *L. natalensis* to identify which populations are unique and worthy of elevated levels of conservation.
- The nature, status and likely impacts of the alien *L. aeneus* population in the headwaters of the Thukela catchment and whether the alien population can be contained.

Value of the Yellowfish Resource to Recreational and Subsistence Users

The species has more recently become a popular quarry of fly fishers and artlure anglers alike. With few exceptions, most of the fish caught by fly anglers are returned live to the water. Coarse anglers do take considerable numbers of these fish during their annual migration but for most part of the year catches tend to be low to moderate. The fish is a popular catch by subsistence anglers in rural areas who catch the fish predominantly on worm and paste baits. There is no organised subsistence fishery dedicated to the exploitation of *L. natalensis* in KZN. Most fish are caught using legal techniques, namely hand-line or rod and line. However, illegal netting is a significant problem in some areas, notably near urban areas or rural settlements. Most netters target spawning congregations. For example, every Spring, subsistence netters decimate stocks in the Mtoti River as they migrate from the Bell Park Dam into the river to spawn. Field rangers from EKNW are sent out seasonally to help curb this problem.

Concluding Remarks

Labeobarbus natalensis is the most ubiquitous freshwater fish in KwaZulu-Natal. It is robust and fairly tolerant of pollution and habitat change but stands the risk of succumbing to low oxygen levels in highly impacted streams and rivers. Mortalities as a result of water pollution are regularly reported from rivers within Durban and Pietermaritzburg. Fly fishing for this species, as an alternative to alien fishes, is becoming more popular. The KZN yellowfish would benefit greatly from a more integrated approach to catchment management by authorities. Ironically, its newly found popularity as a freshwater gamefish could affect the long-term conservation of *L. natalensis* should it be translocated outside its natural range or cultured for its sport fishing potential.

Without public co-operation, particularly that of riparian landowners, there can be little hope that water sources such as wetlands and natural catchments will themselves be conserved in such a way that the rivers they feed remain ecologically healthy. The successful conservation of *L. natalensis* will depend primarily on the protection of their favoured habitats and food organisms (Coke, 1997). EKNW engages positively with stakeholders and interested parties by being an active member of the national YWG and by hosting the provincial Freshwater Fishing Liaison Committee forum.

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STATUS OF THE LOWVELD LARGESCALE YELLOWFISH *LABEOBARBUS MAREQUENSIS* (A. Smith, 1841)

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ABSTRACT

The Lowveld largescale yellowfish *Labeobarbus marequensis* (A. Smith, 1841) is the common large-scaled yellowfish of the Limpopo and middle Zambezi River systems and is widely distributed in east-flowing rivers as far south as the Phongolo system. The morphology of the species and in particular the mouth form and dorsal fin is extremely variable. It is partial to fast-flowing water and breeds in cobble or gravel beds in riffles. The species appears to be highly adaptable, maintaining good populations in moderately polluted rivers and impoundments. Although still abundant and widespread in its distribution range it is becoming less common in South Africa due to water extraction, flow regulation and water pollution. Being an omnivore, it is not an easy species for anglers to catch, but improved techniques and methods are improving its popularity, especially amongst fly fishers.

Introduction

The Lowveld largescale yellowfish, *Labeobarbus marequensis* (A. Smith, 1841), more commonly known as the largescale yellowfish, is the common large-scaled yellowfish occurring in the Limpopo and Zambezi systems (Jubb, 1967) and it is widely distributed from the middle and lower Zambezi System south to the Phongolo system (Skelton, 2001). In South Africa, it commonly occurs together with another true yellowfish, the Bushveld smallscale yellowfish *Labeobarbus polylepis* Boulenger, 1907 and less frequently with a "yellowfish-type" species, the papermouth *Barbus rapax* Steindachner, 1894, in southern Limpopo tributaries (Skelton, 2001).

According to Skelton et al. (1995) the distribution of organisms is governed, amongst others, by the complexity of climate; in freshwater fish the hydrographic and geomorphological history plays an equally important role. *Labeobarbus marequensis* and *B. rapax* are part of the Zambezian fauna that occur in the Zambezi River and its historically associated drainage basins. In contrast, *L. polylepis* forms part of the Southern Temperate Fauna like the rest of the South African "yellowfish" species, all of which are endemic to southern Africa.

This chapter describes our current knowledge of *L. marequensis* and analyses issues of relevance for the future management of the species.

Taxonomic History

Morphologically, the species varies considerably across its range – a major reason why so many previous workers have described the variants as separate species. The list below shows these synonyms and the areas or rivers where specimens were collected. Taxonomic research is needed to determine if these populations are, in fact, distinct species or management units simply due to environmental variation. The Buzi River population, in particular, has very high fin forms and this is in part why it was separated from *L. marequensis* in the recent IUCN assessment.

Barbus (Cheilobarbus) marequensis, Smith 1841. Interior of South Africa. Holotype: BMNH 1845.7.3.95 (dry).
Barbus brucii, Boulenger 1907. Groot Olifant R., Transvaal, South Africa. Holotype (unique): BMNH 1907.3.15.34.
Varicorhinus brucii, Boulenger 1907. Klein Olifant R., Transvaal, South Africa. Holotype (unique): BMNH 1907.3.15.37.
Barbus cookei, Gilchrist & Thompson 1913. Crocodile R., Transvaal, South Africa. Holotype (unique): SAM 1074 [now at AMG].
Barbus dwaarsensis, Gilchrist & Thompson 1913. Dwars R., Transvaal, South Africa. Holotype (unique): SAM 9707 [now at AMG].
Barbus fairbairnii, Boulenger 1908. Gorge below Victoria Falls, Zambezi R., Zambia/Zimbabwe. Holotype (unique): BMNH 1908.11.6.22.
Barbus gunningi, Gilchrist & Thompson 1913. Thabina R., Pienaars R. and Six-mile Spruit, Transvaal, South Africa. Syntypes: (8) SAIAB [formerly RUSI] 30036 [ex TMP 10107] (1), 30037 [ex TMP 10106] (1), 30038 [ex TMP 10110] (1), 30039 [ex TMP 10108], 43017 [ex TMP 10109] (1).
Barbus (Dangila) inermis, Peters 1852. Lower Zambezi R., Mozambique. Syntypes: ZMB 4736 (3).
Varicorhinus nasutus, Gilchrist & Thompson 1911. Gorge below Victoria Falls, Zambezi R. Zambia/Zimbabwe. SAM 8801 [now at AMG].
Barbus rhodesianus, Boulenger 1902. Near Mazoë, Zimbabwe. Syntypes: BMNH 1902.2.12.143-146 (4).
Barbus sabiensis, Gilchrist & Thompson 1913. Sabi R., Magalies R. system, Malelane, Transvaal, South Africa. Lectotype: SAM 10760 [now at AMG]. Paralectotypes: (4) TMP 10111 Magalies R. and Malelane; SAM 10766 (1).
Barbus sector, Boulenger 1907. Groot Olifant R., Transvaal, South Africa. Holotype (unique): BMNH 1907.3.15.35.
Barbus swierstrae, Gilchrist & Thompson 1913. Thabina R., Dwars R., Magalies R. and Pienaars R., Transvaal, South Africa. Syntypes: (4) SAM 9665 [now at AMG] (1), SAIAB [formerly RUSI] 30034 [ex TMP 10114] (1), 30015 [ex TMP 10113] (1).
Barbus victoriae, Boulenger 1908. Gorge below Victoria Falls, Zambezi R. Holotype (unique): BMNH 1908.11.6.21[or 22].
Labeobarbus zambezensis, Peters 1852 - Zambezi R. at Tette, Mozambique. Syntypes: NMW 49730 (1); ZMB 3246 (2), 4744 (7).

Distribution and Population Status

In South Africa, *L. marequensis* is most commonly found in east-flowing rivers (Le Roux and Steyn, 1978) (Figure 1). Crass (1964) reported the Phongolo River as the most southern river occupied by *L. marequensis* but Tom Pike collected specimens in the Bloemveld Dam, in the Mfolozi system, near Vryheid in 1972 (Coke, personal communication). This population is probably alien and may be invasive as well. *Labeobarbus marequensis* occurs in a wide variety of habitats that ranges from pools to rapids and tolerates a wide range of temperatures, enabling it to survive in mountain streams and lowland rivers. Crass (1964) recorded *L. marequensis* up to an altitude of 1220 m in the Phongolo River, but Hecht and Scholtz (1981) could not find any specimens that high up in the Steelpoort River. Lower down, however, it was ubiquitous. In the Groot Letaba River, Chutter and Heath (1993) found it in the escarpment, middleveld as well as lowveld sections.

The conservation status of *L. marequensis* is classified as Least Concern as it is still relatively abundant and widespread throughout its natural distribution range (IUCN, 2007). It is found in six Water Management Areas (WMAs); its current distribution within these areas is described below.

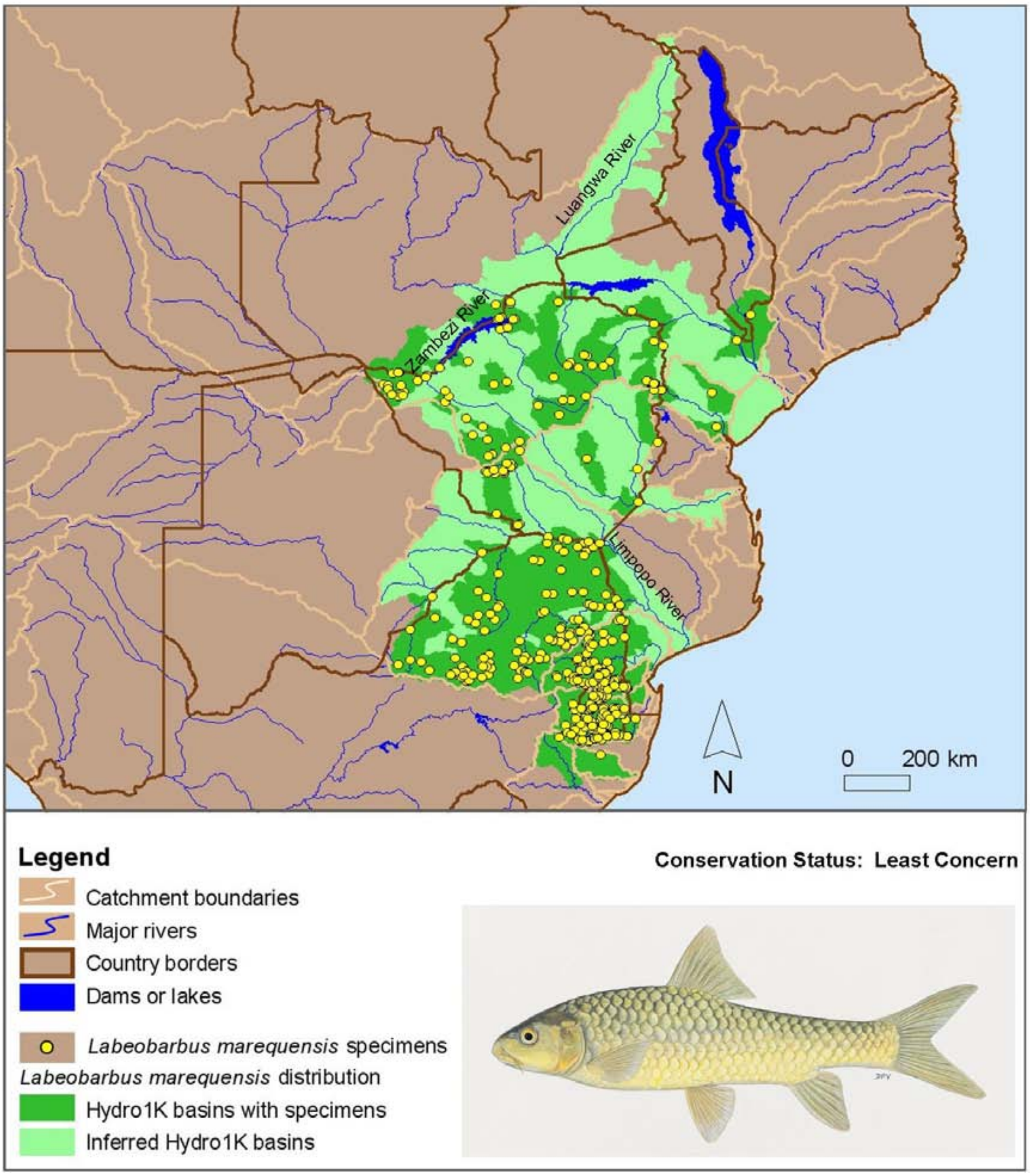

Figure 1: Distribution of *Labeobarbus marequensis*, based on voucher samples (map by Willem Coetzer, SAIAB).

Water Management Area 1, Limpopo

This is the northern-most WMA and represents part of the South African portion of the Limpopo Basin. The region is semi-arid and the mean annual rainfall ranges from 300 mm to 700 mm. The major rivers are the Mokolo, Matlabas, Lephalala, Mogalakwena and the Sand in the west and the Nzhelele and Nwanedi in the east. All these rivers fall within the Limpopo Province, and are regularly surveyed by provincial conservation staff.

Historical data on the distribution of the species is extensive but in recent times only the Mokolo River has been surveyed as part of the River Health Programme (RHP) resulting in a technical report (Angliss et al., 2003) and a State of Rivers Report (SoRR) in 2006. Surveys of the other rivers such as the Nwanedi-Nzhelele and the Lephalala rivers are in various stages of progress but the results are not yet available (Angliss, personal communication). *L. marequensis* was recorded at the majority of the 31 sites surveyed in the Mokolo River System.

Water Management Area 2, Luvuvhu-Letaba

This WMA lies entirely within the Limpopo Province and also forms part of the Limpopo Basin. Whereas the Luvuvhu River is a first order tributary of the Limpopo River, the Shingwedzi and Letaba Rivers are second order tributaries and flow first into the Olifants River. A unique feature of this WMA is the Kruger National Park (KNP) along its eastern boundary, which occupies approximately 35 per cent of the area and through which all the main rivers flow into Mozambique. Due to the topography, the annual rainfall varies from well over 1000 mm to less than 300 mm.

Chutter and Heath (1993) reported that *L. marequensis* was present in all but one of the sites they surveyed in the Groot Letaba River and ranked it as the sixth most common of the 33 species collected. This was confirmed by the specialist study done by Fouché (2004a, 2004b). Fouché et al. (2006) found that the species was still plentiful in the perennial rivers of the WMA and was present at historic sites, except for the Shingwedzi River. Although Pienaar (1978) recorded the species in the Shingwedzi and its tributaries, Vlok and Fouché (2007) found no specimens at the historic sites during a recent survey.

Water Management Area 3, Crocodile (West)-Marico

This WMA borders on Botswana in the north-west. Two of its main rivers, the Crocodile and Marico, give rise to the Limpopo River at their confluence. The climate is generally semi-arid and the mean annual rainfall ranges from 400 mm to 800 mm. Extensive irrigation occurs along the main rivers whereas grain, livestock and game farming are the principal forms of agriculture in the remainder of the area. The urban and industrial complexes of northern Johannesburg and Pretoria and platinum mining north-east of Rustenburg dominate economic activity in the region. It is the second-most populous WMA in the country and economically the most active. Development and utilisation of surface water occurring naturally in the water management area has reached its full potential. A small amount of water is transferred from this WMA to Gabarone in Botswana as well as to Modimole in the Limpopo WMA. Increasing quantities of effluent return flow from urban and industrial areas are a major cause of pollution in several rivers.

The Crocodile, Apies-Pienaars, Elands, Marico and Molopo are the major rivers within the WMA. The environmental agencies of Limpopo, Gauteng and North West Provinces share the responsibility for the rivers. A coordinated survey by the three provinces, which resulted in a State of the Rivers Report (SoRR) for the Crocodile-West River, represents the most recent data on the species. *L. marequensis* was not found in six of the 16 historic sites. Despite anthropogenic pressures on Gauteng rivers, it is still widespread and common in stretches of river that have acceptable habitat diversity, water flow and quality. Until recently, it was relatively common in the Jukskei River within greater Johannesburg indicating adaptability and fair tolerance of human impacts.

Water Management Area 4, Olifants

The major river within this WMA, the Olifants River, originates to the east of Johannesburg and initially flows northwards before curving eastwards towards the KNP, where it is joined by the Letaba River before entering Mozambique. The climate changes distinctly from the cool Highveld in the south and west to the subtropical lowlands east of the escarpment. The mean annual rainfall ranges from 500 mm to 800 mm over most of the WMA. Economic activity is highly diverse and ranges from mining and metallurgical industries to irrigation, dry-land and subsistence agriculture, and tourism. Since the Olifants River flows through the KNP, the provision of water to meet ecological requirements is one of the controlling factors in the management of water resources. Most surface runoff originates from the higher rainfall southern and mountainous areas and is controlled by several large dams. In addition to the Olifants, the other rivers in the WMA are the Mohlapitse, Blyde, Steelpoort and Selati rivers (DWAF, 2004).

As is the case with the Crocodile-Marico WMA, the three provincial agencies from Limpopo, Gauteng and Mpumalanga share responsibility. There is a great amount of historic data and Angliss et al. (2005) have recently completed a technical report on the Olifants River. The species still occurs at all historical survey sites.

Water Management Area 5, Inkomati

This WMA is situated in the north-eastern part of South Africa and borders on Mozambique and Swaziland. The rivers from this area flow through Mozambique to the Indian Ocean. The Inkomati River flows into Swaziland and re-enters South Africa before continuing into Mozambique. Topographically the water management area is divided by the escarpment into a plateau in the west and the subtropical Lowveld in the east. Annual rainfall varies from 1 500 mm in the mountains to 400 mm in the lower-lying areas. Economic activity is mainly centred on irrigation, forestry and a strong tourism industry. A key feature of the water management area is the KNP. The Sabie River, which flows through the park, is ecologically one of the most important rivers in South Africa, whereas the Crocodile River forms the park’s southern boundary. Dams have been constructed on all the main rivers or their tributaries, and flow in the rivers are highly regulated (DWAF, 2004).

Large-scale yellowfish are still present in most of the sites where they would be expected (Engelbrecht, personal communication). Russell and Rogers (1989) were, however, concerned about declining numbers and adult size in some sub-catchments or sections of rivers.
The species was either absent or collected in low numbers in the Inkomati and Lomati rivers, below Maguga and Driekoppies dams (Engelbrecht, personal communication) but it is still abundant and widespread in the Swaziland middleveld (Bills et al., 2004).

During a recent survey of the Sabie and Crocodile (East) Rivers, *L. marequensis* was collected at 13 of the 16 historic sites in the Sabie and two of the three in the Crocodile River (Venter, 2007).

Water Management Area 6, Usuthu to Mhlatuze

This WMA falls largely within northern KwaZulu-Natal and its two major rivers, the Usuthu and the Phongolo, both hold *L. marequensis* and both are shared with Swaziland and Mozambique. The Usuthu has its headwaters in South Africa and flows into Swaziland, whereas the Phongolo River catchment is situated partly in Swaziland. Climate in much of the region is sub-humid to humid, but varies considerably. Mean annual rainfall ranges from 600 mm to 1 500 mm. Economic activity is diverse and includes subsistence farms, irrigated farms, forestry, tourism, and heavy industries in some areas (DWAF, 2004). The species is still widespread and common in both rivers, especially in their middle and lower reaches. The upper reaches seem to be dominated by *L. polylepis*.

Biology and Ecology

Morphology

Labeobarbus marequensis (Figure 2) and the upper Zambezi yellowfish *L. codringtonii* (Boulenger, 1908) are the only two large-scaled yellowfish species in the genus that occur in southern Africa (Skelton, 2001). In both species, the dorsal fin is situated in front of the pelvic fins, but in *L. marequensis* the height of the dorsal fin is less than the length of the head. The dorsal fin also shows considerable regional variation and Jubb (1967) as well as Bell-Cross and Minshull (1988) report a decrease in its height from east to west and from north to south. The dorsal-fin height can even vary within a single population (Skelton, 2001). The mouth is terminally positioned (Figure 3) and the mouth form and the lips are also extremely variable (Jubb, 1961, 1967; Bell-Cross and Minshull, 1988).

The live colouration of the fish also varies and adults in clear water are golden yellow (Bell-Cross and Minshull 1988; Skelton, 2001) but pale olive in turbid water. Pienaar (1978) states that the adults can also be silvery in more turbid waters but usually have a darker dorsal side and white belly. Juveniles (Figure 4) are silvery with a characteristic dark spot on the caudal peduncle (Jubb, 1967). Tubercles develop on the top and side of head as well as on the anal fin when breeding occurs (Skelton, 2001).

Figure 2: An adult *Labeobarbus marequenis* illustrating the deep body and large scales.

Figure 3: The variation in mouth form displayed by *Labeobarbus marequensis* with *forma varicorhinus* shown in the upper two photographs and *forma gunningi* in the two lower photographs (source: SAIAB).

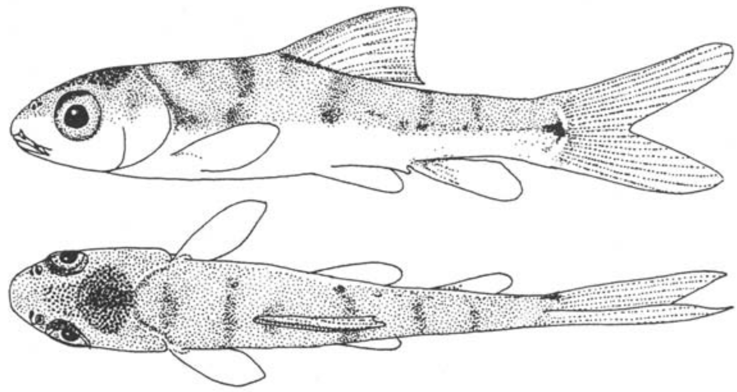

Figure 4: *Labeobarbus marequensis* juveniles from the Mbuluzane River near Simunye, Swaziland showing the juvenile pigment (source: SAIAB).

Habitat preferences

According to Pienaar (1978) and Bell-Cross and Minshull (1988), *L. marequensis* is partial to deep, rocky pools with a swift current but it is also found in sandy stretches and reed-fringed pools in both perennial and seasonal streams.

Gaigher (1973) referred to the species as "unspecialized with a wide distribution and dependent on rapids for breeding purposes". Its absence from the lower Limpopo which is devoid of rapids illustrates this breeding dependence.

Fouche et al. (2005b) found that *L. marequensis* favoured water flowing faster than 0,3m/s in 33 percent of the sites surveyed in the Mutale River compared to 96 percent in the Luvuvhu River. In the Groot Letaba River, the species preferred pools, rapids and man-made impoundments (Chutter and Heath, 1993).

These observations are supported by the more detailed habitat-preference work in the Kruger National Park by Russell (1997) who found that largescale yellowfish prefer the swift-water seams between the rapids and stream margins, particularly where they have gravel and/or cobble beds. Although they favour sites with fringing aquatic vegetation they do not frequently occur in this vegetation.

Breeding

Labeobarbus marequensis undertakes its spawning migrations during spring and summer (Crass, 1964; Pienaar, 1978; Skelton, 2001). From their studies of gonadal development Bell-Cross and Minshull (1988) concluded that adults migrated up swollen rivers to spawn in riffles between October and April.

Fouché et al. (2005b) revealed the close link between flow rate and the onset of the spawning migration by observing the movement of fish through the Xikundu Fishway on the Luvuvhu River during 2004 and 2005. In September 2004 adult fish commenced their spawning run as soon as the water flow increased from less than 0,15 to 0,25 m^3/sec. The following season the river was still flowing at a low 0,05 m^3/sec during September and the spawning run commenced only when it rose to 0,18 m^3/sec in October. Other migrations, such as the recolonising of particular areas by juveniles, also occur but when exactly they take place is not well documented.

Males reportedly mature at a fork length of approximately 70 mm Crass (1964) whereas females do so at a length of 280 mm (Skelton, 2001).

Growth rate and longevity

Very little is known about the growth rate of the species (Russell, 1997). Göldner (1969) found that in Loskop Dam the fish attained a fork length of 110 mm at the end of the first year and 150 to 160 mm at the end of the second year. Females grow faster, attain a greater length and on average become older than males (Gaigher, 1969), a detail underpinned by Göldner (1969) who found females to be three times more abundant than males. Gaigher (1969) established that the size obtained by the fish was related to their distribution and to altitude in particular. Above 610 m the dominant fork length was 160 mm whereas at lower altitudes it frequently reached 300 mm.

Diet

Various authors (Crass, 1964; Pienaar, 1978; Gaigher, 1979; Bell-Cross and Minshull 1988; Skelton, 2001) regard the species as omnivorous as it feeds mostly on algae, plant detritus, immature and adult aquatic insects, snails and even small fish. Fouché et al. (2003) confirmed the findings of Gaigher (1969) and Skelton (2001) that algae formed the bulk of the diet of fish smaller than 60 mm. Fouché and Gaigher (2001) found that the relative gut length of *L. marequensis* was 2,24 times longer than its fork length, a feature typical of herbivorous fishes.

Threats

Although the species is generally regarded as unspecialized (Gaigher, 1973) and non-sensitive (Kleynhans, 1991), it is sensitive to reduction in flow rates and increased levels of siltation, especially at breeding sites (Gaigher and Fouché 2001). Other key impacts include water pollution, in-stream dams and weirs that fragment populations, invasive alien fishes and plants, and illegal gill netting.

Releases from Blyde River Dam are pulsed and coordinated for agricultural purposes and demands. Little or no recognition is given to environmental requirements. From an environmental perspective, releases should mimic the natural hydrological regime of the system. Pulses of flow are considered detrimental to the ecology. Studies at the Xikundu Fishway by Fouché et al. (2005b) clearly indicated that spawning activities of *L. marequensis* is triggered in part by an increase in flow. Unseasonal pulse releases could therefore result in unnatural migratory behaviour.

The Selati River is being diverted completely into an irrigation canal and the stretch of the river below the diversion is now devoid of all flow-dependant species, including *L. marequensis.*

Along the main stem of the Olifants River sand and gravel are being mined on a huge scale. Although these activities are not impacting directly on the aquatic habitat, they are adversely affecting the riparian environment, which in turn is causing increased erosion and deposition of sediments within the river channel.

Illegal netting below weirs with shade cloth is also rapidly gaining ground in all rivers in the WMAs (Angliss, personal communication). If no fishways are provided on weirs and dams along the rivers fish are prevented from reaching their spawning sites and populations are fragmented, resulting in an overall decline in genetic diversity, fitness and population size.

The downstream migration of *L. marequensis* to warmer waters in winter is a matter that is seldom considered. Weirs, dams and other obstructions can prevent this migration from taking place, often with tragic results. Such an event occurred in the Spekboom River in the Inkomati WMA where thousands of fish died when they were trapped behind a bridge on their way downstream (J. Engelbrecht, personal communication).

Although the species is considered to be reasonably hardy and capable of surviving low and medium levels of pollution, the state of some of the rivers, particularly in Gauteng (Muller, in Wolhuter and Impson, 2007), is of great concern. Pollution may have a much greater impact than previously thought (J. Engelbrecht, personal communication). In the Ngodwana River in Mpumalanga, sawmill spills have caused total short-term extinction of aquatic species. Initially, the major concern centred on the endangered Inkomati suckermouth *Chiloglanis bifurcus* Jubb and le Roux, 1969. Fortunately, this species managed to recover quite rapidly as it matures and breeds within one year. In contrast, *L. marequensis* has not yet recovered as much of the larger breeding stock was killed for considerable distances downstream (J. Engelbrecht, personal communication).

The presence of alien fishes in many rivers in its range is another threat to *L. marequensis*. The predatory rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792), is common in the upper reaches of several rivers, albeit in low numbers. The largemouth bass *Micropterus salmoides* (Lacepède, 1802), is probably a more serious threat as it is widespread in many large in-stream dams, as well as in some rivers in the Zimbabwe Highveld. The ubiquitous carp *Cyprinus carpio* Linnaeus, 1758, has established itself in virtually all impoundments as well as the larger pools in some rivers and is not only a serious competitor for food but it also causes comprehensive degradation of the habitat.

The extent to which anglers and interbasin water transfers may have translocated *L. marequensis* is not well known but it is not regarded as a major threat at present.

Conservation Measures to Conserve the Yellowfish Resource

Legislation

Viljoen (in Wolhuter and Impson, 2007) has discussed the disparate legislation regarding bag and size limits for *L. marequensis* in those provinces within its distribution range. This lack of uniformity is a serious hindrance to the appropriate management of the species. For example, in KwaZulu-Natal and Limpopo there are no restrictions on the number and size of fish that may be kept. Anglers in Mpumalanga may keep six fish with a minimum length of 200 mm whereas in North West Province the equivalent figures are 10 and 300 mm respectively. There are no limits for the species in Gauteng. To ensure sustainable harvesting of this species, the national Yellowfish Working Group (YWG) has recommended a maximum daily bag limit of two fish between 30 cm and 50 cm and these may only be captured by rod and line.

Protected areas and conservation programmes

Although Chutter and Heath (1993) regarded the natural resilience of this species as generally high, Russell and Rogers (1989) reported declines within the rivers in the KNP. Deacon (personal communication) pointed out that the KNP did not offer proper sanctuary to fish species because habitats in the park are greatly influenced by land-use activities upstream. Angliss et al. (2005) confirm this by stating "in the absence of an ecological reserve, those mountain catchment areas of the Mohlapitse, Selati and Makhutswi Rivers should be afforded high levels of protection. The upper catchments have been seriously neglected in recent years and there is an urgent need to implement strict veld management." These declines underline the necessity of conservancies, such as those on the Orange-Vaal and Elands Rivers that focus specifically on rivers and their biota.

Growing angling interest in this species, specifically amongst fly fishers, has seen facilities being developed to cater for anglers. Barbus Haven is a conservancy on the upper Magalies River dedicated to conserving and providing catch-and-release angling for largescale and smallscale yellowfish. at the species might also benefit from the large number of private conservation areas currently being established within its natural distribution range. It is known that several private conservation areas are currently being established within the distribution range of *L. marequensis* and hopefully they will benefit it.

Hatcheries and stockings

As far as could be established from the provincial conservation officials in Limpopo, Mpumalanga, Limpopo and KwaZulu-Natal no official stocking of *L. marequensis* is taking place. They were also convinced that no privately owned hatcheries in their respective provinces were propagating this fish. Persistent reports have been received that a hatchery in North West Province is breeding *L. marequensis* and it is known that it has been introduced privately into at least the Bloemveld Dam near Vryheid (Coke, personal communication).

Improved management of water resources

In terms of water supply for the environment, Ecological Reserve determinations should be conducted for all major river systems and in-stream dams. Implementation of the Reserve, and specifically the control of releases from impoundments, would go a long way towards ensuring improved river health.

The Department of Water Affairs and Forestry (DWAF) has completed several of these reserve determinations but generally they are not being implemented. While it is understood that the DWAF has a difficult task in addressing administrative issues behind the process, its inability to implement the Reserve must be seen as a major failing.

Fragmentation of rivers is also a matter of concern and the construction of fishways at newly planned and existing weirs is a major priority. The Water Research Commission has funded a major project on fishways that is to be published as a book in the near future. For this reason a study is currently underway in the Luvuvhu River to establish the extent of river fragmentation in order to suggest where and how fishways should be constructed.

Presumably, the current lack of co-ordination and co-operation among key stakeholders in river and fish management will be overcome when Catchment Management Agencies (CMAs) are established within the WMAs. The first fully operational CMA in South Africa is the Olifants River CMA – this could greatly improve catchment management in this water-stressed area.

Research and Monitoring Needs

Given that *L. marequensis* is not threatened, the River Health Programme is seen as the best tool for monitoring its status. The following research priorities have been identified:

- Determine the effect of in-stream barriers on population genetics and population status and identify appropriate mitigatory actions.
- Determine the genetic and morphological variation within *L. marequensis* to see whether there are any unique geographically isolated populations worthy of more protection.
- Undertake a biological and ecological study of the species to identify key factors that need to be addressed by conservation managers (e.g. growth rates, life history requirements).

Value of the Yellowfish Resource to Recreational Anglers and Subsistence Fishers

Several researchers have commented on the potential of *L. marequensis* as an aquaculture species. Toots (1972) referred to it as a "useful and productive" candidate that could be harvested from constructed farm dams. Gaigher (1971) collected large numbers of the species while investigating the cropping potential of impoundments. Based on the preponderance of small fish in the sample, he concluded that its productivity was low. Saayman et al. (1983) who carried out a similar investigation in the Nzhelele Dam, however, regarded it as one of the commercially viable species in that water.

Yellowfishes have always been a popular quarry with anglers although they are not regarded as good table fish. Cadieux (1980) reported that yellowfishes, including *L. marequensis*, contributed 25 percent to the mass of fish caught in the Transvaal in those years. Gaigher (1969), on the other hand, concluded that many anglers considered *L. marequensis* as a pest because of the large numbers of small fish in the catch. At present, this large and relatively common yellowfish is growing in popularity amongst anglers – the South African record is 5.75 kg and the Zimbabwean one 3.4 kg (Bell-Cross and Minshull, 1988; http//wwwfishingafrica.co.za). In some areas it is also important to subsistence anglers – studies on the Luvuvhu River have shown that it constitutes up to 10 percent of the total mass of fish caught (Van Der Waal, 2000).

Yates (1950), an ardent fly angler, states that he had his "best fly fishing for yellows" in the Inkomati headwaters and in the Lomati River. He did not specify the species caught but careful examination of the photographs in his book, which included scale counts on the lateral line, indicates without doubt that the fish were *L. marequensis*. Over the past decade or two "yellowfishes" have become sought-after targets among fly fishers and each of the nine species has been taken on fly. *L. marequensis* has proved to be one of the more challenging to catch because of the subtle way in which it can mouth a fly and eject it without the angler noticing.

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STATUS OF THE BUSHVELD SMALL-SCALE YELLOWFISH *LABEOBARBUS POLYLEPIS* (BOULENGER, 1907)

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ABSTRACT

The Bushveld smallscale yellowfish *Labeobarbus polylepis* Boulenger, 1907 is restricted to the southern tributaries of the Limpopo, Inkomati and Phongolo River systems and populations are declining from its known localities. *Labeobarbus polylepis* is an indicator species for in-stream flow requirements as its habitat, especially the spawning beds, are sensitive to stream regulation. Knowledge on the reproductive requirements of this species have enabled aquatic scientists to better conserve spawning habitats, reduce anthropogenic disturbances to rivers and ensure environmental flow requirements for the species. The chapter includes detailed information on the spawning requirements and behaviour, and early life history stages of *L. polylepis*. Long-term conservation of this species will depend on effective ecosystem management practices and the role of *L. polylepis* as a flagship species to create public awareness of the need for conserving freshwater systems.

Introduction

The Bushveld smallscale yellowfish, *Labeobarbus polylepis* Boulenger, 1907*,* is a large yellowfish species restricted to higher altitude tributaries of the Limpopo, Inkomati and Phongolo River systems (Figure 1). This temperate species does not occur below altitudes of 600 meters and is naturally restricted to perennial rivers with riffles, runs and deep pools. Although it is a strong swimmer, clearly adapted to living in fast-flowing waters, it readily inhabits dams. *Labeobarbus polylepis* is a true yellowfish as it has a hexaploid karyotype of around 150 chromosomes and parallel-striated scales (Oellerman and Skelton, 1998). It often co-exists with another true yellowfish, the Lowveld largescale yellowfish *Labeobarbus marequensis* (A. Smith, 1841).

The upper reaches of rivers serve as a benchmark for flow in the lower reaches of the river. This species is therefore particularly useful for the determination of environmental flow requirements as it has very specific spawning requirements related to flow conditions.

This chapter describes our current knowledge of this relatively widespread yellowfish with particular emphasis on its breeding biology, the subject of a recent intensive study by the author. The chapter concludes with recommendations for the future conservation of *L. polylepis.*

Taxonomic History

Barbus polylepis, Boulenger, 1907. Type locality: Klein Olifants R., Transvaal, South Africa.
Holotype (unique): BMNH 1907.3.15.3.

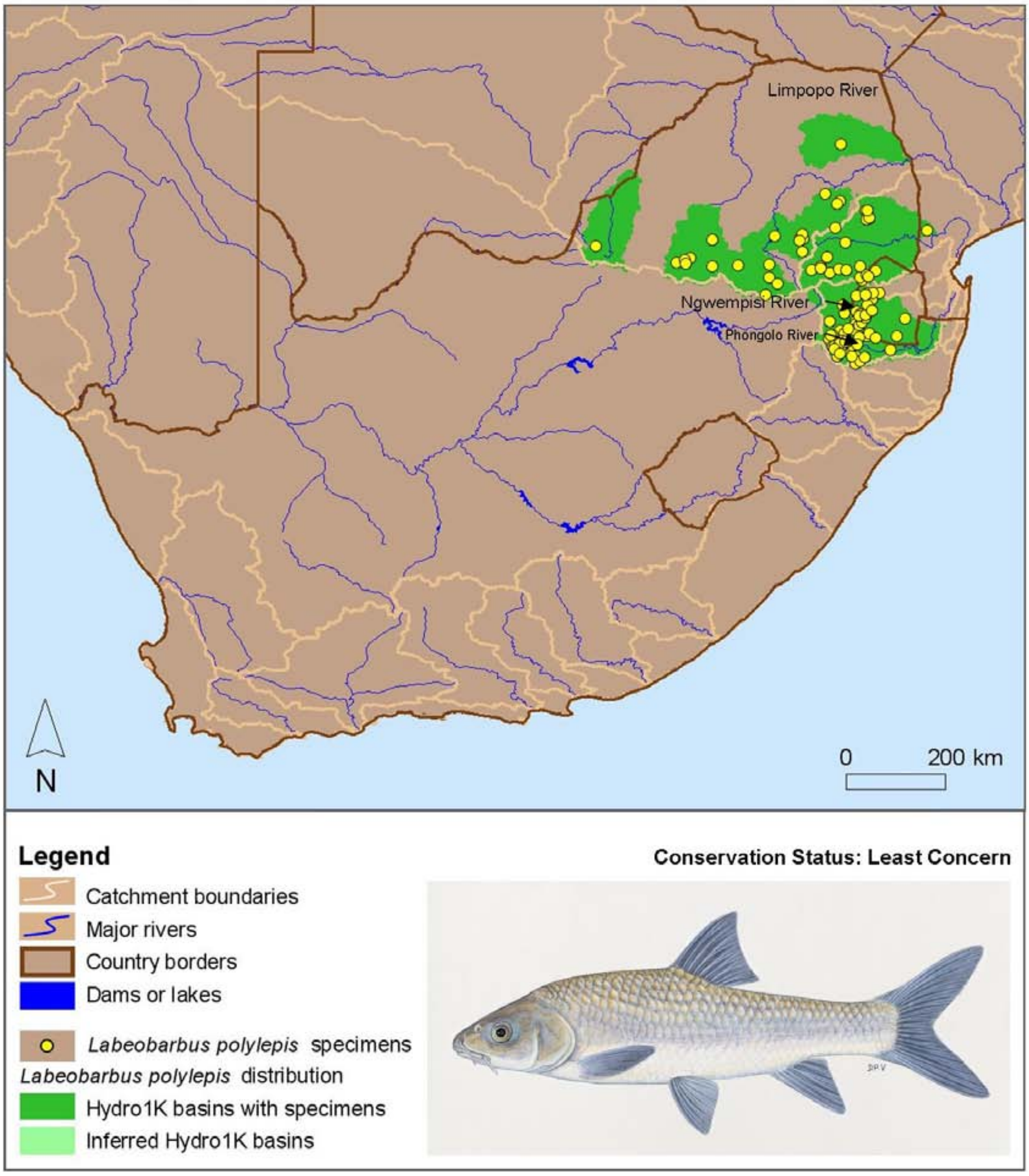

Figure 1: Distribution of Labeobarbus *polylepis,* based on voucher records (prepared by W. Coetzer, SAIAB).

Distribution and Population Status

Labeobarbus polylepis is still widely distributed and relatively abundant across the upper catchments of the Limpopo, Inkomati and Phongolo drainage basins. For these reasons it has been listed as Least Concern (LC) (IUCN 2007).

In general, the overall status of the habitat of the rivers within the distribution area of *L. polylepis* is fair to good, except for the upper Olifants and the southern Gauteng rivers that are in poor health and polluted as a result of urban, mining and industrial development. As for most yellowfish species in southern Africa, the natural distribution range and population densities of *L. polylepis* are on the decline. The status of the species in the Limpopo, Inkomati and Phongolo River systems is presented in Table 1.

Table 1: Status of *Labeobarbus polylepis* in three river systems.

River System	Sub-catchments	Rivers	Population status	Factors affecting species or habitat
Limpopo	Upper Olifants	Klein Olifants Bronkhorstspruit, Wilge, Steenkoolspruit.	Large numbers in dams, fair numbers in rivers. Threatened by hybridisation.	Water pollution (leachate and acidification), land modification, large storage dams, stream regulation, migratory obstructions, genetic pollution/hybridisation between Orange-Vaal smallmouth yellowfish *Labeobarbus aeneus* Burchell, 1822 and *L.polylepis,* alien fish species such as common carp *Cyprinus carpio* Linnaeus, 1758 and bass (*Micropterus* spp.).
	Middle Olifants	Spekboom	Viable population.	Hybridisation with *L. aeneus*.
		Blyde	Large and possibly unique population.	
		Steelpoort	Declining population	Over-abstraction and poor water quality.
	Crocodile-Marico	Apies-Pienaar, Upper Crocodile, Elands & Marico	Declining numbers, low genetic diversity	Water pollution, habitat destruction, large storage dams, stream regulation, migrational obstructions, alien fish species (carp and bass), return flows and sewage spills, urbanisation, river-bed and flow modification.
	Mogol	Tributary in the Waterberg	Rare	No information available
Inkomati	Sabie-Sand		Declining numbers	Overexploitation through gill netting
	Upper Inkomati		Viable population with large numbers in Dams.	River regulation, migratory obstructions, gill netting.
	Crocodile-Elands	Crocodile, Elands and Houtbosloop	Viable populations with possibly unique population in Elands above waterfall.	Alien plant infestation of the riparian zone.
Phongolo		Phongolo, Usutu, Ntombi, Chlelo, Assegaai, Ngwempisi	Large numbers in dams and viable populations in rivers, unique population overall.	Water pollution (urban return flow and sewage spills) in middle and lower reaches. Large storage dams, stream regulation. Migrational obstructions, alien fish species (carp and bass), overabstraction. Sedimentation and siltation.

Biology and Ecology

Morphology and genetics

The dorsal fin formula is D IV, 8 and the anal fin is A III +5. The primary dorsal fin ray is flexible and segmented and originates above or slightly in front of the origin of the pelvic. The scales are in a lateral line 36 to 44 (usually 40), with 14 to 18 (usually 16) around the caudal peduncle.

The mouth is sub-terminal and has variable lips with two pairs of barbels. Males and females develop small white tubercles on head, upper body scales, anal and dorsal fin rays during spawning time. The juveniles are silvery with dark spots on the body, while adults are dark olive green above and bronze on the sides. The fins are characterised as dark grey and green. The yellow tail is fairly distinctive of the species (Figure 2). They reach a maximum total length (TL) of approximately 59 cm and a mass of 6.8 kg (Skelton, 2001).

Figure 2: Adult *Labeobarbus polylepis*, (photo Gordon O' Brien).

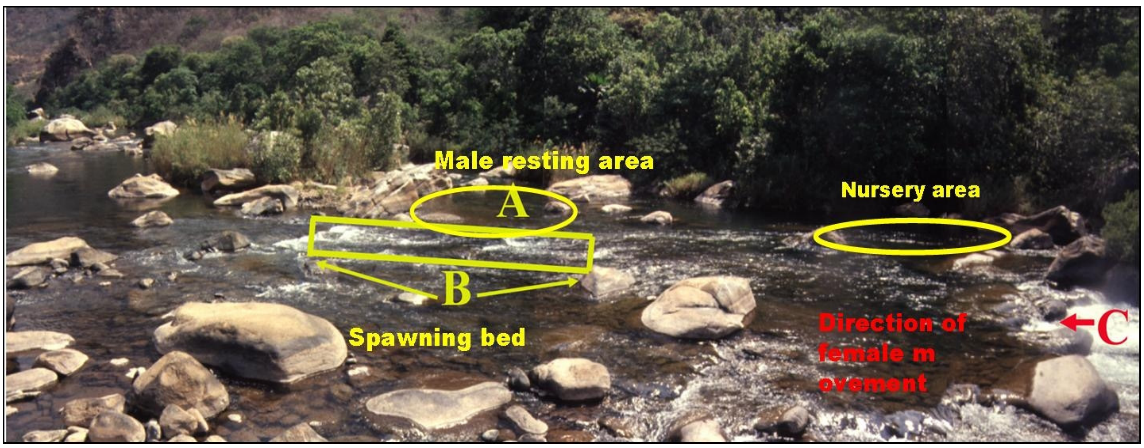

Figure 3: Spawning habitat for *Labeobarbus polylepis* in the Blyde River.

Recent genetic studies (Mulder et al., 1997) confirmed that there are significant differences among four populations of *L. polylepis* in different parts of their three native-river systems. The highest genetic diversity was present in the Spekboom population (Limpopo) and some alleles suggested that there might be hybridisation with *L. aeneus*. This probably occurred when both species were kept at the Lydenburg Fish Hatchery in the 1960s but also through direct introduction of Orange-Vaal smallmouth yellowfish *L. aeneus* (Burchell, 1822) into rivers in the Limpopo catchment.

Habitat requirements and feeding

This temperate species does not occur below altitudes of 600 meters and is naturally restricted to perennial rivers with riffles, runs and deep pools. Although it is a strong swimmer, clearly adapted to living in fast-flowing waters, it readily inhabits dams. At spawning areas, the river classification demonstrated a complex channel: an active channel entrenched within a macro channel. Generally, the river at these spawning sites, has a single-thread pattern, which is stable and sinuous. Within this reach, there is evidence of anastomosing (braided channels) particularly at higher flows. The channel banks are composed of a mixed cobble-gravel-sand matrix, which is relatively stable. Cobbles and boulders in both riffles and pools dominate the channel bed. Channel morphology consists of a succession of riffles and pools. The physical habitat appears to be very good with a stable bed, numerous interstitial spaces between cobbles and a range of hydraulic features. Pools also provide a good habitat with adequate depth and a diverse bed substrate.

Labeobarbus polylepis is an omnivore, feeding predominantly on filamentous algae during autumn and winter and benthic invertebrates in the summer months, but also takes mussels, snails, crabs and small fish.

Breeding biology

This section is summarised from Roux (2006) unless otherwise indicated. Female *L. polylepis* mature at 30 cm and males at around 17 cm. Breeding takes place during spring and summer. There are no distinct differences between males and females except in the Blyde River where ripe-running males have darker dorsal and caudal fins. For the rest, colour and morphology are similar, the most notable difference being the obviously swollen abdomens of gravid females. Gaigher (1969) surveyed the Inkomati River over four seasons and recorded an unbalanced sex ratio for *L polylepis* of 60.2 percent males to 39.8 percent females. Whether this was a sampling artifact or whether it actually demonstrated a higher female mortality is uncertain.

Labeobarbus polylepis occurs in more temperate areas with dry winters and wet summers. Results indicate that this species spreads its reproductive effort across a short period in the early summer season, generally in October. Although spawning has been observed as late as February, this appears to represent opportunistic efforts by relatively small numbers of fish. Typically, spawning behaviour was seen to involve three distinct stages: pre-spawning, spawning and post-spawning behaviour (Table 2). The spawning area is divided into three sections: the spawning beds, male resting areas and nursery areas (Figure 3). This pattern may be important as stimuli for the development of gonads and the maturation of ova.

Table 2: Summary of *L. polylepis* breeding behaviour in the Blyde River in 1999.

Behavioural event and first observation date	Description of behaviour
Reproductively inactive (1/8/99).	No fish observed at inlet or river.
Pre-migration congregation (8/9/99).	Large concentration of *L. polylepis* males observed at Blydepoort Dam inlet. The fish were swimming up and down into and out of the Blyde River. They seemed to be waiting for the right stimuli to start spawning migration up the Blyde River to the spawning beds.
Spawning migration (21/9/99)	Large quantities of fish migrating from dam into river.
Pre-spawning congregation (5/10/99).	*L. polylepis* males concentrated in large shoals in the deep pools close to the spawning beds in the Blyde River. Large females were observed in deeper river habitats close to spawning beds.
Spawning (9/10/99).	*L. polylepis* males in shoals on the spawning bed awaiting females. Limited spawning behaviour seen.
Spawning (12/10/99).	Major spawning activities take place over a three-day period from 12 to 14 October.
Spawning (15/10/99).	Spawning activities decline.
Post-spawning migration and dispersal (15/10/99–30/11/99).	Most females return to dam but some remain in deeper water in the river. Small numbers of males remain close to spawning beds.

Environmental cues associated with spawning

Water samples from spawning sites were analysed for pH, Kjeldahl nitrogen, ammonium, nitrate and nitrite, fluoride, alkalinity, sodium, magnesium, silica, total phosphate, orthophosphate, sulphate, chloride, potassium, calcium, electrical conductivity and total dissolved solids. There was no obvious change in water quality that might be considered to have triggered spawning. However, at spawning beds in the Blyde River, the water was of high quality (clear) and of low conductivity (140 µs/cm) with a temperature of 22°C and a pH of 8.4. Pre-spawning migrations are stimulated when daylight length exceeds 12 hours 5 minutes. Both males and females started congregating over spawning beds when daylight length exceeded 12 hours 24 minutes, with the actual spawn occurring when daylight length was in the 12 hour 30 minute to 12 hour 38 minute range. Other than temperature and daylight duration, meteorological data did not indicate any other obvious trends that could serve as a possible stimulus to trigger spawning behaviour.

Habitat requirements for spawning and nursery areas

The spawning beds (Figure 3) where the eggs were deposited are situated in water with an average depth of 16 cm and a velocity of 0.65 m/sec. The spawning-bed substrate in the Blyde and Spekboom Rivers consisted of 77.3 percent pebbles and gravel, 6.4 percent sand, 16.2 percent silt and 0.1 percent clay. The eggs lodged in interstitial spaces in the cobbles and pebbles in and around the actual spawning site and did not wash downstream as would have been expected.

Male resting areas in both rivers are close to the spawning beds but are deeper and the water flows more slowly – the average depth is 32.5 cm and the average velocity 0.15 m/sec. This enables the males to remain close to the spawning beds and to conserve energy while awaiting females.

Free embryos of *L. polylepis* drift from the spawning beds into nursery areas where they develop into larval fish. Cambray et al. (1997) suggest that larval distribution is dictated by both current speed and water depth. Nurseries are usually quiet backwaters near the spawning beds with a substrate consisting mainly of silt and submerged vegetation. Larvae were first noticed in the nursery areas about 10 days after the spawn. Typically, nursery areas are approximately 25 cm deep and water flows across them at a rate of about 0.02 m/sec. They are linked to the main channel by minor connecting channels. Nurseries may be shaded by riparian vegetation or they may be in full sun where temperatures as high as 38ºC were measured. The abundance of shelter provides better protection from predators and results in higher survival rates.

Spawning behaviour

Spawning activity peaks in early summer, usually October and November, but sporadic breeding by small groups of adults may continue until February. Pre-spawning commences when large concentrations of males and females migrate upstream to the major spawning beds – a distance of approximately 2.2 km on the Blyde River. This pre-spawning migration is triggered when water temperatures rise above 18ºC and daylight length exceeds 12 hours and seems to be essential for many species.

The actual spawning event starts when as many as 150 to 200 males ranging in size from 18 cm to 32 cm (FL) assemble in the male resting areas. These areas are, on average, 33 cm deep and the water velocity is around 0.15 m/sec – the slower current enables the males to maintain their position close to the spawning beds and to conserve energy. Females ready to spawn move upstream from the deeper pools, and swim through the shoal of awaiting males. At this stage, from seven to thirteen males follow the female onto the spawning bed and keep close to her. When they reach the top end of the spawning bed a wild splashing commences and the release of spawn, consisting of eggs and milt, causes a pronounced discolouration of the water. The fertilized eggs sink and lodge in the interstices of the cobbles and pebbles of the spawning bed.

Studies indicate that spawning is governed essentially by water temperatures in the 21ºC to 22ºC range – it ceases when the temperature drops below 20.8ºC or rises above 23ºC. Spawning occurred in full sunlight when daylight length was greater than 12 hours 30 minutes but less than 12 hours 38 minutes. (See my earlier comment.) The spawning area (Figure 3) comprises three sections: the spawning beds, male resting areas and nursery areas.

Embryonic and larval development

Smallscale yellowfish eggs are relatively small with a mean diameter of 1.5 mm and swell to 3 mm during water hardening. The eggs are slightly adhesive and negatively buoyant. The adhesiveness of the eggs further ensures that they attach themselves to the spawning medium. This status quo is maintained until the eggs are water hardened and approximately 46 percent bigger (1.5 mm to 3 mm). They now have a large periviteline space; a feature associated with fish species spawning in fast-flowing waters, to shield the developing embryo during turbulence. The adhesiveness is lost after 30 minutes once the eggs are water hardened.

At a constant water temperature of 21°C, hatching commenced after 96 hours and continued for another 48 hours. Ten percent of the eggs hatched between 96 hours and 120 hours and the remainder between 120 and 144 hours. The average size of the embryos was 7.3 mm total length. They immediately started with a continuous vertical swimming action that lasted for almost five days at which point they reached the free-swimming stage. The free embryos repeatedly swam rapidly to the surface and then dropped back to the bottom. At this stage they were swept downstream to the nursery areas, the extent of larval distribution being dictated by both current speed and water depth. Nursery areas support the rapid growth of juvenile fishes because they have more food, are warmer, and are safe from predation. From their feeding behaviour, it is evident that yellowfish larvae are dependent on invertebrate and algal drift.

Juveniles in the nursery area ranged from 12 to 22 mm in length. When they grew larger they moved to faster-flowing water where the bottom is lined with pebbles and gravel. The juveniles collected here ranged from 25 mm to 110 mm (TL). The change to a different habitat-type may be related to a change of diet or to the larger size food organisms associated with riffles and runs. It may also imply a trade-off between the ability to cope with fast currents and predator avoidance – small juveniles simply can't deal with fast water but as they grow they are increasingly able to cope with it and do so to avoid predators such as birds, fish and macro-invertebrates.

The reproductive style (Balon, 1975) of *L. polylepis* belongs to Etholigical section: Non-guarders, that are open sub-stratum spawners (A.1.), which deposit eggs on rocks or gravel bottoms where their embryos and larvae develop (A. 1.3.). The smallscale yellowfish is thus highly selective and specialised in terms of its breeding requirements. First, the spawning site has to fulfil very special requirements in respect of suitable stream velocity, depth, substrate composition and layout (structure) of the spawning beds. Second, spawning only commences when the specific environmental cues such as daylight length, water temperature and constant low flow satisfy the requirements of the adult fishes.

Threats

There are essentially two impacts from dams: first, fragmentation of the system which causes reduced genetic communication and second, alteration of those environmental conditions (flow, temperature, chemistry) that may result in aseasonal cues or no cues, poor recruitment, and finally, in localized extirpation of the species.

The construction of many large dams such as Nooitgedacht, Vygeboom, Blyderivierspoort Rooikopjes, Vaalkop, Roodeplaat, Klipvoor, Molatedi, Westoe, Heyshope, Jerigo and Morgenstond probably poses the biggest threat to this migratory yellowfish species. In-stream dams in South Africa generally do not release environmental flows and hence alter natural flow patterns by reducing the incidence and extent of floods. The form, hydrology and functioning of rivers worldwide have been increasingly modified by a range of human activities, and these geomorphologic and hydrological changes influence the structure and dynamics of entire biological communities in rivers.

River regulation normally imposes more stable conditions, which favour introduced fish such as carp *Cyprinus carpio* Linnaeus, 1758 and largemouth bass *Micropterus salmoides* (Lacepède, 1802), but it is generally disadvantageous for the native ichthyofauna. The consequences of river regulation are mainly detrimental to lotic biodiversity (Hellawell, 1988). The *Labeobarbus* species and their habitat are threatened by river regulation, since the ever-increasing numbers of dams, weirs, causeways and culverts prevent natural migration. These barriers also fragment populations and cause a loss of spawning grounds – the resulting lack of continuity may prevent re-colonisation of an area after severe drought (Cambray, 1991).

Several areas within the natural distribution range of *L. polylepis* have been separated from each other for very long periods of time by natural physiographical barriers such as waterfalls. The populations that were isolated in these areas are now morphologically distinct. Building dams has led to further isolation and fragmentation of these populations. Furthermore, downstream migrations through dams and weirs are subject to severe predation by alien fish species such as *M. salmoides* which thrive in these artificial lentic habitats.

Water from the Swadini Dam in the Blyde River Canyon Nature Reserve is usually released in late winter and early spring for agricultural purposes. Depending on the time of the year, water temperatures in the river may be significantly lower or higher than above the dam due to hypolimnetic releases. During the *L. polylepis* breeding season, water temperature in the Blyde River below Swadini Dam seldom exceeds 15°C whereas above the dam it tops 20° C thereby stimulating spawning activity. The much lower temperature of water released from the bottom of the dam is probably the reason why the fish below the dam are not stimulated into spawning mode. Even a successful spawning will not necessarily lead to high recruitment if the appropriate temperature and flow velocity are then not maintained long enough to allow embryos and larvae to develop. Furthermore, hypolimnetic releases are significantly depleted in oxygen, enriched in nutrients and carry less sediment thereby increasing the erosive power of the water. Each or all of these factors may mask breeding cues and are probably the reason why *L. polylepis* is unable to breed and maintain a viable population in the Blyde River below Swadini Dam.

Large numbers of *L. polylepis* congregate in the Assegaai River below the Heyshope Dam in early summer during their spawning migration. Inasmuch as there is no fishway to facilitate crossing the dam wall, these fish are blocked and cut off from their traditional spawning grounds. At this time of year water is released for agriculture and the resulting fluctuations in temperature and river levels lead to increased stress in the trapped fish. This in turn manifests itself in external parasites on some specimens. Bottom-release water causes a sudden drop in water temperature and is also characterised by lower oxygen and higher nutrient levels. These factors combine to kill many of the parasite-infected fish. Owing to inadequate spawning habitat in this area, spawning success is low. Furthermore, the fish trapped below the dam wall are an easy target for illegal gill-netters.

The same scenario was observed in a recent case study on the Spekboom River where a massive fish kill occurred at an illegal barrier. This barrier was erected in the river during the summer when adult fishes were upstream on their spawning beds. When the fish tried to return downstream after spawning they were trapped by the barrier. When temperatures fell during the winter months, the fish could not escape to warmer water downstream and many died.

The main tributaries of the upper Olifants, the Klein Olifants, Elands, and Wilge Rivers and the Bronkhorstspruit all rise on the highveld grassland. They are severely affected by several large impoundments such as Witbank, Middelburg, Doringpoort and Loskop Dams and extensive mining activity. Coalmines and other industrial activities in the area contribute enormously to poor in-stream and riparian habitat conditions. Acid leachate from the mines causes the river water to become highly acid and with a high conductivity. Ecologically inappropriate releases of water from the large storage dams result in further environmental degradation downstream, such as increased sediment deposition and erosion due to increased flow velocities in the dams and so outflow water typically has higher erosion power.

The catchments of the Crocodile (West) and Marico Rivers are situated primarily in the Northwest Province and the northern region of Gauteng. The sub-catchments of concern for *L. polylepis* are the Apies-Pienaars, the upper Crocodile, the Elands and Marico Rivers. The Hartbeespoort, Rooikopjes, Vaalkop, Roodeplaat, Klipvoor and Molatedi Dams are the larger reservoirs on these rivers. The land use in the south-eastern part of the catchment is dominated by the urban sprawl of Johannesburg and Midrand and north-west of Johannesburg by small holdings and commercial agricultural activities. The upper Crocodile River sub-catchment includes numerous small to medium opencast mines as well as many large chrome and platinum mines. The ecological condition of the Apies-Pienaars and upper Crocodile River sub-catchments is poor, primarily because of flow and bed modifications caused by high levels of urbanisation and land-use activities. Main sources of pollution include urban return flows and sewage spills. An additional effect here is that much of the water entering the system is transferred from the Orange River in Lesotho. It enters the municipal system and returns as treated sewage-return flow – chemically it is very different. The upper Apies appears to be devoid of fish life in general.

In the upper Inkomati River catchment, poor farming practices have changed many streams from being narrow and deep with clear water into wide, shallow muddy tracts. During periods of high flow, water is very turbid and when the velocity decreases, silt is deposited in the spaces among boulders and cobbles, destroying spawning habitat for those species with demersal, non-adhesive eggs. The infilling of interstices can also reduce the amount of cover available for the larvae and juveniles of some fishes. Previously, flooding would have flushed the fines from many reaches of the rivers but with the building of dams, the extent of scouring has been reduced and silt deposits may accumulate that asphyxiate the eggs and early free embryos. Variable flows with floods are necessary in many rivers to clean the substrate and maintain the physical integrity of the river channel (Cambray, 1991).

The introduction of alien fishes such as rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792) and brown trout *Salmo trutta* Linnaeus, 1758 in the headwaters of some catchments is a cause for concern. In order to create suitable holding water for trout, many in-stream weirs and small dams are built. These inhibit downstream and upstream migrations of *L. polylepis* and juvenile mortality is high because of the predatory trout.

Conservation Measures to Conserve the Yellowfish Resource

Legislation

In order to protect this species in Mpumalanga Province, current provincial environmental legislation specifies that anglers in possession of a valid freshwater angling license may keep only six *L. polylepis* with a minimum total length of 300 mm. Newly proposed recommendations will allow anglers to keep only two fish of this species whilst encouraging catch-and-release as far as possible. However, *L. polylepis* is found in four other provinces, each with its own catch restrictions, making enforcement difficult. Clearly, fish species must be managed by uniform national legislation.

Hatcheries and stockings

A moratorium has been placed on all translocations and releases of yellowfish within the country in order to protect the genetic diversity of the different species. Mulder et al. (1997) have recommended that only fingerlings should be stocked and only within the catchment where they originated. Until such time as a more in-depth study is completed stocking should be confined to dams. It is accepted that indigenous species released into stretches of river, which they occupied previously, would have a smaller ecological impact on aquatic ecosystems compared to alien fish species (Impson and Bok, 1995). Cambray (1998) has cautioned against the placing of such large predators as yellowfish into rivers that did not form part of their natural range, as these would be alien introductions. According to Mulder (2000), in a species such as *L. polylepis,* which is distributed over different river systems, a lack of migration routes and connectivity between the systems may lead to a high degree of genetic divergence among subpopulations. This can produce a highly fragmented gene pool where opportunities for population differentiation, some of which may be adaptive, are enhanced. Co-operation with nature conservation authorities is necessary to improve management plans and strategies, and to deal pro-actively with genetic management of natural populations and the release of hatchery bred fingerlings into wild populations. The genetic integrity of hatchery fish is frequently a major ecological issue and hatchery fish should only be used if they are genetically appropriate for the receiving system.

Protected areas and conservancies

To date, only one conservancy, the Elands River Yellowfish Conservation Area (ERYCA), established in 2004, has been set up within the distribution range of *L. polylepis*. This conservancy covers the Elands River from the town of Waterval Boven to its confluence with the Crocodile River. The goal is to promote *L. polylepis* as a flagship species for the Elands River and the conservation of the aquatic habitat. According to local ERYCA representatives, their efforts are leading to a steady growth in the *L. polylepis* population in the Elands River.

At present three healthy and viable populations of *L. polylepis* are within protected areas, namely the Blyde Canyon Reserve on the Blyde River and the Nooitgedacht Dam and Songimvelo-Malalotja Nature Reserves on the upper Inkomati River. Conservation authorities in Mpumalanga, regard *L. polylepis* as one of the more important species that provide information on how to manage aquatic ecosystems and resources.

Monitoring, Research and Conservation Needs

The key needs for the conservation of *L. polylepis* would be to implement a study on the various aspects of river regulation and migration-route obstructions caused by major storage dams and weirs, and their impact on this species. Environmental flow releases from in-stream dams should be implemented to maintain the ecological health of rivers and improve the breeding success of *L. polylepis*. Ways to facilitate the free passage of yellowfish over or around migration barriers in the different river systems should be given top priority. As man modifies more rivers, managers require information on what allowances should be made for the maintenance of the downstream aquatic environment. To accomplish this, there is, therefore, a need in South Africa to develop habitat suitability index graphs for each of the major life stages of important indicator species.

Other issues requiring attention:

- A more comprehensive genetic analysis to determine whether sub-species or distinct populations (Evolutionary Significant Units or ESUs) are present.
- Identify and conserve key habitats for the species (e.g. key spawning sites).
- How to protect such areas whether through conservancies, formal protected areas, seasonal protection or by other means.
- Long-term research and monitoring programmes to determine the effectiveness of a conservation strategy for the species.
- Prohibiting the transfer and stocking of alien fish within the natural range of *L. polylepis*.
- Maintaining a moratorium on the transfer of yellowfish (Arderne, 2002).
- Incorporating fishways in dam and weir designs.
- The use of dams and/or weirs to protect upstream sub-populations of *L. polylepis* from hybridising with *L. aeneus*.
- The strict control of all aquaculture facilities to prevent hybridisation.
- Prosecuting illegal gill-netters.

Value of the Yellowfish Resource to Recreational Anglers and Subsistence Fishers

Labeobarbus polylepis is an increasingly popular angling species, as the growing number of articles in the angling media testifies. It attains a large size and is relatively abundant and accessible in many rivers in close proximity to major angling centres such as Johannesburg, Pretoria and Nelspruit. Fly anglers, in particular, are finding it a challenging quarry demanding considerable skill to capture. This increasing demand has led to the establishment of professional guiding operations on the upper Phongolo, Inkomati and upper Magalies rivers. Subsistence fishers also take it regularly, often illegally by means of gill nets or seines. This practice needs to be stopped otherwise smallscale yellowfish, especially adults, will become rare in certain rivers.

Conclusion

The habitat requirements for *L. polylepis* to breed successfully are extremely demanding and this may explain why it has disappeared from many impacted rivers in its range. The numerous dams and weirs strung out along rivers and streams severely impede its spawning runs and water releases from these dams rarely provide the environmental cues that stimulate this species to reproduce.

The long-term conservation of this species will depend, therefore, on effective ecosystem management and using it as a flagship species to create public awareness of the dire need to conserve our freshwater resources. However, in order to achieve these goals, knowledge underpinned by basic research is imperative.

In South Africa, basic knowledge of species biology and ecology is simply too meagre at present to provide effective management advice. There is a strong need for further detailed studies on the ecology of keystone species in the various river systems in the country. Sound basic knowledge is irreplaceable when it comes to making decisions on the environment (Skelton, 2000).

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STATUS OF THE ORANGE-VAAL SMALLMOUTH YELLOWFISH *LABEOBARBUS AENEUS* (BURCHELL, 1822)

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ABSTRACT

The Orange-Vaal smallmouth yellowfish *Labeobarbus aeneus* (Burchell, 1822) belongs to a family of cyprinids indigenous to southern Africa. It is common throughout its natural range, the Orange-Vaal River system, as well as in impoundments in the system. *Labeobarbus aeneus* has successfully inhabited a number of rivers and dams outside its natural range. It is considered a least concern species and is common throughout its natural range. Despite the large habitat alterations within the Orange-Vaal River system, in both habitat and flow regime, *L. aeneus* thrives. This is a favourable situation as it is a very popular angling fish with a high recreational angling value. Although *L. aeneus* has demonstrated high levels of biological flexibility, certain anthropogenic influences may affect it negatively in future, particularly water abstraction and pollution. Large fish kills have been recorded as a result of pollution. Although *L. aeneus* is a least concern species according to IUCN listings because of its success and popularity it must be assured that the species does not face the demise experienced by other popular species worldwide and that the species remains a benchmark for future conservation efforts.

Introduction

The Orange-Vaal smallmouth yellowfish *Labeobarbus aeneus* (Burchell, 1822), previously known as *Barbus aeneus* (Burchell, 1822), (Berrebi *et al*., 1996) and *Barbus holubi* Steindachner, 1894 (Hocutt and Skelton, 1983) is a member of the small-scaled yellowfish group. It is endemic to the Orange-Vaal River System (OVRS), but currently has several thriving alien populations due to Inter-Basin Water Transfer Schemes (IBWTS), and accidental and intentional introductions for angling purposes (Jubb and Farquharson, 1965; Cambray and Jubb 1977a; De Moor and Bruton, 1988; Swartz (this volume).

The flow regimes of the Orange and Vaal Rivers and their tributaries have been drastically altered by the construction of large in-stream impoundments such as the Gariep, Van Der Kloof and Vaal Dams as well as the largest interbasin water transfer schemes in the country. Naturally, *L. aeneus* inhabits rivers that have large seasonal water level fluctuations, with summer floods and winter droughts (Gaigher and Fourie, 1984; Eccles, 1986) as well as widely varying water quality. The species has shown itself to be adaptable and tolerant of most anthropogenic changes and is arguably the most common freshwater fish species in the OVRS.

A considerable literature exists for *L. aeneus*, covering most aspects of its biology and ecology, including lotic and lentic environments and rivers to where it has been introduced.

This chapter focuses on current knowledge of this well known and valuable species and highlights management needs to ensure that it
remains a common, widespread and socio-economically valuable species.

Taxonomic History

Cyprinus aeneus, Burchell, 1822. Zak R., South Africa. No types known. Moved into the genus *Barbus* by Barnard, 1943.
Barbus gilchristi, Boulenger, 1911. Kraai R., Barkly East, Cape Prov., South Africa. Holotype (unique): BMNH 1909.12.8.1.
Barbus holubi, Steindachner, 1894. Modder R. (Orange R. system), South Africa. Syntypes: (several) NMW 54174-76 (2, 1, 1), 54189 (1).
Barbus mentalis, Gilchrist & Thompson, 1913. Kimberley Reservoir, Cape Prov., South Africa. Holotype (unique): SAM 9644 [now at AMG].

Distribution and Status

Labeobarbus aeneus is endemic to and ubiquitous in the Orange-Vaal River System (Figure 1). Water temperatures and waterfalls restrict its final distribution in the Lesotho highlands. It is found up to altitudes of 2300 metres above sea level during the summer months, moving to lower altitudes during the winter (Jubb, 1965). *Labeobarbus aeneus* is listed *as* least concern (LC), as the species is still widespread and abundant in most of its original distribution range (IUCN, 2007). There are also large populations in several dams in the catchment, notably Sterkfontein, Gariep and Vaal Dams.

Distribution outside natural range

Man's initiative in engineering the various inter-basin transfer schemes and other watershed linkages has resulted in the breaching of geographically isolated river systems, which have been separated for thousands of years (Cambray and Jubb, 1977). *Labeobarbus aeneus* was also stocked for angling purposes into several new catchments, including the Gouritz, Olifants (Mpumalanga) and Great Kei systems. This resulted in the widespread dispersal of fishes outside of their natural ranges. As a result of the removal of watershed barriers, *L. aeneus* has extended its range into a large number of eastward-flowing river systems in southern Africa. Thriving populations of *L.aeneus* are found in most of these rivers (Swartz, this volume). These river systems include the Gouritz, Sundays, Fish, Great Kei, Mtata, Olifants, Limpopo and Sabi Rivers (Schramm, 1993; Laurenson et al., 1989; Louw, 1970; Cambray and Jubb, 1977; Laurenson and Hocutt, 1985; De Moor and Bruton, 1988). Initial surveys to determine the success of the invasive fish biota within the Fish River system revealed interesting findings. The absence of any individuals exceeding 200 mm FL led researchers to conclude that *L. aeneus* populations were unable to persist from continued introduction via the Orange-Fish River Tunnel (Laurenson et al., 1989). However, subsequent findings revealed a thriving population of *L. aeneus* within the Fish River system including individuals up to 518 mm FL (Stadtlander, 2006). The wide size range of *L. aeneus* as well as the presence of all stages of gonadic development in the specimens examined, confirmed the successful colonisation of the Fish River system (Stadtlander 2006). Laurenson et al. (1989) considered the natural fauna in the Fish River system to be depauperate and deemed the introduction of *L. aeneus* as a benefit.

Two endangered species were recorded in the tributaries of the system and seemed unaffected by the translocation of *L.aeneus* (Laurenson et al., 1989).

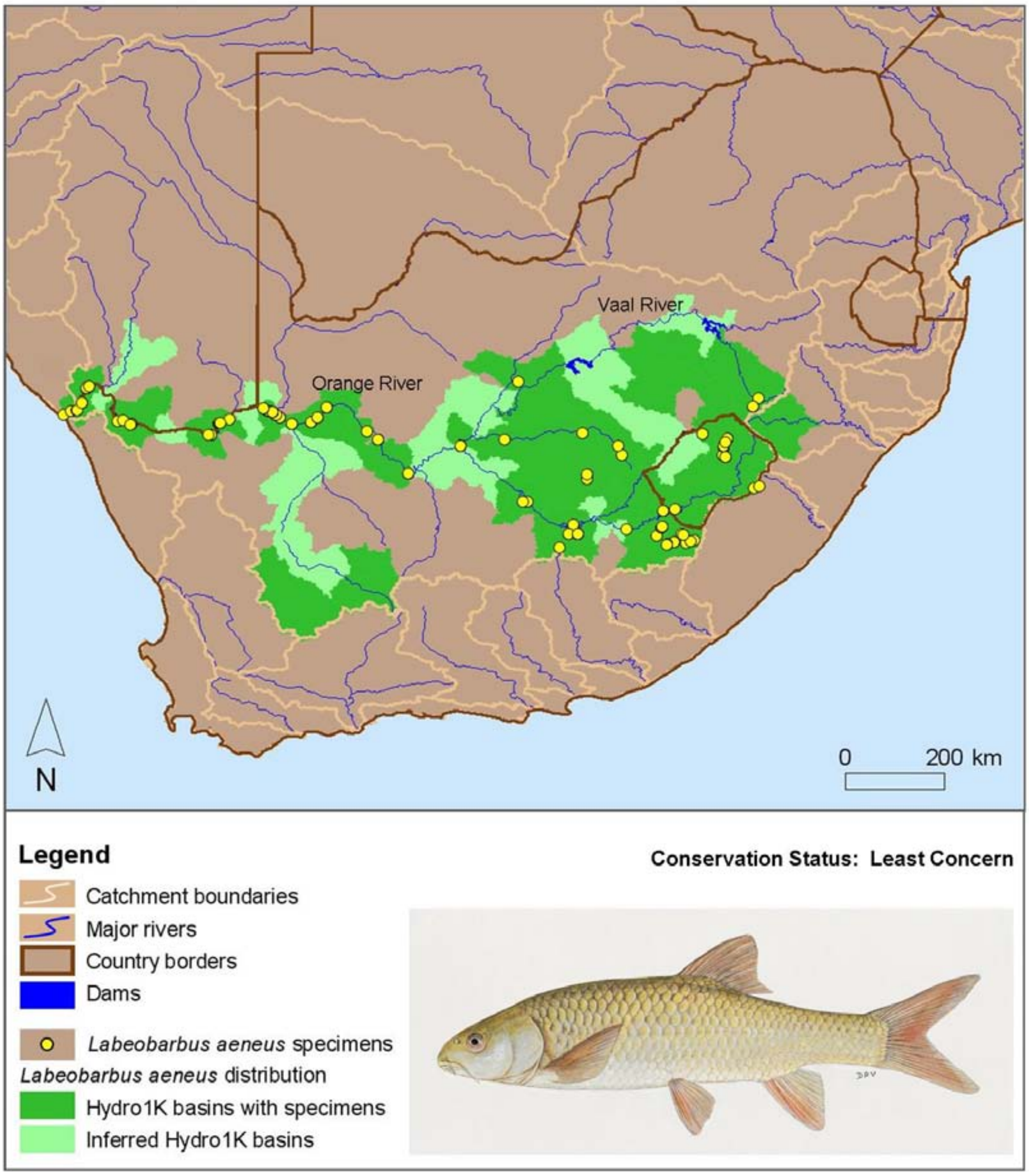

Figure 1: Distribution of *L. aeneus* based on voucher records (prepared by Willem Coetzer, SAIAB).

Current status of habitat

The main streams of both the Orange and the Vaal Rivers are highly regulated. Large impassable reservoirs have been built to store water and generate electricity. These and other large man-made impoundments restrict the upstream migration of fishes. The possibility of downstream passive migration of larvae and juveniles has not been established.

The natural flow regime has been disturbed due to the highly regulated nature of the main stems of the two rivers. Both systems flow throughout the year and it has become critical to design, implement and monitor the Ecological Reserve for each.

The hydroelectric power generating systems on the Orange River result in significant daily flow fluctuations. In addition to the varying flow rates, water is released from the bottom of the dam. This cold bottom water results in river-water temperatures only reaching 20ºC in late November instead of early October. While detailed information is not available, a similar condition prevails below Van Der Kloof Dam.

Large schools of *L.aeneus* migrating upstream into the dam releases are visible throughout the summer months. When water is released the fish cross traps set in rocky bays below the dam wall and when the water recedes, the fish are left stranded in the traps.

The poor quality of the available water is a serious issue at present especially in the Vaal River. The major threats are industrial effluent, agricultural return flow, unfiltered effluent from municipal sewage plants and solid waste in the storm water flow. This should also be addressed when the Ecological Reserve is determined and implemented.

Labeobarbus aeneus has a far wider distribution range than its sister species the Orange-Vaal largemouth yellowfish *L. kimberleyensis* (Gilchrist & Thompson, 1913) due to the fact that it is able to inhabit smaller tributaries. Whereas several of these smaller streams, such as the Kraai River, have near-natural flow regimes and water quality, others are over-abstracted and polluted. Ephemeral rivers such as the Sak and Seekoei are particularly susceptible to over-abstraction of water from the remaining pool refugia during the dry winter months. The University of the Free State is studying the Seekoei River to assess these impacts.

The River Health Programme for the central part of South Africa monitors these systems. Two State of River assessments have been undertaken on parts of the distribution range of the species. A comprehensive assessment of Free State rivers was undertaken in 2003, which reflects the general ecological health of rivers in the region (DWAF, 2003). In addition, the ecological health of tributaries of the Vaal in Gauteng was recently assessed as part of the provincial State of River's programme. Both reports show that several rivers are under major anthropogenic pressure due to a combination of impacts.

Biology and Ecology

Morphology

Skelton (1993) has described the general morphology of *L. aeneus*. The juveniles have a white belly and an olive-green dorsal side with black spots that create a camouflage effect. With increasing age the colour changes to olive green or golden yellow sprinkled with small black flecks but it varies throughout the distribution range. *Labeobarbus aeneus* tends to be more yellow than *L. kimberleyensis* which also lacks the dorsal spots. *Labeobarbus aeneus* has two pairs of barbels lateral of the sub-terminal mouth. There are three variations of the mouth form (Jubb, 1966). The first is called "rubber-lipped" due to very thick lips (Figure 2). The second or "normal" form shows continuous lips with the tip of the mouth slightly more pointed. The third form has lips suitable for scraping food off rocks. The different types of lips are associated with different feeding habits. Mouth morphology is plastic and rubber-lipped fish are able to change their mouth form in captivity to the "normal" form according to feeding conditions and food availability (Jubb, 1966).

There is also variation in body form, with longer finned and deeper fishes found in the lower Orange River compared with elsewhere in the system (Figures 3 and 4). Data on the variation in mass and size of *L. aeneus* from different water bodies is given in Table 1.

Table 1: Data of the size and mass of *L. aeneus* in different water bodies, FL = fork length, TL = total length and SL = standard length (Stadtlander, 2006).

Size (FL,TL or SL, cm) Mass (Kg)		Sex	Age (Ageing method)	Reference and Study site
55 (FL)	2.7	Male	8-9 (scale)	Skelton (1972), Settlers Dam
Avg. 51.6 (-)	2.15-2.66	-	6 (-)	Le Roux (1963),Calitzdorp Dam
49.3-59.4 (-)	1.8-3.6	-	12+ (-)	Le Roux (1963), Farm ponds on the Highveld
59 (-)	-	-	10 (scale)	Mulder (1973),Vaal River
20 (-)	-	-	5 (lapillus)	Laurenson et al. (1989), Great Fish River

Habitat requirements

Typical *L.aeneus* habitat comprises pools, rapids and riffles within the river system (Mulder, 1973; Eccles, 1986; Skelton, 1993,). *Labeobarbus aeneus* prefers clear fast-flowing water with sand or gravel substrates (Mulder, 1973; Skelton, 1993; Dorgeloh, 1994; 1995). Adult and sub-adult fish utilize most of the available habitats in both running water and stillwater systems. Larger congregations of adult fish may be found in or near to riffles during the summer months where spawning and feeding takes place. Juveniles tend to remain in shoals in protected habitats in small tributaries or in protected eddies adjacent to the banks within larger rivers and dams. Detailed information on preferred habitats and migration patterns should be revealed by a telemetry study being carried out in the Vaal River (WRC Report 791).

Labeobarbus aeneus is also able to populate both turbid and clear impoundments successfully although turbid environments are less than ideal (Gaigher and Fourie, 1984; Eccles, 1983; 1986b).

Figure 2: *Labeobarbus aeneus* – “rubberlip” form from Houms River in the lower Orange, Namibia (photos, SAIAB).

Labeobarbus aeneus key features:

- Lateral line scales 27-33
- Dorsal fin origin usually behind the origin of the pelvic fins
- Dorsal fin primary ray typically stout and spinous
- Subterminal mouth
- Snout length equal to or greater than the eye to preopercular groove distance

Figure 3: *Labeobarbus aeneus* from Onseepkans in the lower Orange showing significantly larger fins and a deeper body than specimens from the upper Orange (photo, SAIAB).

Figure 4: *Labeobarbus. aeneus* from Aliwal North showing a more elongated body form and smaller fins (photo, SAIAB).

Feeding biology

Labeobarbus aeneus has omnivorous feeding habits throughout its life. Juveniles rely heavily on aquatic and terrestrial invertebrates, with a dietary shift toward filamentous algae and macrophytes later in life (Gaigher and Fourie, 1984; Eccles, 1986a; 1986b). This less specialized feeding behaviour is a possible reason for the species being so successful when introduced into other waters compared to *L. kimberleyensis*. (Its preference for large rivers and specialised spawning requirements may also restrict the distribution of *L. kimberleyensis*).

The ratio between fork length and gut length increases with age – this indicates the need for greater residence time of food in the gut for digestion of macrophytes and filamentous algae as feeding becomes more omnivorous (Eccles 1986a). Differences in feeding habits, spawning success and survival of the species have been found between clear and turbid habitats (Eccles 1986a). The feeding habits of *L. aeneus* are affected by the turbidity of the water body the species inhabits.

Turbidity affects the vulnerability of larger invertebrates to predation by *L. aeneus* (Gaigher and Fourie, 1984). While the food source may be scarcer due to lower primary production in turbid water, it does not seem to affect zooplanktivory in smaller *L. aeneus* individuals significantly because the zooplankton cannot avoid their yellowfish predators (Gaigher and Fourie, 1984). Eccles (1986a; 1986b) found that in the turbid waters of former Lake Le Roux (presently Van Der Kloof Dam), zooplankton is the primary food source for *L. aeneus* juveniles and it is most abundant during the summer months. In riverine habitats the seasonal decrease in zooplankton during the winter months compels *L. aeneus* to switch to a diet of zoobenthos and terrestrial invertebrates. Turbid waters hamper this change in diet because of a lack of submerged macrophytes and the difficulty the fish has in locating terrestrial invertebrates.

Breeding biology

Spawning is governed by water temperature and flow regime and may take place anytime between early spring and late summer (Tómasson et al., 1984) and may also occur more than once (Skelton, 1972). In breeding ponds, Mulder and Franke (1973) documented a first spawning in October, with a possible second spawning event in January. This is further supported by the observation that a single sexually mature female has numerous egg sizes within the gonad, which may indicate that eggs become ripe at different intervals throughout the spawning season (Stadtlander, 2006). In females between 42 and 55 cm in length (not reported if fork length, standard length or total length) the quantity of ripening eggs ranged from 29 000 to 41000 (Mulder and Franke, 1973). Mulder (1973) reports that there does not seem to be a positive correlation between the quantity of eggs produced and fork length. In general, females produce between 16,000 and 52,000 eggs. Fecundity, if defined as the number of ripe eggs in a gonad at any one time, varies according to several environmental factors. The total number of eggs in a gonad may, however, correlate positively with length. Tómasson et al. (1984) noted that fecundity increased by two to three times for every 10-cm length increment in the alien *L. aeneus* population in the Great Fish River. The age at maturity for female fish was between age group 4 and 5 whereas male fish matured at age group 2. (Because of the absence of any validation of age in *L. aeneus*, actual age cannot be calculated. An age group is assigned instead [Stadtlander, 2006]).

Females mature at a larger size than males, usually from 50 to 100 mm longer. Length at maturity ranged from 340 to 360 mm for females and 220 to 260 mm for males (Stadtlander, 2006). When they are ready to spawn, large numbers of *L. aeneus* move upstream to the spawning sites (Jubb, 1966). Spawning takes place in running water over gravel but has also been observed over gravel beds in stillwaters (Jubb, 1966; Groenewald, 1951 cited in Gaigher, 1976). In the latter case wind action may be important to create the necessary turbulent water conditions. It was noted that a water temperature of 20°C resulted in mature eggs in the gonads of sexually active fish in the Orange River.

Males seem to hold in spawning areas while females and possibly other males hold in pools nearby. It is postulated that critical pre-spawning behaviour takes place here. Individual females then move to the spawning beds where each spawns with up to seven males. The males are covered in sensory papillae, which give their skin a rough texture. There is a frenzied activity as eggs and sperm are released. If specimens are collected during this phase both eggs and milt run freely. Fish are easy to poach or disturb during this time. Due to their serial spawning ability, fish can remain in the spawning area for a long time. At Sterkfontein Dam large shoals remain in feeder streams for several months.

The eggshells are transparent but have a yellow to golden tinge. Initially, the eggs have an average diameter of 1.8 mm and are slightly adhesive but, once fertilised, they swell to about 2.5 mm. The adhesiveness of the eggs can withstand a steady flow of water but any sudden surge will dislodge them. They are negatively buoyant and once dislodged do not retain their adhesiveness. They have a double eggshell – the outer shell can be ruptured and the larvae will still be able to develop and hatch in the inner shell.

After fertilization, the larvae of *L. aeneus* typically hatch after 72 hours at 26°C; development rate depends on water temperature. The larvae remain within the gravel beds during the early stages of their life cycle and are dependant on nutrients absorbed from their yolk sac. If water temperatures remain between 23ºC and 25°C, the larvae become mobile and start to swim actively about 72 hours after hatching. They develop an olive-green to grey dorsal colouring, with characteristic black spots over the entire body, and a silvery white ventral colouring (Figure 5).

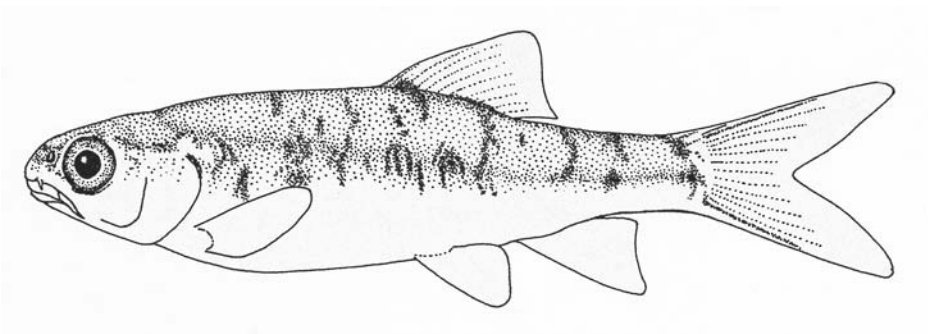

Figure 5: Colour pattern of *Labeobarbus aeneus* juvenile from Gariep Dam.

Threats

Water pollution in rivers containing *L. aeneus* is becoming a critical factor impacting on its future survival. Malfunctioning municipal sewage plants and damaged or overflowing sewage pipes result in unpurified effluent entering rivers.

The natural processes that break down these nutrients result in an increase in the toxic levels of ammonia as well as a decrease in dissolved oxygen levels. At sub-lethal limits the fish become stressed which increases their susceptibility to disease, reproductive failure and reduced feeding and leads to diminished overall fitness. These and other secondary effects may cause eventual death (Weis et al., 2001). When lethal limits are reached mass fish kills occur. These are an increasingly common feature within or below urban areas, especially in the Vaal River below the Vaal Dam. Additional pollutants in return flows from the agricultural and industrial sector aggravate this situation. Urban run-off from storm-water drains does not go through the sewage system and contains massive amounts of automotive pollutants amongst others.

Very high water demand within the catchment, especially in Gauteng, results in rivers being managed for water use with little or no recognition of the environmental flow requirements. This has given rise to artificially managed flows and inter-basin transfers. Habitat degradation in the form of in-stream dams and weirs is a critical issue in the Orange-Vaal River system.

In addition to being used to store floodwaters and manipulate flows these structures prevent fish migrating upstream or downstream. Increased sediment loads in some of the upper catchments, due to poor farming practices, results in rapids and riffles being smothered.

Alien fish species such as the common carp *Cyprinus carpio* Linnaeus, 1758, grass carp *Ctenopharyngodon idella* (Valenciennes, 1844), brown trout *Salmo trutta* Linnaeus, 1758 , rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792), and largemouth bass *Micropterus salmoides* (Lacepede, 1802) all compete with or actually prey on *L. aeneus*. The effect of alien fish on *L. aeneus* is yet to be quantified and although Dorgeloh (1996) found a large food overlap between *L.aeneus* and *O. mykiss* in the Sterkfontein Dam, there was no obvious negative effect. Possibly a bigger problem owing to alien fishes interacting with *L. aeneus* has been the introduction of both endo- and ectoparasites. The fish louse *Argulus japonicus* Thiele, 1900 and the tapeworm *Bothriocephalus acheilognathi* Yamaguthi, 1934 have both parasitised *L. aeneus* (Kruger and Van As, 1983; Stadtlander, 2006). Parasites can decrease the host's growth rates, suppress its appetite and increase its susceptibility to disease as well as causing damage at the site of attachment (Brandt et al., 1981; Avenant-Oldewage, 2001). There may also be synergistic effects between contaminants and parasites. Parasitism may be a secondary effect as a result of pollution decreasing fish immunity and increasing susceptibility (Weis et al., 2001).

Human-induced movement of *L. aeneus* between catchments is a real threat to the genetic integrity of this species. This has already happened with the inter-basin transfers (IBTs) between Lesotho and the upper Vaal, which will have mixed the Kraai population and the widespread middle Orange-Vaal population. Further transfers by landowners, anglers and additional IBTs will increasingly homogenize the stocks.

Water moved between the Tugela and Vaal catchments via Sterkfontein Dam may also be transferring fish species between these two catchments. This needs to be monitored by the Conservation Departments of Free State and KwaZulu-Natal.

Conservation Measures to Conserve the Yellowfish Resource

Legislation

All provinces in which *L. aeneus* occurs have some form of legislation dealing with its conservation. In addition, there is a considerable body of national and provincial legislation that enables authorities to respond to illegal activities on rivers such as pollution, netting, interfering with spawning fish, stocking of alien species etc. Legislation incorporated in provincial nature conservation ordinances also permits the effective management of smallmouth yellowfish and their habitat by means of regulations governing minimum size, bag limits, spawning seasons, spawning areas and such. There are, however, conflicting regulations between provinces. A major concern, is the current lack of capacity in nature conservation at provincial and national level to manage rivers and freshwater fish effectively. Local conservation associations (see below) and effective education and awareness programmes are critical to disseminate information across provincial boundaries.

It is the responsibility of the Department of Water Affairs and Forestry (DWAF) to calculate, design, implement and monitor the Ecological Reserve for both the Orange and Vaal Rivers in due course. The Vaal River will receive preference, as it is the more polluted and impacted of the two rivers at present. It is important for stakeholders to participate in the classification process that follows the calculation of the Reserve. It is vital that the Ecological Reserve is translated into specific water release programmes implemented by dam managers. The releases and their effects on the biota and habitat need to be monitored closely.

Protected areas and conservancies

A cooperative yellowfish conservation association has been established in parts of the OVRS to address the situation on the ground where different provinces have different legislation pertaining to the same fish species. Here riparian landowners unite to manage and control waters that flow through their properties. The Orange-Vaal River Yellowfish Conservation and Management Association (OVRYCMA), established in 1996, is a good example of this approach. In this model, riparian owners along the Orange and Vaal Rivers are encouraged to join the Association with the express purpose of conserving the yellowfish in their waters. The whole process is co-ordinated by a steering committee led by an elected chairperson. Membership is voluntary and free but members who register undertake to reach the following objectives:

- Conserve the yellowfish, especially the scarcer largemouth.
- Organise information days and clinics to promote good river management.
- Encourage and enforce the practice of catch and release for yellowfish and have this principle applied throughout the Orange-Vaal River system.

- Promote sustainable tourism and ensure that the conservation of yellowfish is secured in spite of increased numbers of anglers on the river.

Whereas the overall aim is to develop yellowfish conservation associations along the entire length of the Orange-Vaal River system, an initiative like this needs to divide this huge catchment into manageable portions of river. The initial stretch covered 696 km of the Vaal River between the Barrage and Bloemhof Dam and the association numbered 749 members. While there is no formal contract with the authorities, national and provincial government departments show their support by delegating responsible officials to serve on the steering committee. Communication is by farm visits or newsletters. This has proven to be a very effective method of getting people together and developing a conservation network for a particular river. This type of association can be developed for any river in South Africa, and indeed Africa. There must be a person (champion) and a small energetic committee that drives the process. Networking is a critical requirement. The OVRYCMA has been the leading force in developing the yellowfish conservation initiative at grass-roots level in South Africa. This has created major awareness within the ranks of landowners, anglers and government departments. In addition, it has created an extremely valuable angling industry that is worth millions of Rands each year. This in itself will result in the fish and their habitat being conserved for socio-economic reasons in this developing country.

Funding is always an issue and there are no specific guidelines on how to access funds for management purposes. The management of these associations will not be without their share of human politics. A clear aim and objectives as well as a philosophy that "yellowfish conservation must benefit" will keep the unit going during troubled times. It is preferable to get your local conservation officials and water managers involved. Finally, a good scientific basis is essential for meaningful decision-making.

Hatcheries and stockings

Whereas a successful culture protocol (spawning, dam management, broodfish husbandry, artificial spawning, rearing and transportation) has been developed for the species at Gariep Dam State Fish Hatchery (DTEEA) it is not advisable to culture and stock these fish. Ideally the rivers and angling should be effectively managed to ensure the survival of naturally occurring wild stocks. This will maintain the genetic diversity necessary for the survival of the species. Culturing and stocking of these fish should only be considered for research purposes or in a time of an environmental crisis. If fish are required for stocking a dam they should be collected from a natural population occurring in a river in the same catchment area as the dam. Conservation officials should always be involved in stocking programmes.

The Gariep Dam State Fish Hatchery spawned, reared and stocked *L. aeneus* fingerlings in several farm dams in the upper Orange-Caledon catchment. No fish were stocked in rivers according to the hatchery policy at the time. This stocking practice has been stopped.

Monitoring and Research

The national River Health Programme (RHP) is used as the primary tool to monitor fish communities across South Africa. Of the six provinces in the catchment of the Orange-Vaal River system, Free State, North West, Mpumalanga and Gauteng have active and successful RHPs, but the Northern Cape does not. Yellowfishes are generally used as an indicator species on the Orange and Vaal Rivers to give managers an idea of the ecological state of the river. Healthy populations of *L. aeneus* are a good indication of ecologically healthy rivers, particularly so in smaller tributaries where other sensitive species such as *L. kimberleyensis* and rock catfish *Austroglanis sclateri* (Boulenger, 1901) do not occur.

The Water Research Commission is sponsoring a yellowfish telemetry programme in the Vaal River near Bothaville. The aim of the study is to identify the habitat requirements of both *L. kimberleyensis* and *L. aeneus.* This programme commenced in December 2005 and will continue until at least October 2008. Individual fish are fitted with a tag that emits regular radio signals that can be tracked. The tag's battery life is approximately 90 days. To date 15 fish have been tracked on a daily basis. The preliminary results indicate that both species are fairly sedentary and have specific habitat requirements. Seemingly, *L. kimberleyensis* moves greater distances than *L. aeneus* but whether this behaviour relates to the presence and type of prey still needs to be determined.

The data suggest that local conservation efforts are crucial. These slow-growing fish will not migrate to and quickly repopulate habitats where the local populations have been depleted. The genetic studies do indicate some linkages between populations which may be ascribed to the migration of specific individuals or larvae moving passively down stream. Further research to substantiate these observations is vital as this information will be used to manage the overall population. The relative extent and quality of protected habitat needs to be assessed to establish whether or not critical populations are being conserved. This will need to be well publicized so that potential pollution sources in the catchments are also addressed. A tag-and-release programme is planned to assess the population size of this species in a specific area.

Value of the Yellowfish Resource to Recreational Anglers and Subsistence Fishers

It has been estimated that the value of the fly-fishing and tourism industry that has been created around recreational angling in the Vaal River is in the region of R1.2 billion (B. Venter, EKO Care Trust, personal communication). This includes direct expenditure on items such as tackle and transport and also indirect expenditure on caravans, canoes and so on. The impact of this on the social upliftment of people in the area and the economy is currently being assessed by a Water Research Commission study.

The proliferation of articles on yellowfish in the angling press and the tremendous increase in the popularity of yellowfish angling over the past 10 years will also be addressed by this study. Support for the catch-and-release principle is widely publicised and has been extended to many other species including marine fishes. This in itself has assisted the conservation effort and has also contributed towards developing a sustainable and valuable industry which is now starting to provide funds for specific research programmes such as the telemetry programme mentioned earlier. Provided the major threats to *L. aeneus* are countered, we may be witnessing the development of a self-sustaining fishery.

Granek et al. (in preparation) assess the value of sport fisheries in general and provide global examples of both the recreational and economic value of effectively managed sports fisheries. This massive industry requires firm guidance from conservation bodies. Anglers, industry, landowners and conservation departments must co-operate in managing our valuable natural resources. The Yellowfish Working Group at national level and the OVRYCMA at local level, play important co-ordinating and support roles in this process.

Concluding Remarks

Research is crucial for managers to develop an understanding of the species and how they interact with their environment. This allows informed decisions to be made with regard to compensatory river flow, pollution standards and fisheries management protocols. Several important and substantial research programmes are currently underway on yellowfishes in the Orange-Vaal River system. These involve research on genetics, habitat selection and migration, and a socio-economic assessment of the industry. Whereas there is an abundance of research papers associated with *L. aeneus* very few focus on applied research, an aspect that needs much greater emphasis in future.

Basically, *L. aeneus* is supporting a huge angling and eco-tourism industry in the Orange-Vaal River basin as well as acting as an important food source for poor communities. Only a large healthy fish population can sustain the industry and for this reason a bag limit of two fish per day is being proposed. While *L. aeneus* is relatively common throughout the system it still faces severe threats from water pollution. The ecological reserve needs to be implemented to ensure successful spawning and recruitment. Research and monitoring programmes evaluating the effectiveness of these flows are essential. A source-to-coast integrated water and river management programme can use *L. aeneus* as a flagship species due to its wide distribution.

It must be remembered that studies only provide the fundamental data upon which conservation managers can base their decisions. The implementation of conservation strategies and plans are vital to the survival of this species and the river habitat in which it lives. The social and economic benefits derived from a healthy river exceed any other options available to the people of South Africa. Whereas *L. aeneus* is relatively common throughout its distribution at present it is precisely this status that needs to be maintained. Integrated catchment conservation and management strategies must seriously consider the conservation of this species and its habitat in order to sustain the many who depend on it. While it is essential to develop a national conservation plan it is just as important to sustain and support local conservation efforts such as the OVRYCMA and any similar initiatives.

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STATUS OF THE ORANGE-VAAL LARGEMOUTH YELLOWFISH, *LABEOBARBUS KIMBERLEYENSIS* (GILCHRIST & THOMPSON, 1913)

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ABSTRACT

The Orange-Vaal largemouth yellowfish *Labeobarbus kimberleyensis* (Gilchrist & Thompson, 1913) is a cyprinid endemic to the Orange-Vaal River system. For a number of reasons related to man and his influence on nature, *L. kimberleyensis* has become a high priority conservation species due to its scarcity within its endemic home range. Its slow growth rate, large size at maturity, specific habitat requirements and spawning characteristics make *L. kimberleyensis* susceptible to habitat changes and negative anthropogenic influences. Although the species has been studied concurrently with other large South African cyprinids there is a lack of specific information on the general biology, life history traits and ecology of the species. A better understanding of the species will greatly aid future decision making regarding the conservation and management of the species. Water abstraction and pollution from both industrial effluent and urban run-off, are threats that may have catastrophic effects on *L. kimberleyensis* populations in the future if the right measures are not taken to curb the source of this pollution. *Labeobarbus kimberleyensis* is also a prized angling species. This brings to the fore a number of institutional problems regarding the conservation of *L. kimberleyensis.* The inconsistent use of closed seasons, size limits and bag limits have resulted in the failure nationally of regulations to ensure the survival of the species. *Labeobarbus kimberleyensis* is listed as a protected species in the National Environmental Management: Biodiversity Act. This requires national conservation interventions which in association with the groundbreaking work being carried out by the Orange-Vaal River Yellowfish Conservation and Management Association may turn the tide regarding threats to this charismatic species.

Introduction

The Orange-Vaal largemouth yellowfish *Labeobarbus kimberleyensis* (Gilchrist & Thompson, 1913), usually called the largemouth yellowfish, is a member of the small-scaled yellowfish family which is endemic to temperate region of southern Africa. Its nearest relative is the Orange-Vaal smallmouth yellowfish *Labeobarbus aeneus* (Burchell, 1822). Both species are endemic to the Orange-Vaal River System (OVRS), although the distributional range of both species has increased due to inter-basin transfer schemes, accidental and intentional introductions (Jubb and Farquharson, 1965; Cambray and Jubb, 1977a).

Labeobarbus kimberleyensis is the flagship freshwater fish species of the OVRS. This large predator attains 22 kg and is highly sought after by anglers. The slow growth rates, specific reproductive requirements and feeding habits, make *L. kimberleyensis* susceptible to anthropogenic changes to riverine and interlacustrine habitats (Tomasson, et al., 1984; Mulder 1973). It is much scarcer and has more demanding habitat requirements than *L. aeneus*.

Despite this, the literature record for the species is poor and key aspects of its biology and ecology are poorly understood. This chapter summarises our knowledge to date and highlights management steps that have been taken or are still required to better conserve this magnificent and valuable species.

Taxonomic History

Barbus kimberleyensis, Gilchrist & Thompson, 1913. Kimberley Reservoir, Cape Prov., South Africa. Holotype (unique): SAM 9645 [now at AMG].
Barbus pienaarii, Fitzsimons, 1949. Vaal R. near Villiers, South Africa. Holotype: SAIAB [formerly RUSI] 45824 [ex TMP 21828]. Paratypes: SAIAB [formerly RUSI] 44304 [ex TMP 21829] (2, now 1); TMP 21887 (1).

Distribution and Status

Labeobarbus kimberleyensis is endemic to the Orange-Vaal River system (Figure 1). The species is generally only found in the larger tributaries and dams below 1500m. They are absent from higher reaches of Lesotho and the southern tributaries of the Northern Cape Province (Skelton, 1993). *L. kimberleyensis* has successfully colonised a number of man-made dams, among these are Gariep and Van Der Kloof Dams on the Orange River and the Vaal and Bloemhof Dams on the Vaal River. They are however not common in these dams.

Ichthyologists are, however, generally concerned about population densities across its range which suggests that this species could be listed in a threatened category in the future. The Near Threatened status currently assigned to *L. kimberleyensis* is as a result of the highly regulated nature of Orange-Vaal River system, where it is endemic. Because of the habitat preferences of *L. kimberleyensis* being larger river and mainstream channels, flow regulation within the Orange-Vaal River system may affect the future survival of the species (Impson and Swartz, in press).

Being an apex predator, *L. kimberleyensis* is much scarcer than *L. aeneus*. The species also has more demanding deep-water habitat requirements, although it can utilise the stillwater habitats created by barriers, which provide depth, cover and a variation of prey. The flow in the middle Vaal River below Vaal Dam is mostly treated effluent outside of flood periods, subjecting the fishes to highly variable water quality, especially in the drier months. As a result several fish kills have been reported in this part of the river.

Status of Habitat

The main streams of both the Orange and the Vaal Rivers are highly regulated. Large impassable dams have been built to store water and generate electricity. These and other large man-made impoundments restrict the upstream migration of fishes. The possibility of downstream passive migration of larvae and juveniles has not been established.

The natural flow regime has been disturbed due to the highly regulated nature of the main stems of the two rivers. Both systems flow throughout the year and it has become critical to design, implement and monitor the Ecological Reserve for each. The hydroelectric power generating systems on the Orange River result in significant daily flow fluctuations. In addition to the varying flow rates, water is released from the bottom of the dam. This cold bottom water results in river-water temperatures only reaching 20ºC in late November instead of early October. Hypolimnetic water releases produce water with higher levels of nutrients (including sulphides) and lower oxygen and sediment levels. These abnormal variations impact on cues that induce spawning naturally. A lower sediment load also increases the erosive power of water, leading to a modified substrate downstream of the dam.

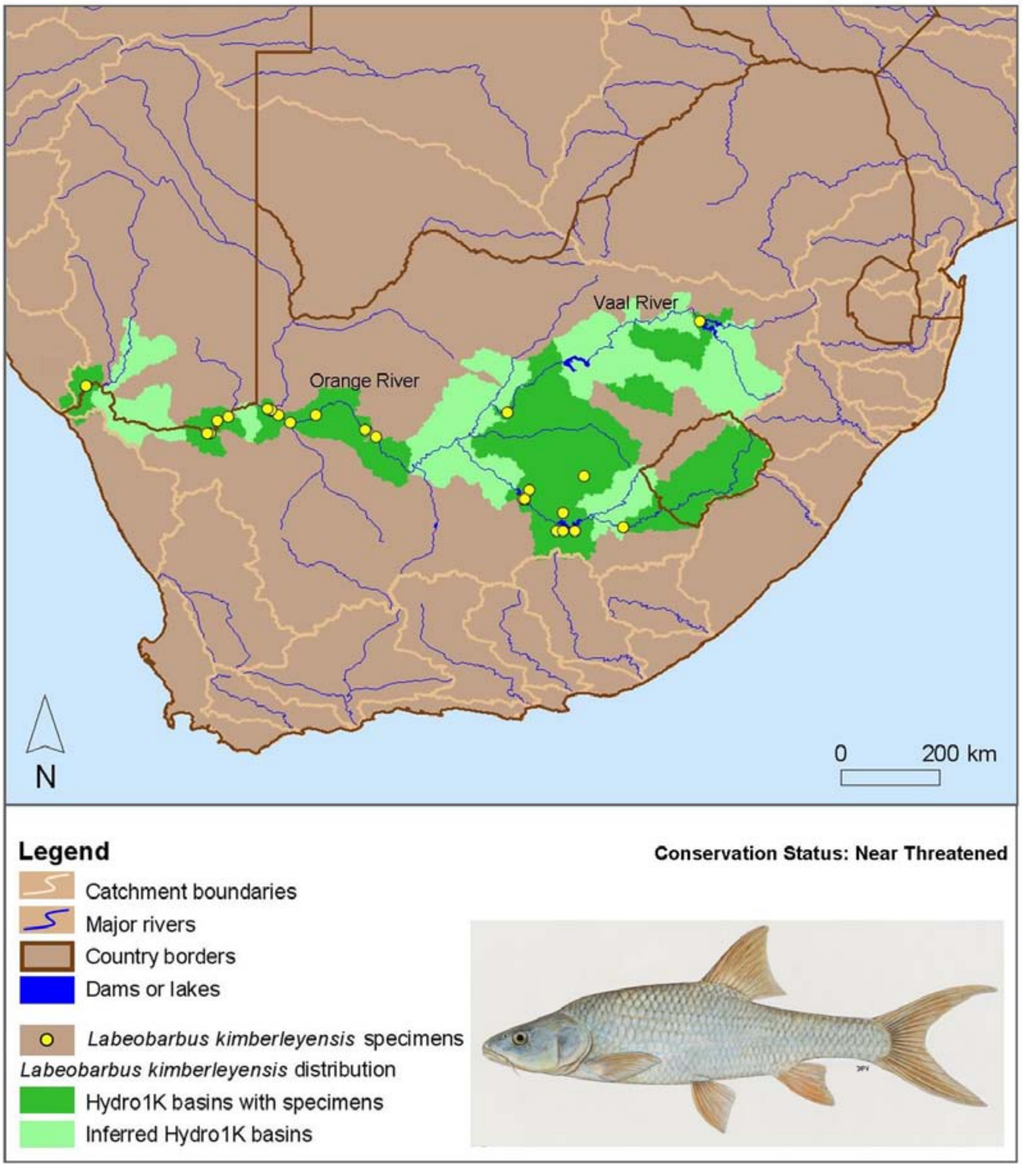

Figure 1: Distribution of *Labeobarbus kimberleyensis* based on voucher records (map by Willem Coetzer, SAIAB).

The poor quality of the available water is a serious issue at present especially in the Vaal River. The major threats are industrial effluent, agricultural return flow, unfiltered effluent from municipal sewage plants and solid waste in the storm-water flow. This should also be addressed when the Ecological Reserve is determined and implemented.

So far two State of River assessments have been undertaken that overlap on part of the distribution range of *L. kimberleyensis.* The Department of Water Affairs and Forestry (DWAF) undertook a comprehensive assessment of the rivers in central South Africa in 2003 to determine their general ecological health and, more recently, similar work was carried out on tributaries of the Vaal in Gauteng as part of the provincial State of Rivers programme. Both reports show that several rivers are under major anthropogenic pressure due to a combination of impacts. Habitat degradation is a major threat to this species.

Biology and Ecology

Morphology and genetics

Skelton (1993) has described the general morphology of *L. kimberleyensis*. Juveniles are silver in colour (Figure 2), changing to golden yellowish with increasing age (Figure 3). This varies between and within river systems and some adults may also show a silver colour. Individuals in turbid waters tend to be more silvery whereas those in clear waters are more yellow (Mulder, 1973). *Labeobarbus kimberleyensis* has a wide terminal mouth, a broad concave forehead and a relatively long head (Figure 4). The distance from the eye to the opercular-preopercular groove is equal to or greater than the length of the snout (Jubb, 1966). The concave head is a good distinguishing feature between *L. kimberleyensis* and *L. aeneus*. The eyes of *L. kimberleyensis* tend to be positioned dorsally rather than laterally as in *L. aeneus*. *Labeobarbus kimberleyensis* also does not show the variation in mouth form as in some other *Labeobarbus* species.

Labeobarbus kimberleyensis is a slow growing predator, with a maximum age estimated at over 13 years (Mulder, 1973). This is highly likely, given the slow growth rate and the large size this species attains. No growth rate studies or age validation for *L. kimberleyensis* are currently available. If the growth rate of *L. aeneus* and *L. kimberleyensis* are similar as suggested in the available literature (Tomasson et al., 1984), then the maximum age of *L. kimberleyensis* may well exceed 20 years.

Figure 2: *Labeobarbus kimberleyensis* juvenile from the Orange River at Aliwal North, 2004 (photo Roger Bills, SAIAB).

Figure 3: *Labeobarbus kimberleyensis* from the lower Orange River at Pella Drift, 2004 (photo Roger Bills, SAIAB).

Figure 4: Head of *Labeobarbus kimberleyensis* showing the terminal mouth and the long post-orbital distance. From the lower Orange River at Pella Drift, 2004 (photo Roger Bills, SAIAB).

Preliminary genetic reports on *L. kimberleyensis* indicate that no differences could be detected between *L. aeneus* and *L. kimberleyensis* using mitochondrial DNA as a marker. This has made the detection of specific conservation units for genetically distinctive groups within the OVRS difficult. Genetic diversity of *L. kimberleyensis* along the OVRS is considered to be low (Bloomer, et al., 2007).

Habitat requirements

Habitat preferences of *L. kimberleyensis* include flowing water in deeper channels and below rapids (Mulder, 1973; Skelton 1993). The depth of water that is required is size dependant with smaller fish favouring shallow rocky habitats. Adults are more common in weirs and pools that have good depth, water quality and cover (rocky reefs, weed beds and overhanging trees).

Feeding biology

Below a length of 300 mm *L. kimberleyensis* feeds mainly on insects and small crustaceans, whereas above 300 mm it becomes primarily piscivorous (Mulder, 1973; Skelton, 1993). Differences in feeding habits and survival can be expected depending on the availability of suitable habitat.

Because of its feeding habits, *Labeobarbus kimberleyensis* generally needs the good visibility provided by clear water, to locate prey. For this reason the major threats it faces, are due to anthropogenic alteration of its habitat (Mulder, 1973). The Orange River system is naturally turbid but the dams generally less so. One would expect turbid environments to be less than ideal for optimal survival. However, preliminary data collected from specimens in the Orange River does not provide evidence to suggest a decline in condition. The fish has eyes that are characteristically situated on the dorsal side of the head. Specimens have been observed to rise from depth to take flies and lures higher in the water column. This suggests that in slightly turbid water the fish sees its prey outlined as a dark object against the light sky-lit surface.

Breeding biology

Labeobarbus kimberleyensis attains sexual maturity at a greater age and length than other indigenous cyprinid species. Males become sexually mature at an age of six years (35 cm), whereas females do so at eight years (46 cm) (Mulder, 1973). The fish breed in mid to late summer over gravel beds in running water, with spawning being governed by water temperatures and flow regime (Tomasson, et al., 1984; Skelton, 1993; Gaigher, 1976). *L. kimberleyensis* reproduces naturally in the turbid waters characteristic of the Orange River. It does well in dams although it is likely that tributaries and inflowing rivers are utilised for spawning. In a post-impoundment survey on Lake Gariep, Cambray et al. (1978) found that juvenile *L. kimberleyensis* were distributed throughout the dam, which suggests local adaptability and the utilization of the dam for reproduction. However juveniles may have dispersed from inlets and tributaries where *L. kimberleyensis* spawned naturally.

In Lake Le Roux (presently Van Der Kloof Dam), *L. kimberleyensis* was found to spawn later than *L. aeneus* (Tomasson et al., 1984). Later spawning may explain its paucity relative to the

L. aeneus, as the temperature regime at this time of the year is harsher and may lead to reduced recruitment success (Tomasson et al., 1984). Survival through the winter may also be reduced as juveniles would be smaller with lower energy reserves and exposed to a wider range of predators. In comparison to other indigenous river-dwelling species, such as labeos, *L. kimberleyensis* has moderate fecundity and fairly large eggs (Tomasson et al., 1984). Mulder (1973) found no positive correlation between size and relative fecundity, with the number of ova being produced varying from 16 000 to 52 000. The eggshells are transparent with a yellow to golden tinge. They have an average initial diameter of 1.8 mm and are initially adhesive although not as much as the eggs of sharptooth catfish *Clarias gariepinus* (Burchell, 1822). We estimate the adhesiveness of the eggs of both yellowfish species to be similar to that of Orange River mudfish *Labeo capensis* (A. Smith, 1841) and moggel *Labeo umbratus* (A. Smith, 1841). Once fertilised the eggs swell to an average diameter of 2.5 millimetres. The adhesiveness of the eggs can withstand a steady flow of water but any sudden surge will dislodge them. They are negatively buoyant and once dislodged do not retain their adhesiveness. They have a double eggshell. The outer shell can be ruptured and the larvae will still be able to develop and hatch out of the inner shell. The incubation period for *L. kimberleyensis* eggs is two to three days.

Larvae utilize their yolk sac during the early post-hatching period during which they remain immobile in the gravel. They absorb the yolk sac and become mobile three to four days after hatching at water temperatures between 23ºC and 25°C (Tomasson et al., 1984). The larvae are initially a translucent yellow to golden colour and develop into silver-coloured juveniles, which actively feed on small drift invertebrates.

Threats

As a consequence of sharing the same rivers and occupying similar habitats, *L. kimberleyensis* essentially faces the same threats as *L. aeneus*. Only those aspects of specific relevance to *L. kimberleyensis* will be discussed below.

As *L. kimberleyensis* does not typically inhabit smaller tributaries, the impact of polluted waters in the main channel is very serious. Unlike *L. aeuneus*, if removed from the main channel *L. kimberlensis* cannot re-colonise from tributary populations. *Labeobarbus kimberleyensis* is also a slower-growing species with greater sizes at maturity, which would make quick replacement of a population after a fish kill in a main channel improbable (Mulder, 1973; Tommason et al., 1984).

Illegal netting is an issue that needs to be constantly monitored and managed. Gill nets can decimate yellowfish especially during their annual spawning migrations. Gill netting permits should only be considered under emergency conditions where available evidence suggests that target species are located in large water bodies that are in the process of drying up. Mesh sizes measuring 144 mm or more should be considered for carp *Cyprinus carpio* Linnaeus, 1758 whereas mud flats in artificial impoundments could be zoned for *C. gariepinus*.

Labeobarbus kimberleyensis is vulnerable to angling pressure for several reasons. Firstly, it is not as plentiful as *L. aeneus* and seems to have more specific habitat requirements (the home range is mainstream rivers). Secondly, *L. kimberleyensis* is a top predator that attains more than

20 kilograms and only becomes sexually mature at eight years or later (its size at 50 percent sexual maturity is 45-cm fork length).

The Fish River is the major tributary of the Orange River below Augrabies falls. Lake Hardap, which is situated on the Fish River, is geographically isolated from the Orange River by a waterfall. Only one yellowfish species exists in Lake Hardap and because it exhibits intermediate characters of both species it is thought to be a hybrid between *L. kimberleyensis* and *L. aeneus* (Gaigher, 1976). Although such hybridisation may pose a possible threat to *L. kimberleyensis* this is unlikely as both species inhabit the Orange-Vaal River system and to date reports of hybridisation are minimal. Different times of breeding may also reduce the possibility of hybridisation (Tomasson et al., 1984).

Alien fish species such as C. carpio, grass carp *Ctenopharyngodon idella* (Valenciennes, 1844) and largemouth bass *Micropterus salmoides* (Lacepède, 1802) all compete or actually prey on *L. kimberleyensis* during the early stages of its life cycle. The effect of alien fish on *L. kimberleyensis* however, has yet to be quantified. Increasing numbers of *C. idella* have been collected in the riverine habitat favoured by *L. kimberleyensis* in the Vaal River. A motivation for a study to assess this impact has been submitted to the Water Research Commission.

The introduction of endo- and ecto-parasites via their alien fish hosts has already led to *L.aeneus* being parasitised. So far *L. kimberleyensis* has seemingly not been affected, but as it is a closely related species there is a possibility of it also being infected.

Conservation Measures to Conserve the Yellowfish Resource

Legislation

The National Environmental Management: Biodiversity Act (NEMBA) makes provision for the development and implementation of a protected species management plan. This needs to be developed for *L. kimberleyensis* which is listed as a protected species by the National Department of Environmental Affairs and Tourism (DEAT).

For the rest, legislative matters pertaining to *L. kimberleyensi* are similar to those involving *L. aeneus*.

Protected areas and conservancies

The organisation and objectives of the Orange-Vaal River Yellowfish Conservation and Management Association (OVRYCMA), which also cover *L. kimberleyensis* have been discussed in detail in the chapter on *L. aeneus*. The Association uses *L. kimberleyensis* as its flagship species with the fish depicted on its signage

Several provincial and national nature reserves or parks are located along the Orange and Vaal Rivers. Those on the Orange are Tussen Die Riviere, Oviston Nature Reserve, Doornkloof-Rolfontein Nature Reserve, Augrabies Falls National Park and Richtersveld National Park.

Along the Vaal are Bloemhof Dam Nature Reserve, Sandveld Nature Reserve and Wolwespruit Nature Reserve. The departments responsible for the management of these reserves are all aware of the conservation actions required to conserve *L kimberleyensis*. These areas do act as small sanctuaries where access and angling is effectively managed. Many however are situated around dams and those that are situated on rivers cannot control or manage the water quality within the habitat. They do, however, provide the public with essential environmental education and awareness.

Hatcheries and stockings

The Free State Department of Tourism Environmental and Economic Affairs (DTEEA) stocked *L. kimberleyensis* fingerlings in Sterkfontein Dam in 1994/95 but currently the philosophy pertaining to stocking of this species is the same as for *L. aneus*. .

Improved management of water resources

The Department of Water Affairs and Forestry (DWAF) will design, implement and monitor the Ecological Reserve for both the Orange and Vaal Rivers in due course. The Vaal River will receive preference, as it is the more polluted and impacted of the two rivers at present. The specific ecological requirements of this species need to be catered for by the proposed flows and water quality. Various in-stream flow requirement studies have been initiated by DWAF in the catchment in order to calculate the flow requirements of aquatic biota at specific water management sites. The Ecological Reserve needs to be translated into specific water releases from the large impoundments situated in both the Orange and Vaal Rivers. Dam managers need to be trained to carry out these crucial releases. The impacts of the releases need to be monitored. It is vital that stakeholders participate in the classification of the river once the Reserve has been calculated. This classification process will decide the final condition of the river.

The monitoring and management of effluent that enters the river is the responsibility of several national, provincial and local departments as well as the various industries themselves (DWAF, Local and District Government, DEAT (Provincial), Industry, Department of Mineral and Energy Affairs, Department of Agriculture and so on). To be effective integrated catchment forums need to be developed to manage the overall problem. The formation of these forums depends on local support of the concept and the presence of a champion who will drive the process.

Biological Monitoring and Research

The monitoring and research needs for *L. kimberleyensis* are essentially the same as for *L. aeneus* and are discussed in detail in that chapter. However, as the reader may note, there is relatively little information on the species.

Value of Resource to Recreational Anglers and Subsistence Fishers

See chapter on *L. aeneus* for details. While the larger *L. kimberleyensis* is a scarcer and more difficult to catch species, it is a prime candidate for catch and release. Fish in excess of 5 kg are regularly caught by anglers nowadays, thanks to this approach. A NEMBA permit (probably in the form of a fishing license) will be needed to target this species.

Concluding Remarks

Labeobarbus kimberleyensis is not a well-studied species and it is essential in the years ahead that we develop a much better understanding of its biology and ecology. Fortunately, several exciting research projects are underway which address aspects of its biology. A number of largemouth and smallmouth yellowfish have been tagged, released and tracked in OVRYCMA conservation areas and researchers are currently monitoring their movements using sophisticated telemetric methods. Another important scientific study seeks to compare genetic and morphological characteristics of largemouth and smallmouth yellowfish throughout their natural distribution range. A study into the social and economic impact of the development of the yellowfish sports fishery is being undertaken in order to make OVRYCMA stakeholders and the general public aware of the value of the yellowfish resource.

It must be remembered that studies only provide the critical data upon which conservation managers can make decisions. The implementation of conservation strategies and plans are vital to the survival of this species and the river habitat in which it lives. The social and economic benefits derived from a healthy river exceed any other options available to the people of South Africa.

From a conservation perspective, *L. kimberleyensis* is potentially in deep trouble. Although it is not presently listed as threatened in IUCN categories (due to its still widespread distribution) it is rare in most places and water quality degradation, alien fishes and other threats impinge on almost the entire population. Improvement of the general riverine environment, huge as this task is, is urgently needed for this species to survive. Local inclusive conservation initiatives such as the Orange-Vaal River Yellowfish Conservation and Management Association are important bodies that can implement legislation and management plans developed by national departments and forums.

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STATUS OF THE PAPERMOUTH *BARBUS RAPAX* (STEINDACHNER, 1894)

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ABSTRACT

Papermouth *Barbus rapax* Steindachner, 1894 refers to the Limpopo River sub-populations of the Angolan papermouth *Barbus mattozi* Guimaraes, 1884 and is regarded as a distinct species. *Barbus rapax* is found primarily at altitudes above 600 m in wide and deep pools of cooler perennial rivers, and seems to be more prolific in large dams than in rivers. Unlike true yellowfishes (*Labeobarbus*), *B. rapax* has radiated striated scales, a serrated dorsal spine and the origin of its ventral fins is in front of the origin of its dorsal fin. *Barbus rapax* represents one of the largest *Barbus* species in southern Africa and is more predacious than any other related minnow. It attains a length of approximately 40 cm, matures after three years and reaches a maximum reported age of nine years. The South African angling record is 1.3 kg, although most fish caught by anglers are between 250 g and 500 g in size. *Barbus rapax* has a single annual breeding event and fish migrate upstream to spawn with the onset of the first midsummer floods. Although *B. rapax* is listed as Least Concern based on the fact that it is still widespread and locally common in some dams within the Limpopo River system, its numbers and remaining habitat have deteriorated markedly recently due to declining water quality and quantity. The many in-stream dams are fragmenting sub-populations and genetically isolating them from other sub-populations. This is aggravated by the loss of riverine habitat suitable for spawning between dams. A better understanding of the breeding and nursery requirements of the species is an essential component for its long-term conservation. Fishways at weirs and dams and frequent translocations between sub-populations may also be important tools to maintain and ensure genetic exchange and the retention of adequate numbers in remaining habitats.

Introduction

The true yellowfishes have been reclassified in the genus *Labeobarbus* Rüppell, 1835 (Nagelkerke and Sibbing, 1997; Skelton, 2001). The papermouth *Barbus rapax* Steindachner, 1894 is now one of the larger *Barbus* species in South Africa. Cyprinidae, and especially the genera *Barbus* and *Labeobarbus,* are a very important component of southern Africa's freshwater fish diversity. Fish play an important role in aquatic ecosystem processes and have a significant impact on aspects such as food chains and pest control within the terrestrial environment. Cyprinids are often the most numerous fish in streams and rivers in this region; yet very few species have been studied in any detail. In an era where many of our freshwater aquatic systems are deteriorating rapidly, there is an urgent need for more information on the life cycle requirements of many of our freshwater fish species in order to manage and conserve the diversity of fish and related ecosystem processes.

This is especially true of *B. rapax*, commonly referred to as the papermouth, a species that seems to be increasingly dependent on in-stream dams for its survival.

This chapter summarizes current knowledge of *B. rapax* and provides an insight into where the strongest populations remain and why the species is increasingly threatened.

Taxonomic History

Four papermouth species have been described for southern Africa.

Barbus mattozi Guimarães, 1884. Coroca R., Angola. Holotype (unique): destroyed.

Barbus rapax, Steindachner, 1894. Limpopo R., Transvaal, South Africa. Holotype (unique): NMW 54495.

Barbus sauvagei, Pellegrin, 1912. South-central region of South Africa. Holotype (unique): MNHN 1894-0014.

Barbus serrula, Gilchrist & Thompson, 1913; Pienaars R., Pretoria Dist., Transvaal, South Africa. Holotype (unique): SAIAB [formerly RUSI] 30023 [ex TMP 10111].

These four species were synonimised under *B. mattozi* (Jubb, 1963 and accepted by Jubb, 1967; Leveque and Daget, 1984; Skelton, 2001). As the original synonymy was not justified and the morphological differences between Kunene and Limpopo River fishes are considerable we do not accept this synonymy. We recognize two groups of southern papermouths based on distinct morphology, colour patterns and geographical distribution. These are *B. rapax* Steindachner, 1894 with a Limpopo-Zambezi-Nata distribution, and *B. mattozi* Guimarães, 1884 with a Kunene River-Namibia-Angola distribution (Figure 1).

Distribution and Status

Barbus rapax was previously synonimised with *B. mattozi*. However, the distribution of papermouth is highly disjunct in southern Africa, with two widely separated and distinct species. The first species, *B. mattozi*, occurs in the Cuanza and Cunene rivers in Angola and Namibia. The second species, *B. rapax*, occurs in the headwaters of the Limpopo, Nata and Zambezi Rivers (Donnelly and Marshall, 2003). However, the Zambezi River specimens are extremely rare with uncertain status, taxonomy and origin. As the papermouth has been translocated all over Zimbabwe (Bell-Cross and Minshull, 1988), these records could represent stragglers from stocked dams. Based on the examination of a single specimen, the Zambezi River population has provisionally been classified under *B. rapax* (R. Bills, personal communication).

Five sub-populations of *B. rapax* possibly still exist within the Limpopo River system, based on our present information. However, this subdivision may be remnants of a single once-widespread population, reflecting the absence and/or loss of suitable habitats to retain permanent residents in between (Figure 2). This assumption is supported by the fact that large numbers of vagrant *B. rapax* have been recorded intermittently between the above-mentioned sub-populations (such as in the lower Olifants River near Phalaborwa and in the mainstream of the Limpopo River), usually after floods. Some other interesting historical distribution records of this species include the Dwars River (a tributary of the Steelpoort River) (Gilchrist and Thompson, 1913) and the upper Olifants River, near Witbank. The large numbers of vagrants recorded intermittently may also be a reflection and/or a relic of the catchment-scale migrational requirements of the species, which may have been necessary for connecting, repopulating and genetic exchange among the sub-populations mentioned above.

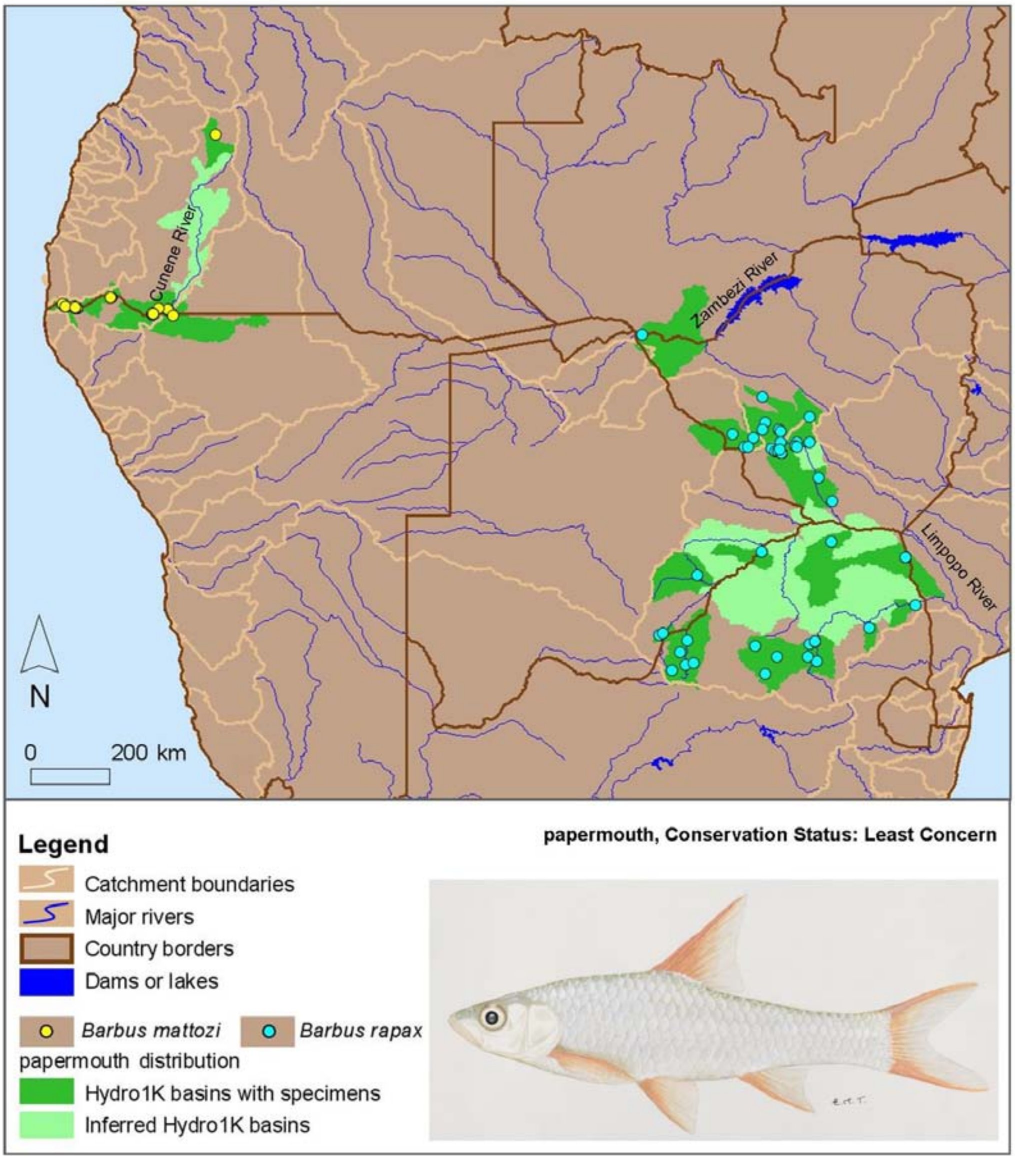

Figure 1: Distribution of *Barbus rapax* and *Barbus mattozi*, based on voucher samples (prepared by Willem Coetzer, SAIAB).

Figure 3: *Barbus rapax* specimen from Kruger National Park shows typical morphological characteristics including serrated spine and terminal, large protractile mouth. (Photo SAIAB.)

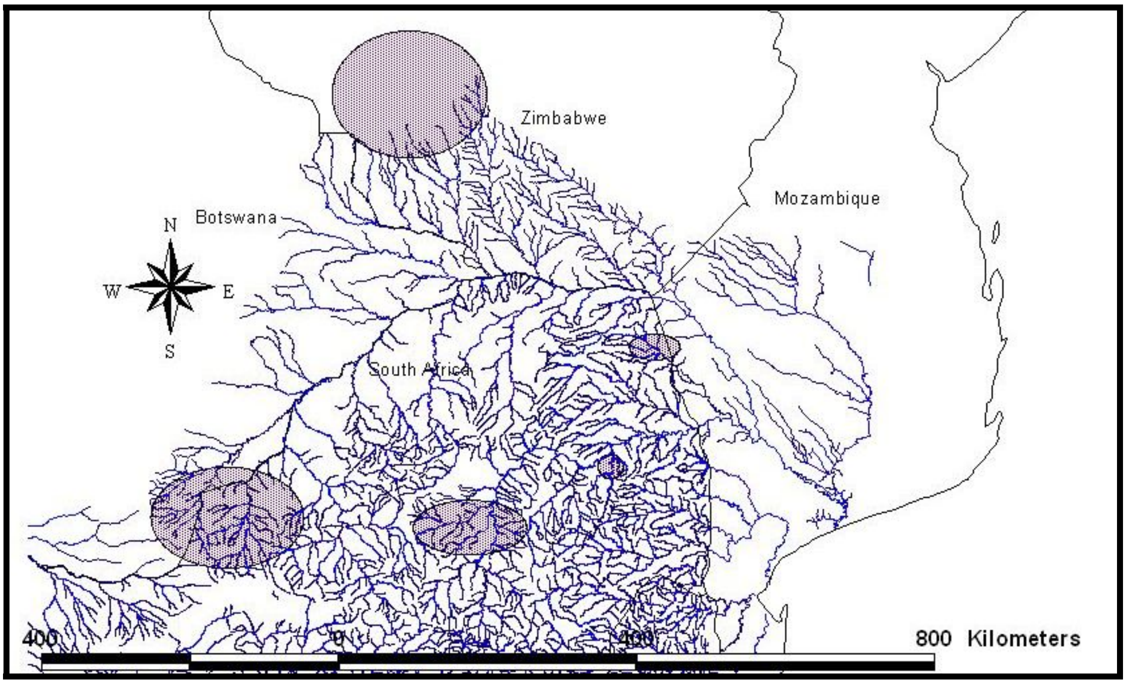

Figure 2: Approximate location of the five identified sub-populations of *Barbus rapax* in the Limpopo River system.

Therefore, the five sub-populations described below and shown in Figure 2 are not only based on available distribution records but also on information and knowledge on the presence of resident sub-populations.

Olifants River above Arabie Dam including the Elands, Pienaars and Moses Rivers

Fish in this sub-population are still abundant in several dams in this area, but recent surveys suggest that their numbers in Loskop and Arabie Dams may be dwindling due to the poor and deteriorating quality of water coming from coal mining in the upper Olifants River. Water abstraction and flow modification significantly influence the availability of suitable habitat in rivers for this species, whereas the many in-stream dams are fragmenting this sub-population and genetically isolating it from other downstream sub-populations.

Blyde River

This sub-population is represented by small numbers of fish in Swadini Dam and it may possibly be present in some larger pools in the Blyde River below the dam. The subdivision in the Olifants River may have been induced by the loss of suitable pool habitats below Arabie Dam and there may still be some genetic exchange between portions of this and the upper Olifants River sub-populations. The loss of pool habitat in recent years between Arabie Dam and the Blyde River can largely be attributed to increased sediment input and deposition in the river, aggravated by reduced and modified flows. This and the upper Olifants River sub-populations are geographically isolated from the other three sub-populations mentioned below, as these rivers only meet on the coastal plains of Mozambique below Massingire Dam.

Upper Limpopo including the Sand, Mokolo, Marico and Crocodile Rivers

Although this sub-population may still be present in some dams in the upper catchments of the region, no specimens have recently been recorded from the area (M. Angliss, personal communication). Their occurrence and numbers are largely impacted by water abstraction, flow modification as well as poor and deteriorating water quality. This sub-population is also highly fragmented and genetically isolated from other sub-populations downstream by the large number of dams on the different watercourses.

Shingwedzi River in the Kruger National Park

This stable and moderately abundant sub-population inhabits the Kanniedood Dam and some larger pools in the ephemeral Shingwedzi River. It may be geographically isolated from other sub-populations because the Shingwedzi River only joins the Olifants River on the coastal plains of Mozambique below Massingire Dam. This sub-population is considered unique as it occurs at an altitude of less than 500 m above sea level – much lower than any of the other sub-populations. There is no evidence to suggest that it extends down into the lower Limpopo in Mozambique.

Limpopo and Zambezi tributaries in south-eastern Zimbabwe

This sub-population is probably still present in several dams and some larger pools in mostly ephemeral streams in the upper catchment of the Shashi River and across the watershed in the Nata, Zambezi and Okavango Rivers. The growth rate of the fish in the Mtsheleli Dam seems to be significantly lower in comparison to Limpopo sub-populations in South Africa (Donnelly and Marshall, 2003).

According to the recent IUCN (2007) assessment of the conservation status of aquatic species in southern Africa, *B. rapax* is listed as "Least Concern". This is mainly because it is still widespread and locally common in some dams within the Limpopo River system. However, suitable habitat and population numbers in some dams have recently dwindled markedly, requiring that the species be regularly monitored to assess its conservation status.

Biology and Ecology

Barbus rapax is a silvery fish with orange fins and the snout is distinctively concave. The barbels are thin and have either one or two pairs of maxillary barbels (Figure 3). The mouth is terminal, large and protractile. There are 29 to 35 scales along the lateral line and 14 around the caudal peduncle. The dorsal fin is IV 8 and the anal fin III 5. A distinctive feature is the last simple ray of the dorsal fin, which is spinous and serrated. Unlike true yellowfishes (*Labeobarbus* spp.), *B. rapax* has radiated striated scales, a serrated dorsal spine and the origin of its ventral fins is in front of the origin of its dorsal fin. It attains a length of approximately 40 cm, matures after 3 years and reaches a maximum reported age of 9 years. The South African angling record is 1.3 kg, although most fish caught by anglers are between 250g and 500g in size (Gaigher, 1969; Skelton, 2001; Jubb, 1967).

According to Gaigher (1969), *B. rapax* is primarily found at altitudes above 600 m in wide and deep pools of cooler perennial rivers and seem to be more prolific in large dams than in rivers. Population estimates for Loskop and Mtsheleli Dams (Göldner et al., 1972; Donnelly and Marshall, 2004) indicate that *B. rapax* was one of the most abundant species in these dams during fish surveys. In rivers, the papermouth is found almost exclusively in large deep pools in the main stem of both perennial and ephemeral rivers as well as in permanent pools in side channels. It is most often captured in the deeper sections of these water bodies or in gillnets during late afternoon and during darkness, suggesting that it is most active during low-light periods.

Numerically, *B.rapax* represents one of the larger *Barbus* species in southern Africa and is more predacious than any other related minnow. It is an active predator that initially feeds on small planktonic crustaceans and insects but as it reaches maturity, it increasingly switches to small fish (Skelton, 2001). Its short gut length (approximately equal to standard length) is indicative of its predatory feeding habits (Kruger and Mulder, 1973; Mulder, 1989). It has also been recorded to feed on water-lily seeds (*Nymphaea* sp). Predators of *B. rapax* include piscivorous birds, otters, large catfish, tiger fish and adult papermouth (Skelton, 2001).

According to Donnelly and Marshall (2004), *B. rapax* has a single annual breeding event and fish migrate upstream to spawn with the onset of the first summer floods. During November 2007, large numbers of breeding *B. rapax* congregated at the head of Swadini Dam on the Blyde River. The level of the dam was extremely low at the time and this created a shallow run in the gravel and sand bars at the head of the dam, suggesting that *B. rapax* is a benthic spawner on sandy bottoms (psammophils) (Welcomme et al., 2006). "Yellowfish" larvae were collected seven days later in the shallow water downstream of the spawning site. Juvenile *B. rapax* probably keep to deeper sections of larger water bodies from where they move into the peripheral shallows to feed during low-light periods. The author has, on several occasions, collected juvenile papermouth mixed with several other small species, in the shallows at Loskop Dam during late afternoon and shortly after dark.

Threats

Barbus rapax has a very narrow preference in terms of its habitat requirements and is therefore largely restricted to larger dams and some of the larger mainstream pools remaining in the upper catchments of tributaries of the Limpopo and Olifants Rivers. Although, it is often abundant in dams, sub-populations are largely isolated from one other. The ever-increasing rate of water abstraction and deteriorating water quality have had a substantial effect on many of the remaining habitats over the last two decades. *Barbus rapax* is most likely an obligatory migratory species, suggesting that its survival is dependent on the ability to migrate to suitable spawning grounds, nursery areas and so on. This, in turn, requires rivers to be continuous longitudinal systems with good habitat and water quality. However, the reality is that the rivers in question are fragmented by dams and weirs separated by mostly unsuitable shallow habitat.

The abundance of *B. rapax* in Loskop Dam is well documented (Göldner et al., 1972). However, this dam is presently subject to an enormous increase in pollution, causing several massive fish kills annually. Because the majority of breeding individuals may be involved in a single annual upstream breeding migration (Donnelly and Marshall, 2003), the species is likely highly susceptible to catastrophes and/or over-utilisation during this period. A pollution incident during such a spawning event may kill most of the breeding fish and/or cause a complete recruitment failure. Similarly, the highly eutrophic Hartbeespoort Dam, which used to have a healthy population of *B. rapax*, now only rarely yields a specimen (Cochrane, 1987; North West Provincial Government, 2005). Protocols used by the National Rivers Health Programme for its State of the Rivers Reports do not provide a direct indication of the present status of *B. rapax* as sampling does not include dams or large water bodies. However, it largely depicts the deterioration of the rivers that feed and connect the remaining available habitats for this species (State of the Rivers Reports, 2001 and 2005).

Research and Monitoring Needs

From the available information on this species, it is evident that there is a need for genetic studies of the different sub-populations. This is essential to understand the impact of fragmentation in and between the sub-populations as well as to address some of the taxonomic uncertainties. This study should also give an indication of the importance or need of fishways and/or translocations to maintain genetic diversity in essential remaining habitats.

To ensure the validity of future management plans for *B. rapax*, there is also a need to determine the exact extent of its remaining distribution and requirements as well as a strategy for successful breeding and recruitment. This should reflect aspects of its abundance and population structure in order to identify crucial remaining habitats in each of the sub-populations. These crucial habitats should serve as a basis for a rapid long-term monitoring program to conserve this species.

Conservation and Utilization

In the past, anglers generally caught Bushveld papermouth more or less fortuitously but they are now being targeted specifically, especially by art-lure anglers and fly fishers. Records in the literature show that subsistence anglers in Zimbabwe (Donnelly and Marshall, 2003) and southern Botswana (Nermark and Mmopelwa, 1994) harvest substantial numbers of *B. rapax* annually. Although this species may not be in immediate danger, we do not understand its breeding and nursery requirements fully or the purpose of the observed vagrant migrations. This is exacerbated by the fact that the sub-populations are also highly fragmented and isolated in the remaining habitats. Moreover, very few of the stronger populations are found in rivers or dams within protected areas. Therefore, none of the sub-populations can be considered completely out of danger, except possibly for the one in the Shingwedzi River. Over and above the fact that the taxonomic and genetic status of this species and its sub-populations need urgent attention, the genetic diversity within the fragmented sub-populations and a better understanding of the breeding and nursery requirements of the species may be an essential component in its long-term conservation. Fishways at weirs and dams and frequent translocations within sub-populations may also be important tools to maintain and ensure genetic exchange and population numbers in remaining habitats. Anglers catching adult specimens should be encouraged to practice catch and release.

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STATUS OF THE CLANWILLIAM SAWFIN *BARBUS SERRA* (PETERS, 1864)

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ABSTRACT

Clanwilliam sawfin *Barbus serra* Peters, 1864 populations have undergone considerable declines in their abundance and distribution range since the 1930s. Predation by alien fish species, water abstraction, habitat degradation and water resources infrastructure have been primarily responsible for this decline. *Barbus serra* is currently listed as Endangered by the IUCN and viable recruiting populations are restricted to tributary reaches where invasions have not yet taken place and disturbances are minimal. The development and implementation of a management plan for this species is a high priority, but major obstacles include lack of capacity amongst local conservation and water resource authorities, low levels of awareness amongst landowners and unsustainable levels of abstraction throughout the catchment.

Introduction

The Clanwilliam sawfin *Barbus serra* Peters, 1864 is endemic to the Olifants-Doring River Basin (ODRB) in the Western Cape (Figure 1) where it may often be found in large schools of over seventy fish. Like the Berg-Breede whitefish *Barbus andrewi* Barnard, 1937, its sister species, *B. serra* is tetraploid rather than hexaploid and therefore not a true 'yellowfish'. Nevertheless, it is one of South Africa's larger barbine cyprinids and shares many broad behavioural and morphological characteristics with this group. The growth of *B. serra* is retarded in tributary reaches by low temperatures and limited habitat availability. Adult fish in these tributary populations may therefore reach little more than 300 mm in length, whereas adults in the main stem can grow up to 450 mm and weigh 1.5 kg.

Until recently, *B. serra* has received a relatively low profile on scientific and conservation agendas and little was known about its behaviour and ecology. As for many of our freshwater fish, the literature on this species is sparse. Most of what is known about the *B. serra* has been recorded in management and technical reports – very little information is available in either the local or international peer-reviewed literature. Historical changes in the distribution of *B. serra* have therefore been accumulated from anecdotal accounts of anglers reported in the journal *Piscator*, CapeNature technical reports, as well as collection databases held at the Albany Museum and the South African Institute of Aquatic Biodiversity (SAIAB). More recent distribution records, particularly from the main-stem reaches of the Olifants and Doring Rivers, were obtained from surveys conducted for the Department of Water Affairs and Forestry (DWAF) and the Water Research Commission (WRC) between 2001 and 2003 (Paxton et al., 2002; Paxton, 2004; Birkhead et al., 2005). A study of the behaviour and ecology of this species, funded by the WRC, is currently underway at the Freshwater Research Unit, University of Cape Town. The results of this study will be available in 2008 and some of the key findings are presented informally in this chapter.

Taxonomic History

Barbus serra, Peters 1864. Cape of Good Hope, Cape Colony, South Africa. Holotype (unique): ZMB 3451.

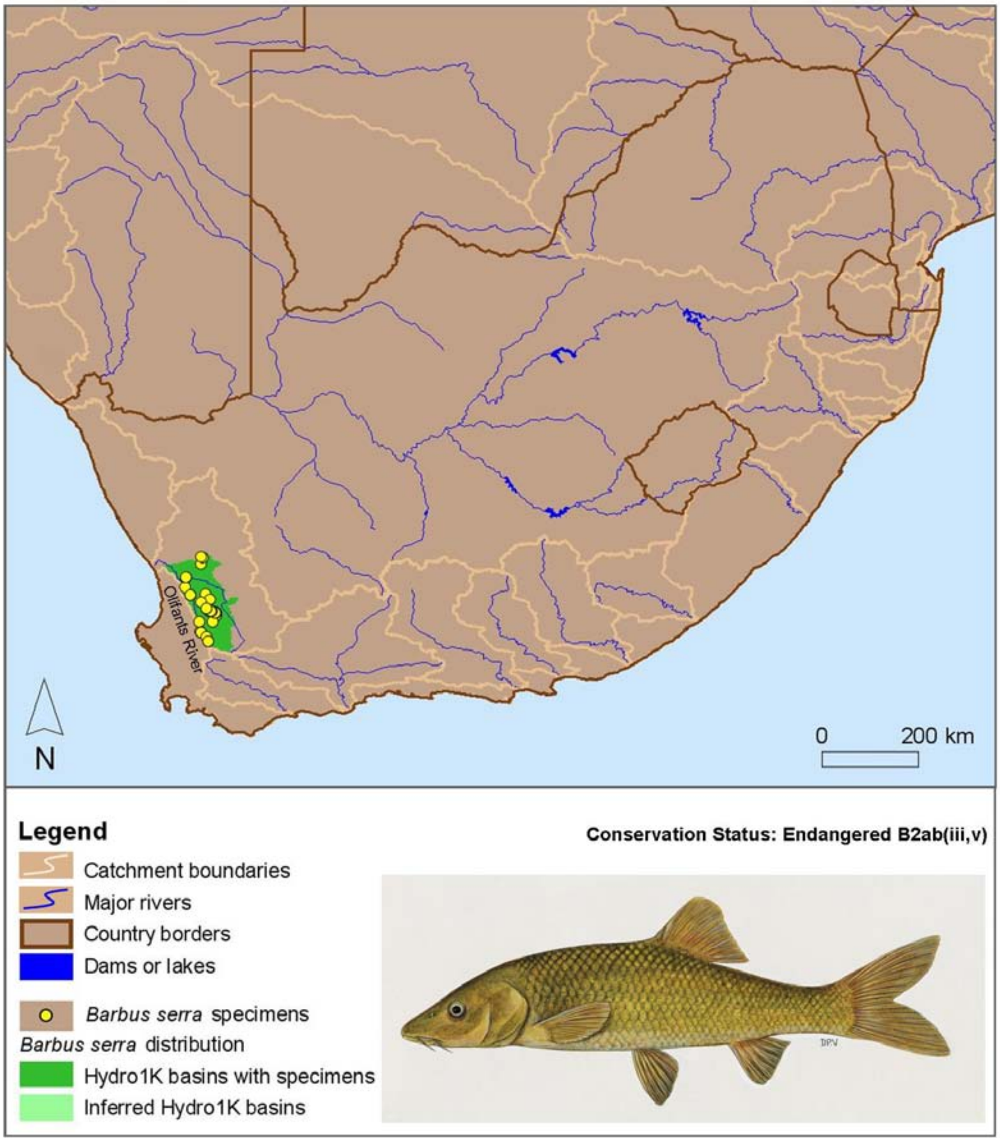

Figure 1: Distribution of *Barbus serra* based on voucher records (map by Willem Coetzer, SAIAB).

Status and Distribution of the Species

Barbus serra is endemic to the main stems and tributaries of the Olifants and Doring Rivers in the Western Cape (Figure 1). Accounts of early collectors and observers suggest that prior to the 1970s *B. serra* populations were distributed throughout this river system (Barnard, 1943; Hoehn, 1949; Brooks, 1950; Harrison, 1963; Van Rensburg, 1966), (Figure 2). However, more recent surveys have shown that this is no longer the case and that substantial declines in absolute abundances and localised extinction of populations have occurred throughout their former range (Scott, 1982; Gaigher, 1973; Paxton et al., 2002), (Figure 3).

Figure 2: Likely original distribution range of *Barbus serra* prior to the introduction of alien fishes (map by Dean Impson and Riki de Villiers, CapeNature).

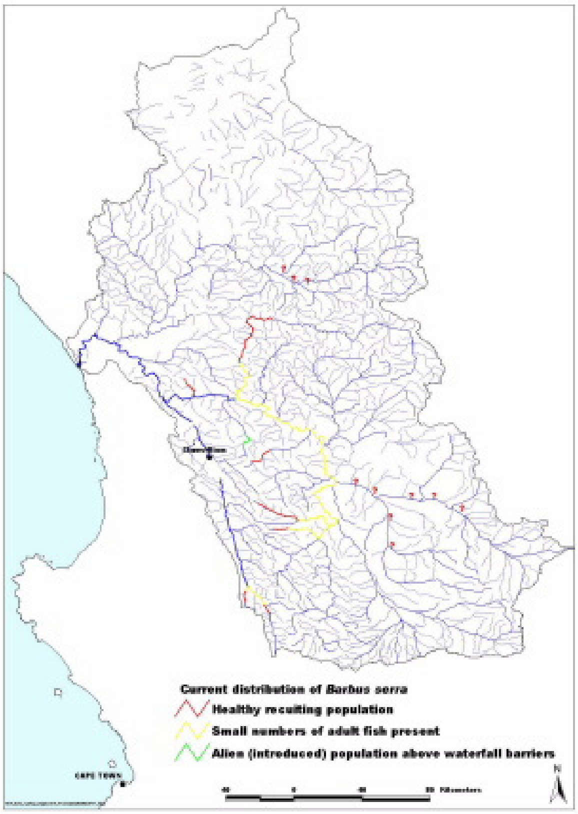

Figure 3: Present distribution range of *Barbus serra*, based on voucher records and survey work (map by Dean Impson and Riki de Villiers, CapeNature).

Thus the current conservation status of *B. serra*, as listed by the International Union for the Conservation of Nature (IUCN), is Endangered (EN B2ab (iii, iv); IUCN 2006).

The DWAF recognises six important management sub-areas within the greater Olifants/Doring Water Management Area (DWAF 2005). Amongst these, the upper and lower Olifants, the Doring and Kouebokkeveld sub-areas are most important in terms of *B. serra* distribution. The status and distribution of *B. serra* populations will be considered below in the context of each of these management sub-areas.

Upper Olifants

The Upper Olifants management sub-area extends from the headwaters of the Olifants River in the Agterwitzenberg to the Clanwilliam Dam and includes the farm Keerom where, in the late 1930s, some of the earliest scientific collections and observations of *B. serra* were made by Dr. Keppel Barnard of the South African Museum (Barnard, 1943). Barnard collected 135 *B. serra*, all under 25 mm in length – his is the only evidence we have of substantial recruitment in the main stem of the Olifants River. Between 1963 and 1964, Van Rensburg (1966) collected 410 *B. serra* from Keerom, suggesting that they were still relatively abundant here at the time. However, a few years later Gaigher (1973) noted that recruitment levels between Keerom and Citrusdal were declining. Bills (1999) recorded *B. serra* at Keerom in the 1990s, but between February 2001 and December 2003, a number of fish surveys were carried out between Keerom and the Clanwilliam Dam. During the course of netting and dive surveys no *B. serra* in any size class were captured or observed (Paxton et al., 2002; Birkhead et al., 2005). It is assumed therefore that viable populations in the Olifants River between Keerom and the Clanwilliam Dam are functionally extinct. The status of *B. serra* populations on the main stem of the Olifants River upstream of Keerom to the confluence of the Boskloof River is unclear. However, upstream of the Boskloof River confluence in the vicinity of the Olifants River Gorge, viable recruiting populations can still be found (Paxton, 2004). Most of the upper Olifants is invaded by alien fishes, with brown trout *Salmo trutta* Linnaeus, 1758 in the upper reaches above Visgat waterfall, and smallmouth bass *Micropterus dolomieu* (Lacepède, 1802) appearing from Boskloof downstream in the gorge. Viable populations also occur in the Boontjies, lower Dwars and Ratels Rivers but none have been recorded in many of the other tributaries in this sub-area that support populations of Clanwilliam yellowfish *Labeobarbus capensis* (A. Smith, 1841), redfin minnows and rock catfishes *Austroglanis* spp. .

Lower Olifants

The lower Olifants management sub-area extends from the Clanwilliam Dam to the mouth of the Olifants River. There are only two distribution records for *B. serra* here: a record from the Albany Museum in 1972 (collections database, Albany Museum) and *B. serra* caught close to the mouth of the estuary in the 1980s (Day, 1981). The latter were collected downstream of the weir at Olifantsdrif near the town of Lutzville, only 15 km from the estuary mouth, suggesting that their former range must have extended throughout the lower river. Surveys that were undertaken in the lower Olifants River more recently (2001 and 2003) covered six sites between the Bulshoek Dam and the estuary and found no *B. serra* (Paxton et al., 2002; PGWC, 2004; Birkhead et al., 2005).

It must be assumed therefore that viable populations of *B. serra* have largely disappeared from this region. Introduced largemouth bass *Micropterus salmoides* (Lacepède, 1802) and *M. dolomieu*, bluegill sunfish *Lepomis macrochirus* Rafinesque, 1819*,* as well as banded tilapia *Tilapia sparrmanii* A. Smith, 1840 and Mozambique tilapia *Oreochromis mossambicus* (Peters, 1852) dominate the fish community in this region. The upper Jan Dissels River, a tributary that joins the Olifants River between the Clanwilliam Dam and the Bulshoek Weir harbours a small population in its uppermost reaches.

Kouebokkeveld

The Kouebokkeveld management sub-area, situated in the Doring River catchment, includes the headwaters of the Riet and Groot Rivers in the south and extends to the confluence of the Groot River with the dry Doring in the north. The status of *B. serra* populations in the upper Groot and Leeu Rivers system is unclear, but there are two records of *B. serra* in the Brandkraals and Twee rivers. These fish were collected in 1973 (AMG, 2041) in October or November. Presumably they were collected below the lower of the Twee River waterfalls and must have migrated upstream to spawn. Although limited numbers of *B. serra* are known to occur close to the confluence of the Groot and Doring Rivers, no young fish have been recorded from this area in recent years (Paxton et al., 2002). A significant population of *B. serra* occurs in the upper Driehoeks-Matjies river system (a tributary of the Groot River), and ecological studies currently underway here suggest that this river system (together with the Ratels River in the Lower Olifants sub-area, and the Oorlogskloof in the Doring River sub-area) represents one of the most important refuges for this species. *B. serra* has also been recorded in the Tra-tra and Biedou rivers.

Doring River

The Doring River sub-area extends from the confluence of the dry Doring River with the Groot River in the south to the confluence of the Doring with the Olifants River near Klawer in the north and includes the tributaries entering from the Cederberg and Karoo. Although small numbers of adult *B. serra* have been recorded between De Mond and Aspoort, their frequency of occurrence and relative abundances are low and only increase in the lower Doring River between the confluence of the Brandewyn River with the Olifants and the Gif River (Impson, 1999; Paxton et al., 2002). No *B. serra* has been recorded in the last 10 km of Doring River before its confluence with the Olifants. Recruiting populations are found in the upper reaches of the Oorlogskloof-Koebee River that joins the Doring River 42 km from its confluence with Olifants, and in the Gif River 20 km upstream of the confluence. This area corresponds to the most northerly limit of their distribution. Of most concern in the Doring sub-area is the absence of fish less than 300 mm TL in the main stem river, suggesting that successful recruitment has not taken place here for several years and leading to speculations that populations may soon disappear from the Doring main stem altogether. In 1998 juveniles of *B. serra* and Clanwilliam sandfish *Labeo seeberi* Gillchrist and Thompson, 1911 were collected in seasonal stream pools on the Gifberg.

Status of the Habitat

Olifants River

The Olifants River rises on the Agterwitzenberg plateau at an altitude of around 800 m. Agricultural development on this plateau is intensive with irrigation fed primarily by farm dams. The river here is in a C-category (moderately modified, DWAF, 1999). Approximately 12 km downstream the river flows through a narrow gorge between the Groot Winterhoek and Skurweberg mountains before entering the wider Olifants River valley a further 25 km downstream at the farm Keerom. Due to the steepness of the valley sides, disturbances between the gorge and Keerom are limited to invasion of the riparian belt by black wattle *Acacia mearnsii*, and the river here is consequently in a B-category (largely natural). Habitat for *B. serra* in this region is therefore considered optimal, the only major threat being the presence of *Micropterus* spp. and *S. trutta*. As the valley slopes widen downstream of Keerom, habitat quality deteriorates to an E-category (seriously modified) as agricultural activity (primarily citrus orchards) becomes more widespread. Water resource use in this area has exceeded availability (Basson and Rossouw, 2003) and the duration of the no-flow period during the dry season has increased from 5% under natural conditions to 45% presently (Birkhead et al., 2005). The tributaries of the Olifants River are still relatively undisturbed in their upper reaches, but habitat quality declines in the lower reaches where farming activities intensify. Invasion of the riparian zone by alien plants and failure to enforce a riparian buffer zone (resulting in bulldozing of the river channel and cultivation on the floodplains), together with unsustainable levels of abstraction, represents some of the most serious threats to habitat quality in these reaches.

Downstream of Citrusdal the river flows north in an alternately braided and single-thread channel before reaching the back-up waters of the Clanwilliam Dam. The Clanwilliam Dam and the Bulshoek Weir and canal system are the most important water resource infrastructure developments in the region, supplying water for agriculture (primarily citrus orchards in the Upper Olifants and table grapes and vineyards in the Lower Olifants). Between them, the dam and weir have inundated 30 km of river habitat that would have included spawning habitat for *B. serra*. The two structures also represent impassable barriers to migrating fish, restricting access by downstream populations to potential spawning habitat upstream. Downstream of the Clanwilliam Dam the river's flow regime is controlled by irrigation releases and the potential exists to substantially improve instream habitat if the Reserve is implemented and multiple release structures are incorporated into plans for raising the dam wall. There are no release structures on the Bulshoek Weir and flows downstream are therefore substantially curtailed. A substantially attenuated flood regime, reduced sediment supply, and cultivation on the flood terraces have transformed the river channel here from a braided system to a single-thread channel. Consequently, the main channel comprises a series of deep pools connected by shallow riffles that have been invaded by reeds and palmiet. The river here is in an E-category. Intensive farming of the Olifants River floodplain downstream of the Doring River confluence to the estuary (90 km) has resulted in entrenchment of the river channel and water quality deteriorates here as a result of agricultural return flows.

Doring River

For the first 150 km from its source north of Ceres to its confluence with its first major tributary, the Groot River, the Doring River is ephemeral with no permanent pools. Downstream of the Groot River, the Doring is seasonal, being reduced to a series of isolated pools between December and June. Compared with the Olifants River, the Doring River remains relatively undeveloped since a large proportion of the river flows through a series of steep-sided gorges. Most of the main channel of the river is therefore considered to be in a B/C-category. Agricultural activity is restricted to areas where the river is more accessible, i.e. at Elandsvlei, Doringbos and the confluence of the Biedouw River. At these sites, changes to in-stream habitat and water quality are significant, but localized. In particular, failure to enforce a buffer-zone, allowing access to the main channel by livestock (cattle and goats) reduces water quality in summer when fish are restricted to the isolated pools and are therefore especially vulnerable to deteriorating water quality conditions. The upper portions of some of the tributaries, in particular those in the Kouebokkeveld, are subject to extensive impoundment by farm dams and abstraction. As a consequence, the period of no-flow conditions that prevail in the Groot River has been extended from 25% of the low-flow period under natural conditions, to 60% under present day conditions, and in the Doring River from 45% under natural to 70% under present day conditions. Climate change is believed to have contributed at least partly to this situation (Birkhead et al., 2005). This has led to reduced quality and quantity of spawning habitat, the domination of the fish communities by predators and a longer period where fish are concentrated with these predators in isolated pools over the no-flow period. Apart from flow-related changes to habitat, another major impact on the Doring River is invasion of the river banks and cobble-bars by oleander *Nerium oleander*.

Major tributaries that feed the Doring and Groot Rivers from their left-bank regions include the Driehoeks-Matjies system and the Tra-tra and Biedouw rivers. Due to the mountainous nature of the terrain, most of these systems are relatively unimpacted with much of the habitat in an A or B category. Localised impacts in the vicinity of the small farming community of Wupperthal on the banks of the Tra-tra River have resulted in channelling and sedimentation. The lower reaches of the Biedouw River are seasonal largely due to water abstraction on the youth camp farm and bank erosion as a result of trampling and grazing by livestock (largely goats) as well as cultivation near the banks has in many places resulted in the destruction of the riparian belt.

Tributaries contributing water from the right-bank region of the Doring River include the Tankwa, Bos, Wolf and Koebee-Oorlogskloof Rivers. Of these, the Koebee-Oorlogskloof is the most important in terms of *B. serra* habitat and recruiting populations are known to occur in the Oorlogskloof Nature Reserve (Paxton et al., 2002). Here the river is currently in a C condition. Further downstream on the Koebee River, localized farming impacts include abstraction, as well as pollution of runoff by livestock. There may be many other small systems that could be important spawning sites and refuge/recruitment areas and that are free aliens.

Biology and Ecology

Morphology and genetics

Barbus serra (Figure 4) is a large cyprinid endemic to the Olifants River system.

Figure 4: *Barbus serra* from the Driehoeks River, Western Cape (Photo Sean Marr).

5A

5B

Figure 5: Juvenile colour pattern of *Barbus serra*: Note configuration of spots along median line (5A) and dorsal surface (5B). Juvenile pattern is very similar to the sister group species *Barbus calidus*. (photos: Roger Bills, SAIAB).

Barbus serra usually co-occurs with *L. capensis* from which it can be distinguished by the following features (Skelton 2001).

- Primary dorsal fin ray is bony and serrated vs segmented and unserrated in *L. capensis*.
- Adult colour is olive vs yellow in *L. capensis*.
- Juvenile colour pattern is a series of spots along the median line and upper body (Figures 5a and 5b) vs a series of irregular vertical bars in *L. capensis*.
- Snout is elongated vs moderate in *L. capensis.*
- Maximum adult size is 500 mm SL vs over 900 mm SL in *L. capensis.*

As already stated, both *B. serra* and *B. andrewi* are tetraploid rather than hexaploid. Both are believed to be more closely related to the Twee River redfin *Barbus erubescens* Skelton, 1974 and Clanwilliam redfin *Barbus calidus* Barnard, 1938, also endemic to the Olifants and Doring River catchments, as well as the Western Cape redfin genus, *Pseudobarbus*.

Age and growth

The earliest biological study of *B. serra* was undertaken between the years 1963 and 1964 when Van Rensburg (1966) examined gonad mass, diet and age-length relationships for 410 *B. serra* specimens collected from the Olifants River near Keerom. Van Rensburg used scales to establish a relationship between increment deposition and fish length, finding the otoliths too difficult to read (Table 1). He had no means of validating the frequency with which the increments on the scales were laid down and therefore makes no assumptions about the age of older fish. He did, however, rear six Clanwilliam yellowfish at Jonkershoek and found they attained an age of 80 mm TL after one year. If it is assumed that growth increments on the scales correspond to one year of growth, then it must be concluded that the age of an adult fish of around 400 mm TL is approximately 10 years (Table 1). No further studies have validated Van Rensburg's findings because of the high mortality that studies of this nature would entail. Growth rates are expected to be significantly different between main-stem and tributary reaches because of the differences in habitat conditions, temperature regimes, and food availability.

Table 1: Relationship between the number of rings formed on scales, and the length of *Barbus serra* as reported by Van Rensburg (1966).

Ring no.	1	2	3	4	5	6	7	8	9	10
Length (cm)	9.1	14.6	19.7	24.6	28.3	31.9	34.1	36.6	38.0	39.3

Feeding

Barbus serra is omnivorous and, in addition to typical drift-feeding behaviour, it will use its elongated snout to grub in the riverbed, grabbing mouthfuls of sediment that are then sifted through the buccal cavity for invertebrates, algae, diatoms and detritus. In areas where *B. serra* has been feeding, numerous pock marks are visible in the sediments. Table 2 shows the stomach content analyses undertaken by Van Rensburg (1966), suggesting that insects and insect larvae (primarily chironimids) make up the largest (47.2 percent) proportion of the *B .serra* diet.

Table 2: Stomach content analyses of *Barbus serra* (Van Rensburg 1966).

Insects and insect larvae (primarily chironimids)	47.2%
Copepoda and Ostrocoda	11.6%
Dinoflagellata	7.6%
Plant material (algae, vascular plants, diatoms)	10.2%
Detritus and sand	23.4%

Reproduction

Barbus serra is a non-guarding, open substratum, lithophilic spawner (A.1.3) (Balon 1975). They are repeat-spawners over several days and multiple-spawners throughout the reproductive season. Spawning takes place on loosely packed pebble and cobble (16 to 250 mm) substrates at depths between 0.3 and 0.8 m and at moderately high water velocities ranging from 0.3 to 0.7 m/s. During spawning, shoals of *B. serra* numbering up to 70 fish gather in areas of suitable habitat. Van Rensburg (1966) found that the mean gonad mass of *B. serra* began increasing from July and peaked in September and October. By January, the gonad mass had declined to pre-July levels. Thus early summer appears to be peak spawning period for *B. serra* and this was confirmed by accounts of spawning aggregations around this time (Brooks, 1950; Harrison, 1977). The preliminary results of studies currently underway in the Driehoeks River have suggested that once mean daily water temperatures reach around 19º C, shoals of up to seventy or more fish gather in fast-flowing water where the females release eggs fertilized by the attendant males among the interstices of clean cobbles and gravel. The eggs hatch out within 2 to 3 days and the newly hatched larval fish will remain in the riverbed for up to 10 days while feeding on their yolk sac. After this period they swim out of the cobbles and are washed downstream into shallow slack waters along river margins. In these warm productive areas they begin feeding on micro-invertebrates and grow into juvenile fish. Evidence from ripe running fish suggests that males mature at between 100 and 150 mm TL and females between 200 and 250 mm TL.

Habitat requirements

In the 1990s, Gore et al. (1991) used the Physical HABitat SIMulation model (PHABSIM) to assess the availability of hydraulic habitat in the Olifants River for several of the endemic cyprinids, including *B. serra*. The objective of this study was to determine whether, in the absence of exotic fish species, there would be sufficient habitat available for endemic species to recolonise the river. Gore et al. (1991) concluded that there was indeed sufficient habitat for the cyprinids in the main stem if a solution was found to the problem of alien fish. However, this study did not include all life history stages. In particular, it did not address the effects on recruitment levels in the main stem, the loss of cobble-bed riffles due to siltation, and the absence of flows that could act as cues for spawning. Preliminary results of a Water Research Commission (WRC) funded study (K5/1483), currently underway in the Driehoeks River to describe the habitat of *B. serra*, are summarised below.

Larvae and early juveniles (5 to 20 mm TL)

Larval and early juvenile *B. serra* (< 30 days old) are found in marginal slack waters at the base of riffles. Optimum depths range between 0.05 and 0.15 m. Water velocity never exceeds 0.06 m/s with optimal values less than 0.01 m/s. Fish in this size class are occasionally, but not exclusively, associated with overhead or in-stream cover (aquatic macrophytes or riparian trees and shrubs).

Juveniles (21–75 mm TL)

Juveniles in this size class (~55 mm TL, 30 to 90 days old) exhibit schooling behaviour and favour slightly deeper marginal slack waters. They are frequently associated with bedrock-dominated reaches in the vicinity of riffles and bedrock cascades. Optimum depths range between 0.3 and 0.4 m and optimal velocity was less than 0.01 m/s. Depth use never exceeds 0.5 m during the day, but migrations to deeper areas (>1 m) have been observed at night.

Juveniles and young adults (76 to 150 mm TL)

Members of this size class were frequently observed at the base of riffles and cascades with adults feeding on invertebrate drift. Optimum depth use ranges from 0.6 to 1.0 m. Velocity use is higher, ranging between 0.01 and 0.15 $m.s^{-1}$. Fish in this size-class make us of hydraulic cover provided by boulders (>250 mm) on the streambed. There is some evidence that habitat selection may differ in reaches where invasive *Micropterus* spp. are present and that juveniles may use cobbles as cover in these places.

Adults (>150 mm TL)

Outside of spawning periods these adults favour deeper pools over 1 m in depth where these are available. They also position themselves in hydraulic cover downstream of riffles where they can be observed feeding on invertebrate drift.

Migration and dispersal

Studies underway on the Driehoeks River have shown that there is a general upstream movement of groups of adult fish from deeper pool refugia where they overwinter to shallow runs and riffles just prior to the commencement of spawning in early spring (also reported by Van Rensburg, 1966 and Gaigher, 1973). These shallower areas are more productive for foraging, provide critical reproductive habitat and may provide some refuge from predation. Once the larvae of *B. serra* emerge, they spend the first month of their lives in shallow slack-water areas along the margins of the river. They are then passively displaced, or actively migrate downstream over the course of the low-flow period. After three months they can be found several kilometres downstream of their natal habitat. Here, they seem to prefer bedrock stretches where ledges and large boulders provide shelter from high winter flows as well as from predators such as yellowfishes, bass, otters and birds. Once they mature, (males at around 150 mm and females at around 250 mm – approximated from the minimum length of ripe fish) they will join the spring migrations of the adults.

Threats

Invasion by alien fish species has undoubtedly been the prime cause of the decline of *B. serra* populations. *Micropterus salmoides* was first introduced in the Lower Olifants River downstream of Bulshoek in 1933 and populations had become well established there by the late thirties. In 1943, 50 yearling *M. dolomieu* were introduced into the Jan Dissels River and in 1945, 1000 fingerlings were placed in the upper Olifants River at Keerom (Roth 1952). Four years later observations by Hoehn (1949) and Harrison (1963) noted that *M. dolomieu* had become well established at Keerom. Although shoals of *L. capensis* and *B. serra* were still in evidence, there were numerous bass in close attendance of the indigenous shoals and a noticeable reduction in the numbers of the smaller indigenous fish.

By 1960, none of the smaller barbine species could be found between Clanwilliam and Citrusdal and *M. dolomieu* was present in large numbers (Jubb, 1961).

Brooks, (quoted in Gaigher, 1973) states that in 1943 he released 50 yearling smallmouth bass in the Jan Dissels River, a tributary of the Olifants River downstream of the Clanwilliam Dam. In 1949, only six years later, he wrote: "For the past two seasons I have looked in vain for the shoals of yellowfish and other indigenous fingerlings – in previous seasons the shallows in both the Olifants and Jan Dissels Rivers were black with these fingerlings. If as I think the bass are destroying the 'yellows', then I regret my part in introducing the bass". By the early 1970s, declines in the abundance of the indigenous fish in the main stem of the Olifants River were becoming increasingly evident. During the course of surveys in 1972, Gaigher (1973) sampled fish at eight sites on the river. No *L. capensis* was netted downstream of Bulshoek Weir and only a few adult fish were caught in the Bulshoek and Clanwilliam reservoirs. Adult yellowfish and *B. serra* were present upstream at Keerom, but it was apparent that no recruitment had taken place downstream of Keerom and Citrusdal for several years.

In addition to the presence of large numbers of alien fish species, however, Gaigher (1973) also noted that water resource developments were playing a role in the decline of indigenous fish. Thus he cites obstruction to spawning migrations (combined with the extensive harvesting of the fish over this vulnerable period), sedimentation of spawning sites, water abstraction, and the failure of winter rains as additional causal factors. Surveys in September 1979, March 1980, January 1981 and March 1982 by Cape Nature Conservation (currently CapeNature) documented the continued decline of indigenous fish populations into the 1980s (Scott, 1982).

Together, the Clanwilliam Dam and Bulshoek Weir represent the most significant alteration to in-stream habitat in the catchment. One of their most direct impacts has been to obstruct the spring spawning migrations. This was noted as early as September 1938 when, 'thousands' of *B. serra*, *L. capensis* and *L. seeberi* were seen massed below dam walls (Harrison, 1977) – evidence that their continued migration was being thwarted by the barrage. When these two structures were built (in 1935 and 1919 respectively), access to some 140 kilometres of spawning habitat upstream was lost to fish living in the lower Olifants River, and a total of 30 kilometres of habitat was drowned out by the two impoundments.

In addition to the impacts of dams, run-of-river water abstraction has reached unsustainably high levels particularly in the Upper Olifants sub-area between Keerom and the Clanwilliam Dam. The Olifants-Doring basin lies within the winter rainfall area, with most of the rain falling between June and August. Spawning activity in the winter rainfall region coincides with a period of declining flows and peak demand between September and December. Water-resource use in the upper Olifants has exceeded availability and a substantial increase in the duration of the no-flow period (see 'Status of the Habitat' above) is having a detrimental effect on the native species by reducing the quantity and quality of spawning habitat over spring, concentrating developing larvae and juveniles with predatory alien fishes in ever-diminishing pools, and providing optimal spawning habitat for the alien fish species over the summer. There are proposals for additional water resource developments in the basin and the impacts of these are likely to spread through the entire catchment. In the absence of a clear management strategy for *B. serra* and other endemic species in the ODRB further declines and loss of populations are highly probable. Over-abstraction from eastern tributaries of the Olifants River is probably the reason why *B. serra* no longer occurs in the main stem and tributaries between the Clanwilliam Dam and the Oudste River. Ironically, this over-abstraction, whilst preventing migratory runs of *B. serra*, has probably resulted in the conservation of the permanent residents as access by aliens has also been reduced.

Conservation Measures to Conserve the Yellowfish Resource

The pressing social needs in the Olifants-Doring WMA suggest that freshwater systems will come under increasing demand to the meet the needs of ever-expanding urban and rural populations and it is essential that any water resource development proceeds in a manner that doesn't place additional stress on remaining *B. serra* populations. A comprehensive management plan is beyond the scope of the current report, but some priorities for such a plan are presented here. While water resources management and governance is considered to be one of the highest priorities in the region, local authorities and landowners generally do not appreciate the need for incorporating sustainable management practices to conserve river and wetland corridors. Although conservancies have been established in some areas and there are proposals to establish more (Table 3), these tend to focus on achieving broader tourism and biodiversity objectives and rivers and wetlands do not feature prominently on conservancy agendas. Education and awareness programmes aimed at key stakeholders including individual landowners, conservancies, water user associations and catchment management agencies, should, therefore, form an essential component of any management action plans.

Consideration needs to be given to tributaries that provide refugia for recruiting *B. serra* populations, especially since their small size and limited runoff make them particularly vulnerable to disturbance. Unregulated expansion of farming and tourism activities in tributary reaches currently poses the most serious threat to the continued viability of *B. serra* populations – in terms of increasing water demand, disturbance to the river channel and riparian corridor as well as pollution by agro-chemicals.

Table 3. Conservancies, Natural Heritage Sites and Provincial Nature Reserves of importance to *Barbus serra* conservation (DWAF 2005).

Existing conservancies	**Proposed conservancies**	**Natural Heritage Sites**	**Provincial Nature Reserves**
Biedouw	Keerom	Visgat	Cederberg Wilderness Area
Cederberg	Kouebokkeveld	Bo-Boskloof	Matjiesrivier
Wupperthal	Olifants Mountain	Groenfontein	
Ratels	Witzenberg		

Individual landowners, through conservancies have an important role to play in working with conservation and management agencies to implement sustainable farming practices. Some of the more important management considerations that need to be implemented at the conservancy level include *inter alia*: enhancing the efficiency of irrigation schemes, increasing off-channel storage capacity, reducing dry-season abstraction, clearing alien vegetation and enforcing buffer zones to limit run-off of agro-chemicals.

The National Water Act (NWA, 1998) is the principal legal apparatus that governs water use and management in South Africa and it requires that water users ensure that there is enough runoff to meet the requirements of the ecosystem component of the Reserve. A comprehensive Reserve for the Olifants and Doring Rivers has been determined (Birkhead et al., 2005), but there is limited capacity for ensuring compliance or for implementing water abstraction and storage licensing. It is intended that the delegation of water resource management from government to catchment level be achieved through Catchment Management Agencies (CMAs). Once these CMAs are established, they will provide the appropriate framework for ensuring water user compliance as well as for implementing management and conservation plans. Some of the broader, catchment-level concerns for main-stem *B. serra* populations include unsustainable levels of abstraction in the Kouebokkeveld and Upper Olifants regions and continued expansion of existing farmland. The ODRB CMA will have an important role to play in this regard to ensure that these issues are addressed.

The National Environmental Management: Biodiversity Act, 2004 (NEMBA) offers additional legislative support for the protection of targeted fish species in the ODRB WMA. NEMBA provides for the drafting of management plans for indigenous or migratory species that warrant special conservation attention. The Department Environmental Affairs and Tourism (DEAT) provides guidelines for the development of Biodiversity Management Plans for Species (BMP-S) for facilitating the implementation of NEMBA (DEAT, 2006). As yet, no management plans targeted at the larger endemic cyprinids in the catchment exist, but a broad conservation assessment for the ODRB WMA has been completed that identifies spatial priorities for freshwater ecosystems (Nel et al., 2006).

In 2004, CapeNature launched the Greater Cederberg Biodiversity Corridor (GCBC). This initiative recognises the need for maintaining connectivity between protected areas, and has been instrumental in increasing landowner awareness of conservation in the last three years. Initiatives by CapeNature targeting freshwater fish more directly include the proposed rehabilitation of selected rivers by eradicating bass using piscicides and reintroducing indigenous fish species to the cleared reaches. These projects have the potential to reclaim important river reaches for *B. serra*, but can only be effective in selected tributaries if certain conditions are met. Restocking programmes need to take genetic considerations into account, and population-level genetic studies will need to be completed on *B. serra*, particularly if fish are to moved between tributary and main-stem reaches or between the Olifants and Doring catchments. However, protection and consolidation of the remaining viable populations should be a priority over re-stocking.

Research and Monitoring Needs

A WRC-funded study on *B. serra* is currently underway at the Freshwater Research Unit, University of Cape Town. This study is focused on the environmental flow requirements, movement and reproductive ecology of the *B. serra* in the Driehoeks River and the results are expected to be available in 2008.

However, several knowledge gaps still exist that will not be addressed in the current study and these are listed below.

- A non-lethal method of determining and validating the ages of *B. serra*.
- Genetic studies to determine population structure within the catchment and to determine levels of genetic interchange between tributary and mainstem populations.
- Monitoring of population distributions, abundances and recruitment to assess the outcomes of management actions in selected river reaches, including tributaries and mainstem reaches.
- Studies to determine the concentrations of pesticides in rivers and their effect on native fish populations.
- Upper lethal temperature tolerances for all life-stages.
- The role of interstitial flow for the incubation of eggs.

Regular monitoring surveys of this endangered species are essential to ensure that we have updated information about its population status and distribution. The Western Cape has a well-capacitated River Health Programme and it is understood that fish surveys of the large river systems will be undertaken every 3 to 5 years. With over 40 monitoring sites on the Olifants-Doring system, this should ensure an acceptable future monitoring effort on *B. serra*.

Value of Yellowfish Resource to Anglers and Subsistence Fishers

Currently *B. serra* is not harvested for commercial or subsistence use, primarily due to its very low abundances. It is listed as endangered by the Western Cape Nature Conservation Ordinance making catch and kill illegal in public waters. However, during the earlier part of the 20th century the larger cyprinids, including *B. serra*, were harvested throughout the Olifants and Doring River systems. Fish near the confluence of the Olifants and Doring Rivers were dynamited, loaded onto ox wagons and sold in local markets (Mr. Koos Greeff, landowner, Melkboom, personal communication). In the Doring River, fish were clubbed while on the spawning beds and this practice continued on the Biedouw River where *L. seeberi* is reported to have been collected in this manner as recently as 2002 (Mr. Manus Hough, landowner, Uitspanskraal, personal communication). There is some evidence that this practice may pre-date colonisation and that local San tribes may have taken advantage of spawning events in this way (Parkington, 1977).

Many of the river reaches where *B. serra* may still be found are relatively inaccessible and little frequented by local anglers. Thus, although the potential exists to promote *B. serra* as a well-managed recreational resource, angling for this species is relatively undeveloped. Should angling for *B. serra* be actively promoted, it is essential that sufficient reserves be set aside to ensure that some populations are not subject to fishing pressure. Consideration will also need to be given to closed-seasons to minimize disturbance to spawning fish. However, it is strongly recommended that recreational angling for *B. serra* be withheld from rivers such as the Driehoeks, Oorlogskloof and Ratels, even catch-and-release angling, as this would add to the appreciable stresses already besetting existing populations. This would also provide an incentive for anglers to start establishing conservation areas with the aim of developing fisheries in the future. Dams within the distribution range of the species could be stocked to provide more acceptable recreational angling opportunities for anglers.

Concluding Remarks

Given the current status of the *B. serra*, the drafting of a management plan that will address impacts to this species in both the main-stem and tributary reaches is essential to ensure the persistence of remaining populations. The current capacity of local conservation and water management authorities needs to be increased to ensure that these management plans are implemented and that vigilance with regard to further agricultural or water-resource developments in the catchment is maintained. The future of the remaining *B. serra* populations in the ODRB will depend on ensuring that tourist and agricultural development in the tributary reaches proceeds in a manner that doesn't lead to unsustainable levels of abstraction, reductions in water quality, or that compromises the integrity of the river channel. In the main-stem reaches, excessive abstraction from the river channel during the summer months will need to be curtailed by increasing off-channel water storage and abstraction during the winter high-flow period. This is especially important in the Olifants River main stem upstream of the Clanwilliam Dam and the Kouebokkeveld region in the Doring River catchment. Management and conservation measures need to adopt broad-based whole ecosystem approaches that incorporate the principles of Integrated Catchment Management without neglecting specific catchments for special interventions (e.g. clearing alien fish species and river rehabilitation) where these are necessary.

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STATUS OF THE BERG-BREEDE WHITEFISH *BARBUS ANDREWI* (BARNARD, 1937)

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ABSTRACT

The Berg-Breede whitefish *Barbus andrewi* Barnard, 1937, as its name implies, is endemic to the Berg and Breede River Systems of the Western Cape. It has undergone major declines in its distribution range and abundance since the 1930s and has probably become extinct in the Berg River in the 1990s. Invasive fishes (primarily bass, *Micropterus* spp.) and habitat degradation due to over-abstraction, instream dams, river canalization and the inappropriate use of fertilizers and pesticides are largely to blame for this state of affairs. *Barbus andrewi* prefers bigger rivers making it highly vulnerable to alien fish predation and competition. The species is currently listed as Endangered by the IUCN and viable recruiting populations are restricted to several impoundments, with few, if any, main-stem sub-populations remaining in areas that are free of alien fishes. Its biology and ecology are poorly known and a species management plan is urgently required. Sharptooth catfish *Clarias gariepinus* (Burchell, 1822) have recently invaded both the Berg and Breede Rivers with unforeseen consequences for *B. andrewi*. Eradication of alien fishes from priority tributaries is essential, if the species is to make a comeback in rivers. There is growing awareness of and interest in *B. andrewi* amongst anglers and several impoundments in the distribution range of the species have been stocked under permit from CapeNature. Current obstacles include insufficient capacities for river and fish management at the Department of Water Affairs and Forestry and CapeNature, low levels of awareness amongst landowners and anglers, and unsustainable levels of water abstraction throughout the catchments.

Introduction

The Berg-Breede whitefish *Barbus andrewi* Barnard, 1937, locally referred to as the witvis, is a large cyprinid that is endemic to the Berg and Breede River systems of the Western Cape (Skelton, 2001), (Figure 1). *Barbus andrewi* is not a true yellowfish, *Labeobarbus*, because of significant morphological and genetic differences. *Barbus andrewi*, like its sister species in the Western Cape, the Clanwilliam sawfin, *Barbus serra* Peters, 1864, has a serrated primary dorsal fin ray and is a tetraploid cyprinid, unlike the *Labeobarbus* group which has an unserrated primary dorsal fin ray and is hexaploid (Skelton, 2007). The Western Cape has two true yellowfishes, the indigenous Clanwilliam yellowfish *Labeobarbus capensis* (A. Smith, 1841) (Impson, this volume) and the alien Orange-Vaal smallmouth yellowfish *Labeobarbus aeneus* (Burchell, 1822), introduced legally into the Gourits River system in 1953 (Harrison, 1959).

Eighty years ago, anglers regarded *B. andrewi* as a pest because it was so common. However, it is now classified as Endangered (IUCN, 2007) with healthy sub-populations restricted to several dams. It is now rare in rivers and probably became extinct in the Berg River in the 1990s.

Very little is known about the biology and ecology of *B. andrewi*, although there is a reasonable literature on its culture requirements (Smith, 1987; Bok and Immelmann, 1988). This report describes our current knowledge of this once common species and highlights research and management recommendations that are needed to improve its conservation status in future.

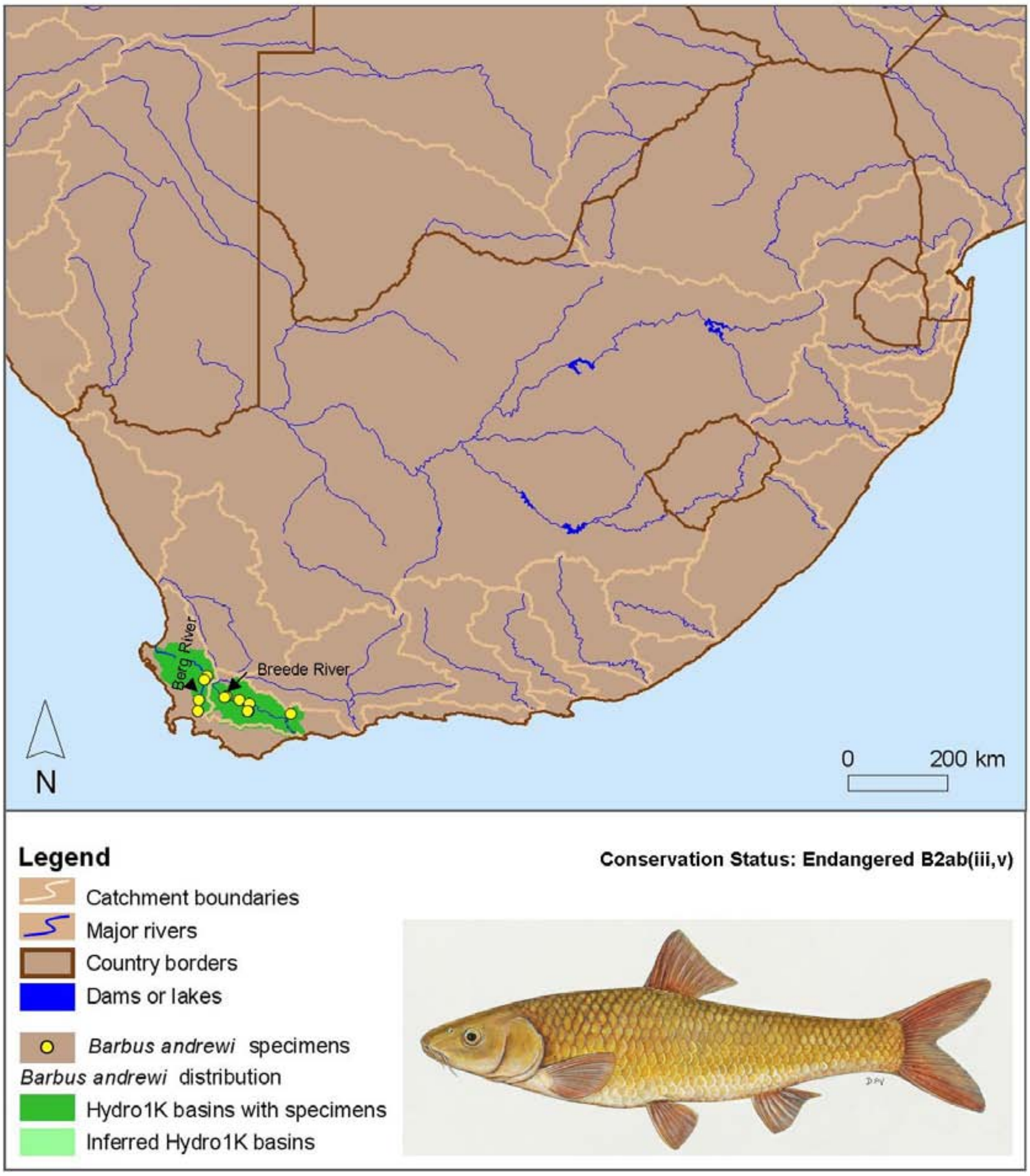

Figure 1: Distribution of *Barbus andrewi*, based on voucher records (prepared by Willem Coetzer, SAIAB).

Taxonomic History

Barbus andrewi, Barnard 1937. Berg River, sw. Cape, South Africa. Holotype (unique): BMNH 1901.2.11.9 [ex SAM].

Distribution and Status

Historical Perspective

Barbus andrewi was originally abundant in both the Berg and Breede River Systems (Harrison, 1952), (Figure 2). These river systems, like many other Cape Floristic Region (CFR) rivers, are characterized by low freshwater fish diversity (Impson et al., 1999; 2002), both having four currently recognized species. *Barbus andrewi* co-exists with Cape Galaxias *Galaxias zebratus* Castelnau, 1861 and Cape kurper *Sandelia capensis* (Cuvier, 1831) in both systems, and with Berg River redfin *Pseudobarbus burgi* (Boulenger, 1911) in the Berg system and the Breede River redfin *Pseudobarbus burchelli* A. Smith, 1841 in the Breede system. Hey (1927) noted that *B. andrewi* was "present in the Berg in very large numbers from its junction with the Dwars downstream". He noted too that: "The Breede…holds great numbers of witte vis (*whitefish*)".

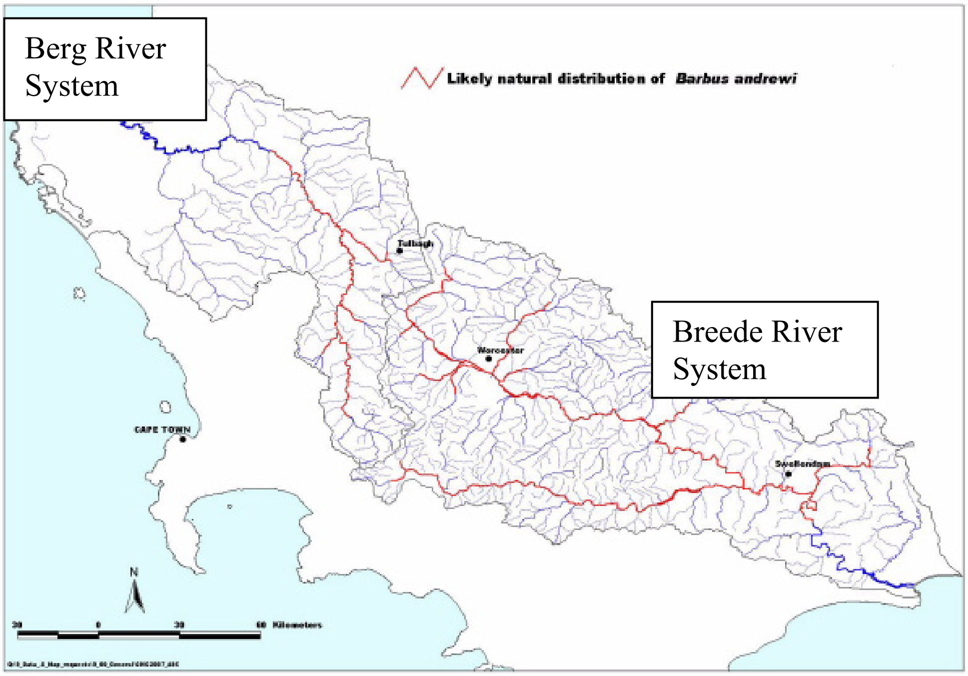

Figure 2: Probable original distribution of *Barbus andrewi* in the Berg and Breede River systems (map by Riki de Villiers, CapeNature).

A description of the middle Berg River near Paarl in 1934 gives a clear insight of the ecological condition of the river before the advent of bass (*Micropterus* spp.) invasion and intensive agriculture in the catchment: "Clean stony runs alternated with basins of large water-worn stones and long deep pools, fringed with palmiet rushes and overhanging trees and bush, silt beds being confined to the backwater. The bed was in splendid condition and the dire effect of soil erosion had not begun to appear. There was a large population of indigenous fishes.

Shoals of witvis up to about 4 lb. in weight, and rooivlerk (redfin) minnows amounted to thousands of individuals. The Cape kurper lurked under all favorable stones or swam boldly in the open water, and the little galaxias haunted the marginal weedy areas" (Harrison, 1953).

In a detailed fish survey of the inland waters of South Africa in 1925, Hey (1926) recorded *B. andrewi* in the Dwars and Wemmers Rivers of the Berg system, and in the Riviersonderend, Hex, Holsloot and Smalblaar Rivers of the Breede system. This was, however, not an exhaustive survey of all perennial rivers in these catchments.

Barbus andrewi was also recorded in the upper Vier-en-Twintig River (Hoehn, 1947) and Klein Berg River (Harrison, 1951), tributaries of the Berg River. In addition, Harrison (1952) recorded it from the Breede River below Ceres waterfall, as well as the lower Witte, Holsloot and Buffeljags Rivers.

Anglers and staff at the Inland Fisheries Department of the Cape Provincial Administration regarded the large numbers of indigenous fish in these rivers as a problem at the time, even though Hey (1926) had noted that the predatory rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792) and brown trout *Salmo trutta* Linnaeus, 1758 were eliminating small indigenous fishes from the upper reaches of rivers in the Berg and Breede catchments. Harrison (1953) reported, "…the local anglers of Groot Drakenstein (upper Berg River) were much concerned with the problem of reducing the huge population of indigenous fish in the Berg River so that there would be room for trout". Various experiments had been tried, such as the destruction of witvis when they were massed for spawning in spring with no noticeable results." The Groot Drakenstein Angling Association resolved at its 1929 meeting: "that perch and black bass be introduced into the Berg River with the view to eliminating or greatly reducing the witvis pest" (Harrison, 1953). Hey (1947), then in charge of the Inland Fisheries Department noted that "In my opinion the witvis are present in such numbers (in the Berg River) that they consume the lion's share of all the smaller food items…As an experiment it is proposed to clear a section of the river with witvis and stock heavily with smallmouth bass to allow them to gain an ascendency"

Current status and distribution

Several species of alien fish were introduced into the Berg and Breede systems between 1890 and 1950, but the introduction of smallmouth bass *Microterus dolomieu* (Lacepède, 1802) into both systems between 1938 and 1945 (Harrison, 1953) was the catalyst that caused a slow collapse of *B. andrewi* recruitment. Several fish surveys of the Berg River system have been undertaken since 1990 (Department of Water Affairs, 2004; Clarke, 2004) and none have caught any *B. andrewi*. The last known specimen caught in the Berg River by an angler was in 1995 (Jordaan, 1995). Consequently, CapeNature, the provincial conservation agency for the Western Cape Province, recently considered the species extinct in the Berg System (Impson, 2003; 2005). So, in little over 60 years, a once widespread and abundant "yellowfish" had become locally extinct!

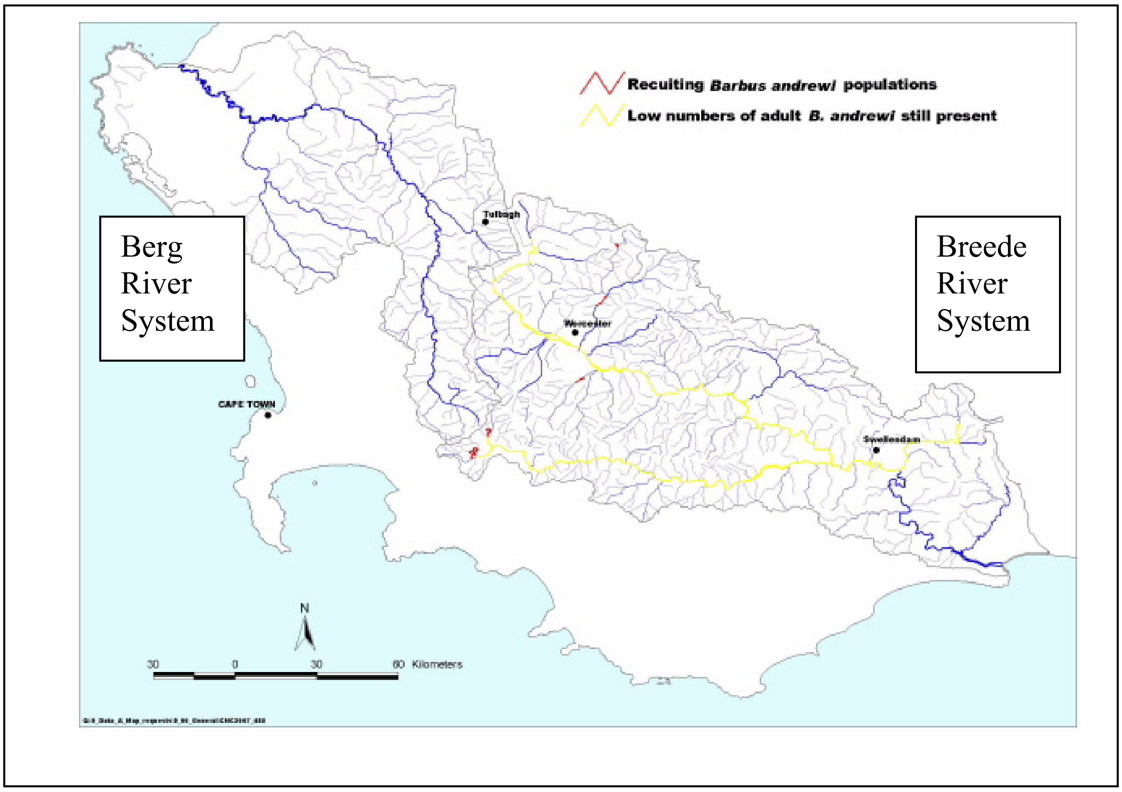

Figure 3: Estimated current distribution of *Barbus Andrewi* based on survey results (map by Riki de Villiers, CapeNature)

Figure 4. An adult *Barbus andrewi* from the Hex River, Breede River System.

The Breede system is characterised by very low numbers of *B. andrewi* in lotic environments, due to bass (*Micropterus* spp.) invasion and habitat degradation. Surveys of the mainstream by Ratte (1993), among others, failed to produce any whitefish. Sporadic reports by anglers, riparian farmers and conservation staff at CapeNature indicate that the following rivers still contain *B. andrewi*:

- Very low numbers are resident in the Breede from Mitchells Pass, below Ceres, to where the Buffeljags River enters the Breede River below Swellendam. This entire river area is infested by a variety of alien fish species.
- The upper Hex River, a tributary of the Breede River, near Worcester used to have good recruitment of *B. andrewi* until a farmer's son illegally stocked smallmouth bass in 2004 above a causeway barrier. These bass have moved 4 to 5 km up the river to Kanetvlei in three years, and very large populations of *S. capensis* and *P. burchelli* within this area are in the process of becoming locally extinct. A further impact on *B. andrewi* is the existence of predatory *O. mykiss* in the river, which are annually stocked under permit by the Worcester Trout Anglers Society.
- The Buffeljags River, a peat-stained tributary of the Breede River, near Swellendam has low numbers of adult fish that co-exist with bass, likely *M. dolomieu*, and bluegill sunfish *Lepomis macrochirus* Rafinesque, 1819.
- According to anecdotal reports, the only river that may still have a recruiting population of *B. andrewi* in its original distribution range is the upper Riviersonderend above Theewaterskloof Dam. If true, then active recruitment now occurs in less than 1 percent of the original distribution range of the species.
- A large population of *B. andrewi* is found in Brandvlei Dam outside Worcester. Local reports indicate that a healthy population is also resident in the Sanddrif Dam on the Hex River System.
- Several farm dams in the Berg and Breede catchments have been stocked with this species since 1980, with most stocking activity taking place since 2000. *Barbus andrewi* breeds successfully in impoundments that have rocky beds in shallow water (Impson, 2000).

Estimates of current distribution of *B. andrewi* are shown in Figure 3. They are currently listed as Endangered under criteria B2a(ii) and B2b(iii,v), due to declining populations, increasing levels of threat and small Area of Occupancy (IUCN 2007).

What is significant from survey work is that *B. andrewi* is not a permanent resident of small mountain streams. Anecdotal information from anglers indicates that it occasionally enters these for spawning purposes. Hence the ecological condition of these areas is less critical for the existence of this species than it is for *L. capensis* and *B. serra*, which are resident in both small and large rivers. The key variable driving *B. andrewi* to extinction is predatory alien fishes, not slightly or moderately degraded rivers. What *B. andrewi* requires is ecologically healthy larger rivers – rivers free of predatory alien fishes that have good habitat diversity, a near natural flow regime and good water quality. Few, if any, such areas remain.

Biology and Ecology

Morphology and genetics

The whitefish is a large *Barbus* with a serrated dorsal spine and its 100-chromosome count classifies it as a tetraploid. The sister species is *B. serra* from the Olifants-Doring River System and the sister group to this pair seems likely to be the Clanwilliam redfin *Barbus calidus* Barnard, 1938 and the Twee River redfin *Barbus erubescens* Skelton, 1974 which are smaller species but also tetraploid serrated-spine barbs. *Barbus andrewi* can be distinguished from all other Berg and Breede cyprinids by its large adult size (600 mm SL, 3.4 kg), the serrated dorsal fin spine and the absence of red colouration at the fin bases. It can be distinguished from its sister species *B. serra* by its larger scales, hence its lower scale counts (lateral line 38-41 vs 41-44, around the caudal peduncle 16 vs 20), its higher anal fin branched ray count (6 vs 5) and its slightly shorter snout.

Skelton (2001) has described the general morphology of the species. Harrison (1952) noted that the name whitefish/witvis probably arose from the "silvery blink of the smaller fish or the under-parts of the adults as they turn in the water". Young fish are silvery with irregular dark spots or vertical bars. These become duller with age particularly on the dorsal surface, fish then have a general pale yellowish tinge, with large adults becoming a dull bronze green or brassy on the dorsal surface with the ventral area pale yellowish or silvery (Harrison, 1952), (Figure 4). The fins are often pale rosy or dull orange-salmon with the pink tinge often becoming intensified in breeding males (Harrison, 1952).

Impson and Bloomer (1997/1998) found genetic variation between sub-populations from the Breede and Berg Rivers to be insignificant. This study used the last two whitefish ever caught from the main stem – they were possibly not original genetically pure stock, as an interbasin water transfer scheme feeds water from Theewaterskloof Dam (which has some *B. andrewi*) to the upper Berg River.

Habitat requirements

Habitat requirements have been poorly studied. Adults prefer deep pools of larger rivers, where rock or overhanging vegetation cover, especially palmiet (*Prionium serratum*), is present. Juveniles are common in riffles. They also thrive in impoundments (Impson, 2001). *Barbus andrewi* gathers in large schools, a likely response to predation by otters and cormorants in the clearer waters of the south-western Cape. They appear to be wary when seen by divers, as are *B. serra* and *L. capensis*.

Feeding and breeding biology

These aspects have also been poorly studied. Adults are omnivorous, feeding on benthic aquatic invertebrates and algae (Skelton 2001). Juveniles feed on "invertebrate drift" and small aquatic invertebrates. *Barbus andrewi* breeds in late spring, when water temperatures exceed 20^{o} C; the author has seen fish spawning in the Hex River in late November. A mixed school of adult and possibly sub-adult fish migrated a short distance upstream to a glide about 1 m deep. Spawning took place in midmorning.

At regular intervals 3 to 4 males would chase a female downwards towards the bed over which spawning took place. The spawning group would disturb the pebbles and cobbles (this could be heard underwater) as the males rubbed against the larger females. Males were estimated at 25 to 40 cm TL, with noticeably gravid females ranging from 40 to 60 cm TL. Spawning adults seemed to be a darker grey colour whereas adults outside the spawning season are bronze yellow in the clear waters of the Hex River. Adults, especially males, at this time have a pinkish-orange edging to the pectoral, pelvic and anal fins. After spawning activity, eggs that were not caught up in the interstices of the pebbles could be seen drifting downstream where smaller fish eagerly ate them. Fecundity is high with 2.5-kg captive females yielding about 100 000 eggs (Smith, 1987). *Barbus andrewi* spawns successfully in impoundments over gravel and rocky beds in shallow water (Impson, 2001).

Threats

The major threats are the negative ecological impacts of invasive alien fishes and habitat degradation (Skelton, 1987). Experts agree that the predatory impact of *M. dolomieu* is the most significant factor driving this species to extinction. Two other species of *Micropterus* are also present, namely largemouth bass *Micropterus salmoides* (Lacepède, 1802) and spotted bass *Micropterus punctalatus* (Rafinesque, 1819). Basses were introduced into both systems between 1938 and 1945 (Harrison, 1953) with devastating ecological impacts, causing localized extinctions of *Pseudobarbus*, *S. capensis* and *B. andrewi*; associated with changes to the structure of aquatic invertebrate communities (Lowe et al., in press). *Oncorhynchus mykiss* and *S. trutta*, introduced in the late 1800s, dominate the upper reaches of several rivers, including the upper Berg River, Dwars River, Elandspad River, Molenaars River, Vier-en-Twintig River, Witels River and Witte River. Their impact has also been severe, especially on the smaller species (Hey, 1926). Carp *Cyprinus carpio* Linnaeus, 1758 was legally stocked, probably in the 1920s, whereas *L. macrochirus* and banded tilapia *Tilapia sparrmanii* A. Smith, 1840 were introduced as fodder fishes for bass. Mozambique tilapia *Oreochromis mossambicus* (Peters, 1852) was legally stocked into farm dams in both catchments; probably from 1960 onwards – from here they escaped and are now abundant in the lower reaches of both mainstreams. In the 1990s, anglers illegally introduced the sharptooth catfish *Clarias gariepinus* (Burchell, 1822) into both systems (Impson, 1996a). This large aggressive omnivore is continuing to spread upstream and is invading smaller tributaries. Impson (1996a) predicted that *C. gariepinus* could have a serious negative impact on bass numbers; these predictions have proven to be accurate, with prominent bass fisheries collapsing recently in the middle Breede River as well as the Theewaterskloof and Voëlvlei dams (Impson, 2006b). All these alien fishes now dominate the prime habitat of *B. andrewi* and through predatory and competitive impacts have caused slow but spectacular population collapses in both systems. As mentioned previously, the recent appearance of *C. gariepinus* has greatly reduced bass and bluegill numbers, which, ironically, may lead indirectly to a small recovery of *B. andrewi*.

Alien fishes have not been the only impact on *B. andrewi*. Their preferred habitat, the middle and lower reaches of the larger rivers, are generally characterised by intensive agricultural development, culminating in over-abstracted, impounded and polluted rivers that are a haven for alien fish species such as *C. carpio*, *C. gariepinus* and *O. mossambicus*. Several major fish kills due to water pollution have also taken place. The first notable kill, which resulted in the deaths of hundreds of *B. andrewi* occurred in the Berg River near Paarl in 1953 due to industrial pollution (Harrison, 1953). More recently, in 1996, an accidental spill of 141 350 litres of 87.7% alcohol from a wine production facility at Paarl into the Berg River resulted in the deaths of thousands of fish over more than 30 km of river (Dallas, 1996). This time the dead fish were alien fishes, as indigenous fishes had long since disappeared from this reach of the river. This spill may have also caused the final extinction of *B. andrewi* in the river, although no dead specimens were seen.

Wheat, grapes and deciduous fruits are the major crops – all characterized by heavy seasonal applications of fertilizers and copper-based pesticides. Due to deficient and poorly enforced legislation, crops and orchards have been planted right to the riverbank. The degradation and loss of the riparian zone are major negative impacts on the healthy functioning of the river; so too are the inputs of fertilizers and pesticides causing the loss of pollution sensitive biota and excess growth of algae during the warmer months. Several rivers within the intensive agricultural zones are regularly bulldozed for flood control purposes; and some, such as the Holsloot River at Rawsonville, are mined for rock and sand. These activities had resulted in severe localized impacts with the loss of habitat diversity and deep pools that *B. andrewi* require for survival.

Measures to Conserve the Yellowfish Resource

Legislation

The species is listed as "endangered" by the provincial Nature Conservation Ordinance making "capture and kill" illegal in public waters. It receives additional protection as it is a listed species in the Regulations for indigenous species that are included in the National Environmental Management: Biodiversity Act.

Protected areas and conservation programmes

The Berg and Breede catchments incorporate several large protected areas (Limietberg, Hottentots Holland and Vrolikheid Nature Reserves) that include rivers of high conservation value. Unfortunately, *B. andrewi* is not resident in any of these smaller rivers. However, many reserves have dams because of previous land-use activities (most of Vrolikheid Nature Reserve was a farm) and these will be stocked with *B. andrewi* once they are cleared of alien fishes that were stocked several decades ago. Several rivers in both systems have considerable potential for alien fish eradication. These rivers have in-stream barriers above which alien fish can be eradicated, probably with piscicides such as Rotenone. These rivers include the lower Witte River (Impson and Bok, 1997), Vier-en-Twintig River, Klein Berg River as well as the recently invaded Hex River.

No conservancies have been established specifically for *B. andrewi*. The national Yellowfish Working Group, established in 1997, includes in its aims promoting awareness of threatened yellowfishes and increasing research and monitoring effort on such fishes. A Western Cape chapter of this group was established in 2006 with the mandate of improving awareness of indigenous Western Cape yellowfishes and creating sanctuaries for these fishes in dams that can also provide angling opportunities.

Hatcheries and stockings

Barbus andrewi has been cultured at provincial hatcheries operated by the former Cape Department of Nature and Environmental Conservation (CDNEC) at Amalinda in East London and at Jonkershoek outside Stellenbosch (Smith, 1987; Bok and Immelman, 1989). The species was bred to re-stock suitable habitat and suitable impoundments. Capacity constraints and low levels of fish production forced Cape Nature Conservation to discontinue culture of whitefish in 1995 (Impson, 1996b). Subsequently, CapeNature established a dedicated whitefish fund to enhance recovery efforts. These efforts involve angler awareness, riparian landowner education and promoting this species as an angling alternative to bass and trout (*O. mykiss* and *S. trutta*) within its distribution range. Whitefish have recently been stocked in several farm dams in both catchments to create "safe" populations for later recovery efforts (Impson, 2005). Fish used for stocking have generally been sourced from dams; although Hex River fish have been used for stocking two dams in the Breede catchment when it became evident that bass had invaded the Hex. A commercial hatchery at Bonnievale (De Rust), within the Breede River catchment, received permission in 2005 from CapeNature to culture *B. andrewi*. Limited success has been achieved to date and none of these fish have been stocked.

Improved management of water resources

Catchment Management Agencies for the Berg and Breede Water Management Area are being established. Once properly staffed and funded (likely in 2008/9), these CMAs should improve river management in the Berg and Breede systems. The implementation of the Environmental Reserve is another key requirement. The Berg River Dam, in the upper Berg River, was completed in July 2007 and will be managed under strict operating rules including the implementation and auditing of environmental water requirements. Comprehensive Reserves have been determined for both river systems.

Monitoring and Research Needs

A detailed fish survey of the Berg River system was undertaken in 2003 as part of a State of River assessment. Since then several off-stream dams, including Voëlvlei Dam have been stocked with *B. andrewi*. The success of these interventions needs to be quantified through fish surveys and genetic studies. Part of the reason for stocking the species into farm dams is to establish sanctuary stocks for re-stocking river areas when appropriate. For this to be successful, dam stocks should be genetically diverse.

A priority research project requires the rehabilitation of one or more rivers for the re-stocking of *B. andrewi*. The project will require the localized eradication of alien fishes and may include habitat improvement measures such as recovery of the riparian zone and better water quality.

A detailed fish survey of the Breede River system will be undertaken in 2007/2008 as part of a State of River assessment. This will include the main stem and larger tributaries and will also focus on the nature and status of the growing sharptooth catfish invasion. Whether the recent invasion of the Berg and Breede systems by *C. gariepinus* actually benefits *B. andrewi* by reducing bass numbers needs to be quantified.

Apart from culture studies by Smith (1987) and Bok and Immelman (1989), *B. andrewi* has been poorly researched. A detailed investigation of its current distribution, population status, biology and ecology is necessary (Skelton, 1987). This should culminate in a species management and recovery programme.

Value of the Yellowfish Resource to Recreational Anglers and Subsistence Fishers

Historically, *B. andrewi* provided good sport for anglers, and being good eating was a popular and important source of protein for farmers and their employees. Farmers and their labourers regularly trapped fish at spawning time. At present, *B.andrewi* cannot support a high value and popular recreational fishery because it is either too scarce or else is fairly abundant only in relatively inaccessible areas. Since the late 1970s, CapeNature has stocked whitefish into farm dams and a few rivers with the intention of creating sanctuaries and improving angling for the species. These efforts will be increased in future as it is essential that enough viable refuges are established to safeguard the species and allow for re-stocking of rivers when appropriate. The establishment of the Western Cape Yellowfish Working Group in 2006 is an encouraging sign as increasing numbers of anglers want to catch whitefish and assist in viable and rewarding conservation programmes.

Angler awareness and education has received considerable attention via a range of popular articles on *B. andrewi* and other indigenous Western Cape yellowfishes as well as on environmentally friendly angling ethics (Edwards 1986; Impson, 1998; 2000; 2002; 2003; 2004). The future for the species looks brighter now than at any stage since 1930. At least it is becoming more appreciated now.

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MANAGING TRANSLOCATIONS AND ALIEN POPULATIONS OF YELLOWFISH AND OTHER LARGE CYPRINID SPECIES

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ABSTRACT

All the large indigenous cyprinid species in South Africa are potentially invasive alien species, and alien populations of Orange-Vaal smallmouth yellowfish *Labeobarbus aeneus* (Burchell, 1822) and Clanwilliam yellowfish *L. capensis* (A. Smith, 1841) have become established and are causing ecological damage. There are reports that most other large cyprinid species have been translocated within and/or outside their natural range, but very little is known about whether they established alien populations and there has been little to no research on the ecological impact of these introductions. Translocations can also homogenize genetic diversity across the range of a species and hybridisation between different but closely related cyprinid species can have unpredictable consequences. Large cyprinid species in South Africa have been moved mainly in misguided conservation management interventions, for recreational fishing purposes and due to interbasin water transfer schemes. Steps will have to be taken to prevent the establishment of further alien populations of large cyprinids, to prevent the loss of unique genetic lineages and general genetic diversity and to design rehabilitation programs where aliens have already been introduced. These steps will have to include further research and surveys to map alien populations, understand conservation genetic management issues and to assess ecological impacts of the introductions. Stricter legislation, a national register of translocations, public education and a general change of philosophy across all conservation authorities in South Africa are required if the problem is to be addressed successfully.

Introduction

Indigenous fish species in South Africa are being promoted for recreational fishing, mainly to prevent the further spread of alien invasive species that have caused immeasurable damage to our aquatic environment. The promotion of indigenous species has, however, dangers of its own if it encourages a new wave of introductions of large cyprinid species (Swartz, 2001). Alien invasive species are recognised as one of the greatest threats to the ecological and economic welfare of the planet (Matthews and Brand, 2004). For freshwater fish, alien invasive fish species are regarded as the most serious threat globally (Cowx, 2002). Therefore, movement of fish species into new waters has to be seen as a serious threat to aquatic biodiversity, regardless of the origin of the alien species.

In defining alien species, no distinction should be made between alien species that originate from the same or a different river system, biogeographical region, country or continent. Translocated species and alien species are therefore both treated as alien unlike de Moor and Bruton (1988). Introductions outside the natural range of a species but within the same river system can be as damaging as an alien species from another continent. Introductions of closely related species from nearby locations have the added danger of hybridisation with species in the receiving system. They may also have adaptations to similar environments in the neighbouring area that gives them a competitive advantage of being a successful invader in the receiving system. Since no distinction is made between alien and translocated species, there is also no distinction intended in the present chapter between the terms "moving" or "translocating".

Large cyprinids such as *Labeobarbus* spp. have been moved outside their native river systems and outside their natural range within their native river system, where they can damage ecosystem functioning. Some translocations into dams and rivers have unfortunately not been recorded, and we know very little about the impacts that these aliens have on the indigenous populations of fishes, aquatic invertebrates, plants and aquatic food webs. Even when fish are moved within their natural range, it can cause a loss of genetic diversity and the spread of parasites, especially when hatchery fish are used for stocking.

This chapter summarises our knowledge of translocations of the true yellowfishes (*Labeobarbus*), as well as Berg-Breede whitefish *Barbus andrewi* Barnard, 1937, Clanwilliam sawfin *Barbus serra* Peters, 1864 and papermouth *Barbus rapax* Steindachner, 1894. The ecological impacts of these translocations are discussed and the chapter is concluded with recommendations to prevent the further translocation of yellowfish and other large cyprinid species.

Which Yellowfish Species are Invasive?

The Orange-Vaal smallmouth yellowfish *Labeobarbus aeneus* (Burchell, 1822) has been moved more often and has established more alien populations than any other of the indigenous cyprinids in South Africa and is second only to carp *Cyprinus carpio* Linnaeus, 1758 from Asia, as South Africa's most widespread alien cyprinid invader. It has a much wider natural distribution than its sympatrically-occurring sibling species, the Orange-Vaal largemouth yellowfish *Labeobarbus kimberleyensis* (Gilchrist & Thompson, 1913). The latter seems to be much more of a mainstream habitat specialist and therefore restricted to larger rivers such as the Vaal and across the length of the Orange (Senqu in Lesotho). *Labeobarbus aeneus*, however, is abundant in mainstream and tributary habitats and seems to be much more of a generalist. This generalist nature has made it a very adaptable species resulting in it being a favourite species to stock for angling purposes and very successful in establishing after being translocated. It has also been moved very successfully through interbasin water transfers (IBTs), because of its wide distribution and adaptability. There is, however, no reason to believe that *L. kimberleyensis* would not establish in large rivers outside its natural range, and care will have to be taken not to translocate this species as well.

Two other *Labeobarbus* species, namely Clanwilliam yellowfish *Labeobarbus capensis* (A. Smith, 1841) and KwaZulu-Natal yellowfish *Labeobarbus natalensis* (Castelnau, 1861) have established alien invasive populations within as well as outside their native river systems. These alien populations pose a threat to organisms that have evolved in the absence of large predatory fish such as these yellowfishes, and suggest that the latter may be ecologically dangerous invaders in non-native rivers, as well as in parts of their native rivers. All the other *Labeobarbus* species are a potential threat, not only to aquatic organisms and food webs, but also because of the possibility of hybridisation with other members of their genus.

Barbus andrewi and *B. serra*, both threatened tetraploid large cyprinid species from the Cape Floristic Region, have not been introduced outside their natural river systems, but the latter species has been introduced outside its natural range. The successful colonisation of Brandvlei Dam within its native range in the Breede River system from the Holsloot River, suggests that *B. andrewi* could be an invasive species in non-native habitats, especially if the water is turbid to protect it from visual predators such as smallmouth bass *Micropterus dolomieu* (Lacepède, 1802). *Barbus rapax* has been introduced outside its natural range in Zimbabwe and similar to the *Labeobarbus* and tetraploid *Barbus* species, it has a very generalist feeding strategy, which could make it a dangerous invasive species.

History of the Introduction and Distribution of Alien Yellowfish and Other Large Cyprinid Populations

Labeobarbus and large *Barbus* species in South Africa, have been introduced mainly for recreational fishing purposes or as misguided conservation actions by conservation authorities, especially through their state hatcheries. Unregulated and illegal introductions by anglers and landowners also occur, mainly for recreational fishing reasons, especially in farm dams, often without realisation of the potential harmful consequences of their actions.

The earliest recorded successful alien yellowfish introduction is that of *L. aeneus* into the Calitzdorp Dam in the Gamka catchment of the Gourits River system in 1953, from fingerlings bred at the Lydenburg Provincial Fisheries Institute (Jubb, 1963, 1965). From Calitzdorp Dam, *L. aeneus* has spread to the rest of the Gourits River system and is now a widespread and common species, especially in main-stem areas.

In Eastern Cape Province, *L. aeneus*, also from the Lydenburg hatchery (Jubb, 1965, 1967), was released into Settlers Dam on the Kariega River system in 1963 and into the Tsomo River in the Kei River system in 1964 (Jubb, 1965). It has, subsequently, established large populations in the Lubisi and Xonxa Dams (Schramm, 1993).

Labeobarbus aeneus was also introduced as an angling species into the Olifants River (Limpopo River system) in 1961 and into Kyle Dam (Mtilikwe River, Lundi system) in Zimbabwe in 1965 (Jubb, 1967).

In KwaZulu-Natal, *L. natalensis* was moved into sections of the Pholela River (Mzimkhulu River system) and the Little Mooi River (Thukela River system), above waterfalls that previously demarcated its natural range (Crass, 1964). According to Bell-Cross and Minshull (1988) it has also been introduced into the Ruzawi River in the upper Save system.

Bell-Cross and Minshull (1988) also report that *B. rapax* was stocked in several dams in and around Bulawayo and the Matopos and they don't discount the possibility that it may have been introduced into the Nata River (Makgadigadi-Okavango system). This means that it may not be native to the latter system.

None of the large cyprinid translocations, done for conservation purposes, have proved successful in improving their conservation status and some major negative effects have been recorded

(Impson et al., 2007; Marriott, 1998). Translocations were often done without any regard for potential impacts on receiving systems, including genetic mixing of stocks. Hopefully this practice has now stopped due to a moratorium on general stockings proposed by the Yellowfish Working Group (Arderne, 2002) and all stockings should now be done within the natural range of the species and with fish derived from sources close by.

Even when the stated goal was conservation, recreational fishing has played a role in the decision-making process, because of the desire to give landowners an alternative to alien invasive fishes. *Labeobarbus capensis* has not been translocated outside its native river system, but has been introduced above waterfalls outside its natural range. They were also moved within their natural range, which may result in the homogenisation of genetic stocks. In the mid 1980s, in a misguided attempt to improve the conservation status of *L. capensis*, Cape Nature Conservation (predecessor of CapeNature), placed specimens above a barrier waterfall in the Twee River (Impson et al., 2007), where they have now become invasive aliens (Figure 1). *Labeobarbus capensis*, *B. serra* and the Clanwilliam redfin *Barbus calidus* Barnard, 1938 have all been introduced into the Boontjies River above Meidegat Waterfall in the Bushmanskloof Private Nature Reserve (Tharme and Anderson, 1999; Impson and Tharme, 1998) which is outside their natural range. The fish were sourced below the waterfall and in the neighbouring Biedouw River (Impson and Tharme, 1998). D. Impson (personal communication) has confirmed that *L. capensis* and *B. serra* have become established in the Boontjies River above Meidegat Waterfall, representing an additional alien population of the former species and the first recorded alien population of the latter species. Two ecologists assessed the situation before the translocation and concluded that the introduction would not have negative ecological consequences (Impson and Tharme, 1998). However, the long-term impact of these fish on aquatic invertebrates in this upper catchment has not been assessed.

Several large cyprinid species have been kept at hatcheries for conservation and research purposes. No escapes have been recorded to date, but more specific surveys are needed to investigate whether any of the hatchery fish may have entered local waters and hybridised with indigenous populations.

Lowveld largescale yellowfish *Labeobarbus marequensis* (A. Smith, 1841) was kept at the Umgeni Warmwater Fish Hatchery at Nagle Dam in KwaZulu-Natal (Pike, 1989), but it is not sure if any of these fish escaped or were distributed from the hatchery. An Albany Museum record that suggests that *L. marequensis* may occur in the Umfolozi River requires further investigation. Wright and Coke (1975) report that Natal Parks Board bred *L. natalensis* at the trout hatchery at Royal Natal National Park in KwaZulu-Natal but whether it was stocked anywhere is not mentioned.

Barbus andrewi was reared at the Jonkershoek Hatchery for research purposes (Jubb, 1965), but has never been recorded in the Eerste River system. In 2005, however, it was stocked into off-stream dams at Jonkershoek 2005 to promote angler awareness and appreciation of the species (D. Impson, personal communication). This may lead to an alien population in the Eerste River system.

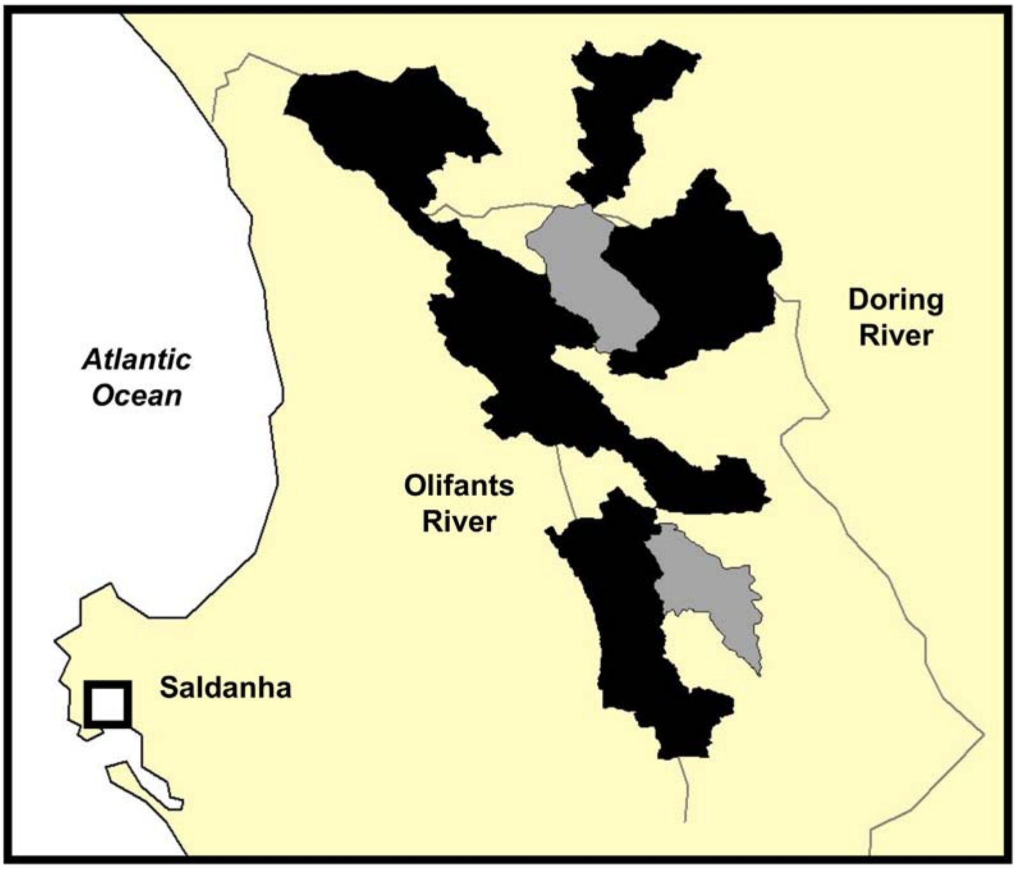

Figure 1: Map of the Olifants River system that shows up to quaternary-catchment level where *Labeobarbus capensis* has established alien populations. Note that the scale of the map is not appropriate to indicate exact boundaries between indigenous (black) and alien (grey) populations, both of which are present.

Privately owned hatcheries and aquaculture facilities in Bonnievale, Western Cape (*B. andrewi*) and near Hartbeespoort Dam (likely Bushveld smallscale yellowfish *Labeobarbus polylepis* Boulenger, 1907) are a potential threat if they breed and distribute fish species or genetic stocks that do not occur naturally in the waters to which they are subsequently introduced. This poses, possibly, the biggest future threat to yellowfish genetic conservation if these hatcheries were to supply yellowfishes across South Africa without permits from receiving provinces.

Interbasin water transfer schemes (IBTs) have also been responsible for translocations, often classified as accidental introductions. From 1975 onwards, *L. aeneus* established in the Great Fish and Sundays River systems following the completion of the tunnels and conduits that connected the Orange and Great Fish River systems and subsequently the Great Fish and Sundays River systems (Cambray, 1977; Cambray and Jubb, 1977; Russell, 1998/1999). As a result of fisheries development and IBTs, *L. aeneus* is the only large African cyprinid species that is known to have established outside its native river system in South Africa. It now inhabits the Gourits, Sundays, Kariega, Great Fish, Great Kei and Limpopo River systems (Figure 2) (Skelton, 2001). There are also unconfirmed reports that it occurs in the headwaters of the Thukela River system. Potentially, IBTs could permit *L. kimberleyensis* to establish in the Great Fish and Thukela River systems.

Translocations Within the Natural Range

Moritz (1994) defines Evolutionary Significant Units (ESUs) as historically isolated and divergent lineages based on the criteria of monophyly of mtDNA and frequency differences at nuclear DNA loci. Conservation strategies should allow evolutionary processes that have shaped intraspecific diversity, to continue into the future (Moritz, 1999; Moritz, 2002; Moritz et al., 2002; Crandall et al., 2000). An axiom of this approach is not to translocate individuals between different ESUs (Moritz, 1999).

Freshwater fish often show genetic differentiation between different river systems, and sometimes within them. A precautionary approach should therefore be followed to avoid mixing fish from different river systems and even different tributaries within the same river system in the absence of phylogeographic and population genetic studies.

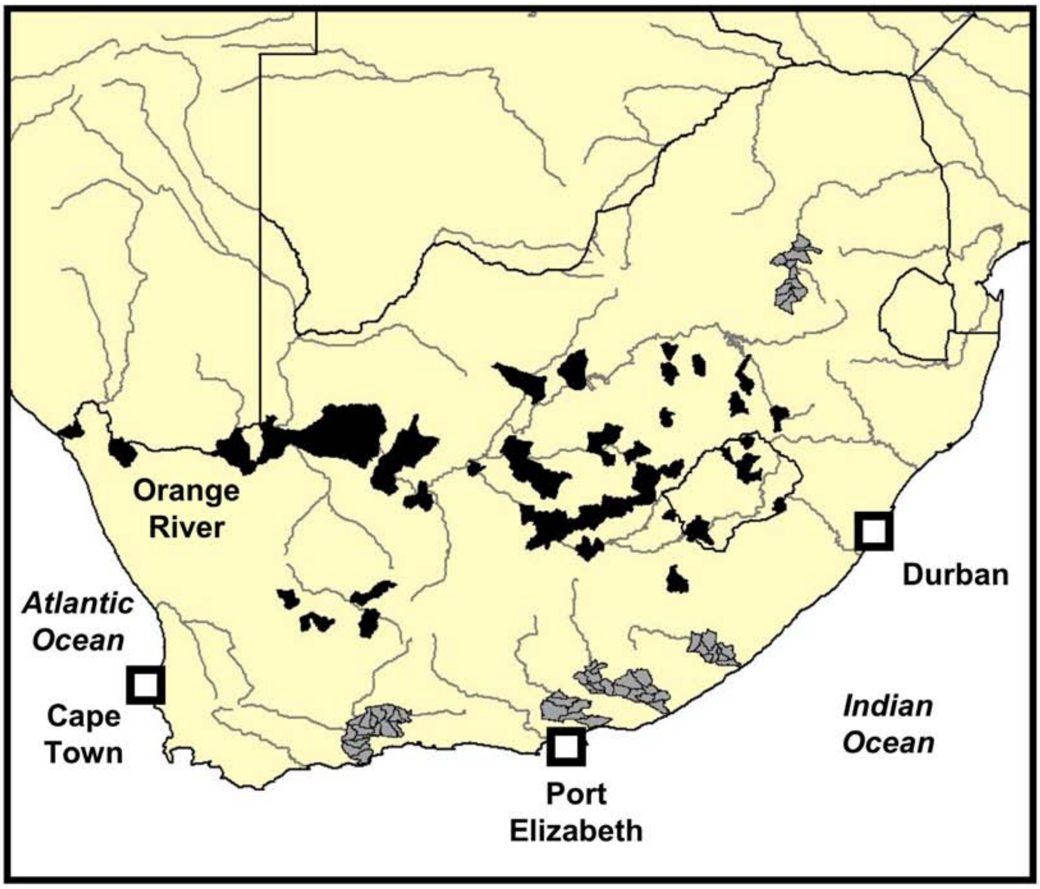

Figure 2: Catchments in South Africa, up to quaternary level, showing indigenous (black) and alien (grey) populations of *Labeobarbus aeneus.* The gaps in indigenous distribution of this species are mainly due to a lack of museum records. The alien distributions have been mapped based on literature information and survey experience and is not based on actual museum records. The latter is required to confirm the occurrence of alien populations.

Apart from translocation outside their natural range of some large cyprinid species, translocation within their respective natural ranges has also taken place. *Labeobarbus aeneus* and *L. kimberleyensis* from the Gariep Dam State Fish Hatchery were stocked throughout the Free State

Province (Haschick, 2000). CapeNature and its predecessor organization Cape Nature Conservation have stocked *L. capensis* and *B. serra* into many farm dams in the Olifants River system after the establishment of the Clanwilliam Yellowfish Hatchery in 1979 (Scott, 1982). The Clanwilliam hatchery ceased operating in the mid 1990s because of budget constraints and poor overall success with culturing indigenous fishes (D. Impson, personal communication). It is possible that certain existing populations of *L. capensis* in tributaries of the Olifants River system may have been established in this way and are, therefore, either not natural or a mixture of natural and introduced stock. For example, it is not known if the populations in the upper reaches of the Rondegat River and the Driehoeks-Matjies River have been stocked, are natural, or a mixture of stocked and natural. The practice is still continuing, with several farm dams within the natural range of the species being stocked for conservation purposes and as a means to discourage landowners from using alien invasive species. Fortunately, current stockings use fish from the nearest river system in support of management guidelines for yellowfish stocking recommended by the Yellowfish Working Group (D. Impson, personal communication).

Barbus andrewi has been translocated to several farm dams in the Berg and Breede River catchments from natural populations. Most of these translocations have, however, been done by CapeNature staff as part of a co-ordinated plan with landowners to conserve this threatened species. Moreover, it was done within the natural range of the species. The Western Cape provincial conservation authority (now CapeNature) also bred *B. andrewi* artificially (Smith, 1987; Bok and Immelman, 1989). Success was apparently only achieved with Breede River adults, and offspring of these were stocked into tributaries of the upper Breede System (personal communication with S. Thorne in Impson and Bloomer, 1998/1999). The only cause for concern in these translocations is the mixing of historically isolated lineages of *B. andrewi*. Impson and Bloomer (1998/1999) recorded a lack of genetic variation between the Breede and Berg River systems, based on the evaluation of mitochondrial DNA from four populations. They suggested that the species could be reintroduced into the Berg River system because of this apparent lack of differentiation between the two stocks. According to Impson (2003), Cape Nature Conservation translocated *B. andrewi* from the Breede to a farm dam at Porterville in the Berg River system in the early 1980s. It is possible, that these fish could have escaped from this dam into the Berg River, which means that Impson and Bloomer (1998/1999) may have analysed Breede stock of *B. andrewi* in the Berg River. Thus, it is possible that the original Berg *B. andrewi* was a historically isolated population distinct form the Breede River population. Since the study of Impson and Bloomer (1998/1999), several private dams and the much larger Voëlvlei Dam in the Berg River system have been stocked with Breede River System fish (Impson, 2003). Stockings for conservation purposes have generally utilised *B. andrewi* from Brandvlei Dam, which may have lower genetic variation (Mulder, 1989; Impson and Bloomer, 1998/1999). To safeguard the species, it is essential that stockings for conservation purposes use the best genetic stock available. With the Hex River population being the only other substantial surviving population, options for effective conservation genetic management are restricted. Nonetheless, genetic investigations and a conservation genetic plan are needed to manage the recovery of this species effectively.

Labeobarbus natalensis has been stocked sporadically in various parts of KwaZulu-Natal by predecessor organizations of Ezemvelo KZN Wildlife, but details of translocations are sketchy. This species occurs in several different river systems that would have kept populations separate from each other, increasing the possibility of historical isolation. Sub-populations of *L. natalensis* from different river systems may have been mixed. However, a precautionary approach should have been followed by not mixing populations from different river systems.

Research and Monitoring Requirements

Map the distribution of alien populations

Even the most common and widespread large cyprinids are not well represented in museum collections throughout their range. Additional records are needed to assess the distribution of indigenous and alien populations. Even photographs can be deposited at the South African Institute for Aquatic Biodiversity to record the distribution of species, if one wishes to release the fish. Accurate locality (including latitude and longitude coordinates), date and collector information is needed for these records to be accessioned in the National Fish Collection at SAIAB. This can contribute significantly to our understanding of the distribution of our large cyprinid fishes. Collecting this kind of information, can also benefit future conservation planning, providing evidence of the occurrence of the species if they ever disappeared from an area. It can also help conservation authorities detect new alien populations, so that mitigating actions can be implemented.

Surveys are also needed to confirm whether certain alien populations still persist, and reports of new translocations have to be confirmed. These confirmations should not be based on field identification alone, but evidence should be provided, by accessioning vouchers (preferably including photographs of the live colouration) at museum facilities such as those provided by SAIAB. Additional tissue samples linked to individual vouchers will allow geneticists to investigate potential hybridisation.

Conservation genetic management planning

Much more accurate information is required about the intraspecific genetic diversity of the large cyprininds, to guide conservation genetic management. Especially the confusion around the taxonomic status of *L. aeneus* and *L. kimberleyensis* needs to be resolved as soon as possible. Historically isolated lineages should be sought and mapped to guide conservation authorities on where to conserve them.

Ecological impacts

The impacts that alien yellowfishes have on aquatic ecosystems are poorly studied (Impson, 2001) and hence not well understood. Alien *L. aeneus* has proven to be highly adaptable, resilient and prolific in several of the rivers into which it has been translocated. In several sections of the Gouritz and Kei River systems, they appear to be the dominant species and being large, omnivorous and abundant, they may be exerting negative ecological impacts on these systems (Impson, 2001). They probably prey on and compete for food (and maybe breeding grounds) with natural populations of fishes and invertebrates. As fish communities change from being indigenous to alien dominated, they substantially affect the food web of which they are part, with unpredictable consequences. We know that the presence of *L. capensis* in the upper Twee threatens the survival of Twee River redfin *B. erubescens* Skelton, 1974 (Impson et al., 2007; Marriott, 1998), but more studies are needed to understand the impact on aquatic invertebrates and ecosystem functioning (Impson, 2001). Similar studies are needed in other areas invaded by large cyprinids. The risk of introducing new diseases and parasites to native fish populations is further reason why translocations should be discouraged.

Conservation Recommendations

Due to the research requirements outlined above, a precautionary approach is suggested in translocating large African cyprinids. In Impson (2001) and Swartz (2007), simple advice is provided to conservation and fisheries managers to prevent the establishment of more alien populations and to prevent undesirable translocations within the natural range of species that can have a negative effect on genetic diversity. The advice can be summarised as follows:

- Never move any species outside its natural range.
- Never mix different populations that have not been tested genetically and found to be genetically exchangeable (see Crandall et al., 2000).
- Stock farm dams only from nearby populations within the same catchment but do not stock above natural barriers. The dams should not give the fish access to areas that would otherwise have been inaccessible.

There are international standards that should be followed when considering translocations. The IUCN (www.iucn.org) has a specialist group that deals with threats and guidelines of translocations. South Africa needs a national policy and guidelines that follow these standards. In addition, a national register of translocations is required and information about translocations should be published to help scientists and conservation managers to understand future distribution patterns.

Hatcheries have been and will continue to be a threat to freshwater fish conservation goals. Conservation authorities should not support hatcheries and their activities because of the following threats (Swartz and Bloomer, 2003):

- Artificial selection in hatchery environments can eliminate adaptive gene complexes (Waples and Teel, 1990; Garcia de Leániz et al., 1989) and often leads to loss of genetic diversity (e.g. (Leary et al., 1993; Quattro and Vrijenhoek, 1989; Briscoe et al., 1992).
- Hatcheries have high densities and diversity of aquatic parasites, often from different regions, because of the high density of fish and differences of their origin. During stocking these parasites are spread across river systems with their fish host.
- Different species or populations from different river systems or regions can be mixed unintentionally.
- There are invariably escapes of fish or parasites or both into local river systems.
- Lack of knowledge of the genetic structure of the species prior to translocation can lead to the loss of unique evolutionary lineages and homogenisation of genetic diversity through hybridisation and introgression (Dowling and Childs, 1992; Leary et al., 1993; Avise et al., 1997; Quattro et al., 1996).

Education and awareness efforts should highlight the dangers of moving any fish species and define all fish species outside their natural range as alien. Promoting only indigenous populations of fish for "eco-friendly fishing" is a step in the right direction. Other actions are required, such as an improved environmental impact assessment system for South Africa, preventing translocation of fish through interbasin transfer schemes, implementing more effective law enforcement to prevent fish translocations by the general public and more effectively regulating and, in some cases, prosecuting hatcheries that promote translocation of fish. Unfortunately several alien yellowfish and other large cyprinid populations have already established, therefore river rehabilitation and associated eradication of alien fish populations will become an increasingly important conservation activity. It is difficult to reach the original ecological status of a water body prior to an introduction of alien species and the costs involved in successful rehabilitation programs can be astronomical. Prevention will therefore always be better than cure when it comes to the movement of large cyprinids or any other freshwater fish species.

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APPENDIX:
LITERATURE ON SOUTH AFRICAN YELLOWFISHES AND OTHER SPECIES ASSESSED IN THIS REPORT

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