FOSAF

THE FEDERATION OF SOUTHERN AFRICAN FLYFISHERS

PROCEEDINGS OF THE 14TH YELLOWFISH WORKING GROUP CONFERENCE

WILLEM PRETORIUS RESORT, FREE STATE PROVINCE
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Edited by Peter Arderne

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Welcome to the 14th Yellowfish Working Group Conference. For a number of reasons this year will be a small conference by our normal standards but there are reasons for this which I will touch on later. There are again a number of the usual faces in the audience who continue to support this event and who make an impact in their own environment in terms of river conservation activities – and this is how it should be.

Aldo Leopold, a botanist at Madison State University in the 1930's and 1940's, who is regarded as the father of modern wildlife management, said that you can tell a man's ecological education by what he does with an axe and a spade – what one chooses to cut down and what one decides to plant can say much about ones understanding of the environment. The same can be said about the ecological understanding of an angler by what he does with his rod and priest. That is, what we choose to catch and keep or what we choose to release - as thinking anglers. What should I do with the bass that I catch in the Bronkhorstspruit while fishing for large-scale yellowfish?

The focus of the Yellowfish Working Group has not remained with angling and fly fishing. It has evolved over the last 14 years into a river conservation forum with a focus on yellowfish as flagship species.

Each year a theme is given to the conference and this year this theme focuses on management effectiveness of river conservation strategies as well as the effectiveness of the yellowfish working group. So, how are we doing ……. bearing in mind the aim of the YWG:

To promote the long-term conservation of nine indigenous Yellowfish Species occurring in Southern Africa through sustainable and economic land use management.

Over the years this conference has served as a forum for the sharing of ideas. We have initiated genetic studies, facilitated the establishment of river conservancies, lobbied against poor river management and pollution, debated issues in open forums and considered legislation. With this as our legacy, thus far, we can best be described as an interest group that consists of landowners, scientists, students, government, conservation agencies, conservationists and anglers. It is a loose structure with no specific office bearers or regional structures although these exist to a degree. The Working Group is partially funded by the Northvaal Chapter of the Federation of Southern African Fly Fishers (FOSAF) that also provides a secretarial function. This function includes the arrangement of this conference and a monthly newsletter. There is a scientific panel that also provides input on issues of a technical nature and whose services are free. Our membership list is over 350 individuals and membership is also at no charge.

Considering the above how effective has the YWG been? Well, the YWG is often quoted, in various quarters, as a success story and this is probably because of the openness of discussions and the diversity of people involved in the group. The YWG has recently been quoted in the Hunting and Fishing Journal and members may often be quoted in scientific papers or in popular fishing magazines. This implies there are a number of very active people in their

respective work environments and in this lies the strength of the YWG. Examples of this can be shown in the way the YWG has responded to the wading debate and produced an awareness pamphlet on this topic. Riparian owners, as a result, are demarcating spawning beds to prevent anglers from wading in these areas. This year heralds in the start of a new debate, that of catch-and-release. What should we kill and what should be let go? It will be the responsibility of the YWG, together with scientists and anglers to come up with a sustainable solution to this matter. The aim then, for this forum, is to share ideas, connect people, organisations and ideas with each other. The Working Group supports people out there so that they can generate positive change.

Effectiveness of this forum can be considered in two ways.

1. The effectiveness of this working group itself. This is not really possible in that this forum has no people that it can deploy in the field. Our only measure of success can then be regarded in terms the extent and influence the YWG has as a catalyst for positive changed.
2. Effectiveness can be measured in the working environments of our members. It is the projects that our member undertake in their professional and private capacities that must be assessed and within them develop, in their design, monitoring and evaluation (M&E) processes. To what extent this is happening in the greater scheme of things is debatable? For example, how is M&E built into the River Health Programme of the Department of Water Affairs? What can they use to show the effectiveness of this particular programme?

My own view is conservation goals are poorly set, if at all, and are therefore difficult to measure at all.

This year our papers cover a wide array of issues which range from angling practice, river conservation, river status reports and management practices. There are all the important inputs from the Provincial conservation agencies that really are the barometer of sound river conservation management and best practice. These reports, I feel, remain the backbone of this conference because they set the tone of whether good conservation is taking place or not. It is sad therefore to note that there are so few provinces represented at the conference this year.

The programme format this year has changed somewhat to not include a workshop at the end. Also, there are fewer papers on both days to ensure that conference fatigue does not set in. There is no fishing and this might account for the usual bunch of anglers not being here.

Finally, I would like to thank Peter Arderne for making this conference happen and doing all the arrangements. Thank you all for supporting this event and I hope you all have a fruitful conference.

PROVINCIAL REPORT - LIMPOPO PROVINCE -2010

PSO Fouché[1] and SSM Rodgers[2]

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Introduction

Presently there is no current research focussed on yellowfish within the province and it is mostly general research within the distribution areas of yellowfish. After the crocodile deaths the focus within the province is on the Olifants River. As was predicted by Mick Angliss at the 2009 YWG conference the River Health Programme (RHP) in the province has come to a virtual standstill.

Sadly Mick Angliss has resigned from the provincial department and therefore does not form part of this team any more. His valuable contributions and sharp wit will be missed.

1. Within provincial Environmental Affairs (LEDET)

The departmental team within LEDET consists of Stan Rodgers and Pierre Fouché. The most work done is focussed on their contribution to the Provincial State of the Environment report and follows RHP protocols and

The following can be reported on:

As far as river health surveys are concerned:

- The Luvuvhu River follow-up survey has been completed and the report is being prepared.
- The follow up in the Olifants River has been temporarily stopped because of high flows but will continue when flow decreases.

The team is also looking at pollution from sewage works in the Mogalakwena.

A joint meeting between department and researchers from Limpopo provincial universities was held in Polokwane on 12th June 2008. The meeting was scheduled to discuss the possible impacts of particular dams in the province. This included the newly constructed Nandoni Dam in the Luvuvhu River and the Flag Boshilelo Dam where the wall had recently been raised. As an outflow from this meeting both the universities have registered research projects in which the department is taking part. Both these projects are funded by the Water Research Commission and have commenced in 2009.

A further meeting that focussed on the Olifants River in particular, initiated by Mick Angliss and Stan Rodgers, was held in Polokwane during 2009. The meeting was attended by researchers and officials involved in the Olifants River and offered an opportunity to reconcile the work done and plan for future research and actions.

2. Related research at the two provincial universities.

2.1 The University of Limpopo (UNILIM).

At UNILIM the team involved in research in the Olifants River is lead by Prof. Antoinette Jooste and assisted by Dr. Wilmien Powell. The Water Research Commission funded project is entitled "Environmental and Fish Health Management in two impoundments in the Olifants River: Flag Boshielo Dam and Phalaborwa Barrage, Limpopo Province with reference to human health risk". The am of their study is to evaluate the health, bioaccumulation of metals and

parasite composition of selected fish species and from the bioaccumulation results a human health risk assessment will be determined. Their objectives are *inter alia* the following:

- To evaluate the water quality of Flag Boshielo Dam and the Phalaborwa Barrage by testing selected water and sediment constituents
- To determine the fish condition and health of selected fish species from Flag Boshielo Dam and the Phalaborwa Barrage by applying the Fish Health Assessment Index
- To evaluate the bio-accumulation levels of selected metals in the liver, gills and muscle of certain fish species
- To identify all ecto- and endoparasites of selected fish species
- Generating of information on abiotic and biotic parameters to evaluate ecosystem health and the areas requiring monitoring on a short and long term basis
- Generating data on the ecological status of the Flag Boshielo Dam and the Phalaborwa Barrage and identification of the critical water and sediment constituents influencing biodiversity changes (if any)
- Generating benchmark information and data on ecology, biodiversity and fish diseases to enable formulation of management action plans (if necessary)
- Monitoring and comparing the impact of pollution in two impoundments of the Olifants River in the Limpopo province.

2.2 University of Venda (UNIVEN)

2.2.1 Nandoni Dam.

The UNIVEN team, lead by Paul Fouché and assisted by Justice Ramunasi, is involved in a project entitled "Establishing the fishery potential of the Nandoni Dam." In addition the UNILIM team is involved at the Nandoni Dam as part of this WRC funded programme. The general aims of the project are:

- To establish the physico-chemical conditions of the dam.
- Determine if stratification (temperature, oxygen, chemical) occurs.
- Investigate the productive status (phyto- and zooplankton) of the dam and relate it to physico- chemical aspects.

With regard to fish the aims inter alia include

- To determine the present fish community structure and the subsequent changes in species composition and numbers.
- To establish aspects such as condition factor, growth, breeding (physiological preparation for breeding, fecundity, length at sexual maturity, breeding seasons) and feeding habits.
- To determine the fish condition and health of selected fish species applying the Fish Health Assessment Index.
- To identify all ecto- and endoparasites of selected fish species.
- Generating of information on abiotic and biotic parameters to evaluate ecosystem health and the areas requiring monitoring on a short and long term basis.

Preliminary findings of the Nandoni Dam project.

During the surveys twelve species were collected from the nets and figure 1 shows that *Schilbe intermedius* was the most abundant at more than 62% of the total catch, followed by *Oreochromis mossambicus* at close on 29% and *Labeobarbus maequensis* at just over 5%. A total number of 1237 specimens were collected (Table 1) with the largest number collected at sites 3 and 4. The difference in dominance in table 1 is of interest with *S. intermedius* dominating at all the sites except at site 3 where a similar number of *O. mossambicus* were recorded. The pattern observed with *L. marequensis* should be noted with the majority of specimens collected at sites 2 and 3.

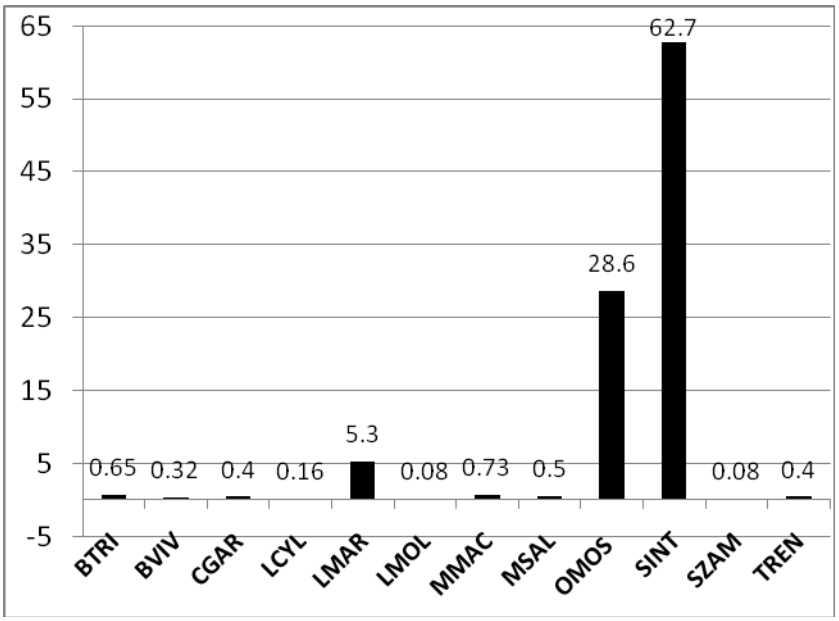

Figure 1: The number of fish, presented as a percentage of the total number, collected in the gills nets at sites 2, 3,4 and 5 in Nadoni Dam during the period October 2009 to February 2010. (BTRI: *Barbus trimaculatus*, BVIV: *Barbus viviparous,* CGAR: *Clarias gariepinus,* LMAR: *Labeobarbus marequensis,* LCYL: *Labeo cylindricus,* LMOL: *Labeo molybdinus,* MSAL: *Micropterus salmoides*, OMOS: *Oreochromis mossambicus,* SINT:*Schilbe intermedius,* SZAM*: Synodontis zambezensis,* TREN: *Tilapia rendalli.*

Table 1: The number of fish collected in the gill nets at sites 2,3,4 and 5 at Nandoni Dam during the period

Site no	Total no fish	*Barbus trimaculatus*	*Barbus viviparous*	*Clarias gariepinus*	*Labeo cylindricus*	*Labeobarbus marequensis*	*Labeo molybdinus*	*Marcusenius macrolepidotis*	*Micropterus salmoides*	*Oreochromis mossambicus*	*Schilbe intermedius*	*Synodontis zambezensis*	*Tilapia rendalli*
2	287	3	2	0	1	32	0	2	4	87	152	0	2
3	329	5	2	0	1	7	1	2	1	156	152	0	2
4	392	0	0	4	0	22	0	5	1	37	321	1	1
5	229	0	0	1	0	4	0	0	0	74	150	0	0

The overall condition and health of the fish was good at Nandoni Dam (preliminary results of three surveys). No obvious external signs or blood parameters indicated that the fish are stressed. None of the parasites from the fishes at Nandoni Dam were recorded in excessive numbers, except for *Contracaecum* larvae from *Clarias gariepinus*. However, large numbers of this nematode larva is fairly common in freshwater ecosystems. The digenean larvae, including *Clinostomum*, *Euclinostomum* and possible the digenean cysts, are of zoonotic importance and these larvae have the potential to develop in humans.

As is shown in tables 2 and 3 the poor water quality of the inflowing rivers is reason for concern and should be addressed as a priority.

Table 2: Chemical analyses of the water samples collected at inflow sites 10 – 12 in the Nandoni Dam during the period September to December 2009. (Site 10 is in the Mvudi River, Site 11 in the Dzindi River and site 12 is in the Luvuvhu River). (All the results are in mg/l)

Site number	Date of survey	Ammonium mg/l	Nitrite mg/l	Nitrate mg/l	Phosphate mg/l
10	September	0.27	0.11	3.3	1.09
10	October	0.67	0.14	2.0	0.49
10	November	0.73	0.15	2.3	0.35
10	December	0.17	0.07	1.5	0.25
11	September	0.2	0.11	2.2	0.21
11	October	0.42	0.12	0.8	0.52
11	November	0.23	0.1	2.1	0.41
11	December	0.18	0.05	1.3	0.21
12	September	0.19	0.06	0.7	0.19
12	October	0.17	0.06	2.2	0.16
12	November	0.13	0.05	2.5	0.28
12	December	0.13	0.07	2.0	0.13

Table 16: Chemical analyses of the water samples collected at sites 13 – 14 during the period September to December 2009.

Site name and number	Date	Ammonium mg/l	Nitrite mg/l	Nitrate mg/l	Phosphate mg/l
Mvudi River	September	0.23	0.05	2.6	0.25
Mvudi River	October	3.32	0.89	2.7	2.95
Mvudi River	November	2.59	0.88	5.4	1.73
Mvudi River	December	0.35	0.18	2.7	1.25
Dzind River	September	0.21	0.23	3.7	0.95
Dzind River	October	0.15	0.06	0.3	0.27
Dzind River	November	0.11	0.06	0.8	0.17
Dzind River	December	0.17	0.07	2.1	0.38
Luvuvhu River	September	0.21	0.04	0.4	0.18
Luvuvhu River	October	0.09	0.05	1.3	0.54
Luvuvhu River	November	0.11	0.05	2.9	0.26
Luvuvhu River	December	0.22	0.05	0.5	0.2

2.2.2 Shingwedzi River.

Wynand Vlok and Paul Fouché have recently completed their baseline survey of this river and the report will be released in the latter half of 2010. Part of the results have been published in the first 2010 volume of the African Journal of Aquatic Sciences. Sadly no largescale yellowfish, which dominates in this province, was collected during the survey.

3. Co-operating bodies.

As part of the projects a number of freshwater experts have been co-opted and are currently assisting with research within the province.

- Dr Wynand Vlok (BioAssets) is involved in the fish ecology at Nandoni Dam and also forms part of the team assisting in the SAEON funded long term monitoring programme of the Olifants River.
- Dr Jan Roos, a phytoplankton and water quality expert is involved in the investigation of primary production in Nandoni Dam.
- Dr Irene Barnhoorn of the Medical Faculty of UP, and an expert on endocrine disrupters and heavy metal accumulation, now forms part of the Nandoni Dam team.

4. Private initiatives.

The ongoing biomonitoring exercise on the Nzhele River in the Maremani Nature Reserve led Mick Angliss is in its seventh year and some interesting results have been obtained. The impoundment on the reserve has a healthy population of largescale yellowfish which are breeding at the inflow.

5. Co-operation with other institutions.

The following institutions form part of important projects in the province:

- Griffiths University of Australia is funding a Masters (Mphil) student doing research on the effect of water releases in the Mokgalakwena River on the macro-invertebrates. This river, although seriously fragmented, has some largescale yellowfish. The student is co-supervised by Paul Fouche.

The Ndlovhu node of SAEON, based in Phalaborwa, has embarked on the development and establishment of a long term monitoring programme in the Olifants River. The training of a technician forms part of the project and Wynand Vlok and Paul Fouché are assisting with the education

ASPECTS OF THE REPRODUCTIVE BIOLOGY AND ECOLOGY OF THE LOWVELD LARGESCALE YELLOWFISH, *LABEOBARBUS MAREQUENSIS*, IN THE LUVUVHU RIVER CATCHMENT.

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Abstract

This study investigated the breeding biology of the species using traditional methods that *inter alia* included studies of the gonadal development, sizing of eggs and egg counts. In addition the breeding ecology was studied through a seasonal investigation of selected breeding sites. The results, supported by both the gonadal development and the presence of small juveniles, showed that the species spawns twice during a year and that each of the spawning events is an extended one. The summer spawning event coincided with an increase in both the temperature and discharge and was thus influenced by the effect of the hydrological regime and increase in temperature. Breeding occurred at sites where the flow of water occurred over boulders and cobbles. Breeding habitats should be in close proximity to both fast and slow deep biotopes with nursery areas nearby. Male *L. marequensis* collected in this study became sexually mature when their fork lengths exceeded 90 mm and females after attaining a fork length of 240 mm.

1. Introduction.

The life cycle of a fish consists of a number of periods starting at the embryo and ending when the animal eventually dies (Nikolsky, 1963). The adult period, when the organism is able to reproduce, formed the focus of this study. In preparing for spawning the gonads grow in size up to a point where the gametes are ready to be released. This maturing process is cyclic and is continuous with repeating steps, or stages, that occur between spawning events.

Fecundity, or the number of eggs produced in fish, is an adaptation that ensures the survival of the species and fish have a relatively higher fecundity when compared with terrestrial organisms. Fecundity is increased through fractional spawning. This refers to a process when small groups of the eggs in an ovary "ripen" at different times and this strategy is characteristic of tropical and sub-tropical fish. The size of eggs which also relates to their survival varies from species to species and the diameter of mature eggs can vary from a fraction of a millimetre to as large as few millimetres (Helfman *et al.* 2000).

A further important link in the life cycle of fish is its growth or increase in size which not only varies with age but varies between seasons (Helfman *et al.*, 2000). Closely related to seasonal status or condition of the fish, which refers to the mass to length ratio, is the condition factor. It is generally accepted that the larger this ratio, the better the general condition of the fish. The gonads and in particular their mass in relation to the body weight is referred to as the Gonado-Somatic Index or GSI (Branson, 1962; Knight and Ross, 1992; Layman, 1993) which according to Helfman *et al.* (1997) is a "popular, simple and instantaneous measure of reproductive effort". The seasonal changes in the GSI is characterised by an increase to a peak followed by a sharp decrease and Knight and Ross (1992) stated that "spawning occurs during this down slope from the peak".

Worldwide the spawning of the family Cyprinidae, to which *Labeobarbus marequensis* belongs, has been extensively studied (Hubbs and Walker, 1942; Lachner, 1952; Settles and Hoyt, 1978;

Duarte and Alcaraz, 1989; Blinn *et al.* 1998; Platania and Altenbach, 1998; Albanese, 2000). To an extent this is the case with the indigenous cyprinids where the larger, economically more important species, have received preference (Göldner, 1969; Baird, 1971; Mulder, 1971; Bloemhoff, 1974; Hamman, 1974 and 1981; Koch, 1975; Tómasson *et al.* 1984). However very little detailed knowledge is available on the reproductive biology of *L. marequensis*. Crass (1964), Pienaar (1978), Bell-Cross and Minshull (1988) and Skelton (2001) reported on breeding behaviour while Crass (1964), Gaigher (1969) and Skelton (2001) indicated the fork lengths at which maturity is obtained. Other work done relates to the seasonality of breeding in the Incomati River system Gaigher (1969) and the size of the eggs (Hecht, 1982).

Based on this lack of knowledge regarding the preferred microhabitat and conditions required for spawning, the time of breeding, the biological changes that precede spawning and spawning behaviour in particular were formulated. This study aimed to investigate the breeding biology of the species using traditional methods that *inter alia* included an investigation of gonadal structure and development. Secondly, the breeding ecology was investigated through a seasonal investigation of selected breeding sites in the river system.

2. Materials and methods

2.1 The study area

The study was completed at five sites in the middle reaches of the Luvuvhu River system within the historical distribution range of the species. Care was taken to select sites where the full range of velocity-depth biotopes (Kleynhans, 2007) was present as this would ensure that the necessary habitat requirement of the species would be included. In addition the data collected during an earlier study at the Xikundu fishway were included.

2.2 Field protocol and sampling of fish.

One of the sites was used as a pilot site and was surveyed for a period of twelve months. The findings obtained were used as a basis to determine the survey period for the other four sites. At each site the potential habitat types distinguished on the basis of substrate dominance velocity and depth were identified and a map drawn which indicated the homogenous habitat as a separate "area". Fish were then collected in each area using the protocol and methodology described by Kleynhans (2007). The fish collected were identified, the fork length and mass determined and all the specimens, except for representative specimens of each 10 mm interval fork length size classes, needed for gonadal studies, were returned to the river. The representative specimens were preserved in 10% formalin and transported to the laboratory.

2.3 Breeding ecology.

In order to determine the breeding ecology the data of the specimens of the *L. marequensis* collected in each of the mapped areas was kept separate and analysed.

2.4 Recruitment.

Length-frequency analyses were used to determine periods of recruitment. This refers to the times when a regular influx of recruits occurs over a short time period and from the resulting modes the time of spawning was inferred (Tómasson *et al.*, 1984).

2.4 Breeding biology.
In the laboratory the preserved fish specimens were dissected and once exposed the state of the gonadal development was assessed and classified (De Villiers, 1991). The gonads were removed, blotted dry and the mass determined to the nearest milligram. One of the gonads was then divided into two equal halves that were separately stored in 4% formalin.

The condition of the fish was expressed by calculating the body mass to body length ratio as a percentage and to exclude the effect of the gonads their mass was excluded. The condition factor (CF) was calculated using the following formula:

$$CF = \frac{(\text{Fish mass} - \text{Gonad mass})}{L^b} \times 100 \quad \text{(Mulder, 1971)}$$

Where: L^b is the body length ratio

To establish the seasonal trends, or reproductive seasonality the monthly Gonadosomatic Index (GSI) values were calculated:

$$GSI = \frac{\text{Gonad mass}}{\text{Total fish mass}} \times 100 \quad \text{(Gaigher, 1976)}$$

The mass of a small (3 mm^3) sample of each ovary was determined to the nearest milligram. The sample was then placed in 4% formalin and gonadal tissue and connective tissue were separated mechanically, which included vigorous shaking and decanting, after which the separated connective tissue was removed with foreceps. A 0.2 *ml* sub-sample was removed with a micro-pipette and transferred to a counting chamber (Gaigher, 1976) and all oocytes with yolked nuclei or fully yolked ova were counted with the aid of a dissecting microscope at 10X or 30X magnification. The total number of ova in the ovaries was calculated using the formula adapted from Mulder (1971):

$$T_o = \frac{T_s \times A}{B}$$

(Where: T_o is the total number of ova in gonad, T_s the number of ova in sub-sample, A the mass of ovary and B the mass of sub-sample)

A second sample of 0.1 *ml* was extracted and the diameter of a minimum of 50 ova was measured to the nearest 0,01mm. Measurements were done using a calibrated ocular micrometer and a light microscope (400x magnification). The ova were grouped into 0,125 mm size classes and the data presented in a histogram to establish the modalities of size distribution (Gaigher, 1976).

As proposed by Tómasson *et al.* (1984), fish with mature gonads in classes 2, 3 and 4 (De Villiers, 1991) were regarded as sexually mature. Length at sexual maturity was determined as the length at which 50 % of the fish had maturing or mature gonads and was calculated to determine the relationship between fish length and fecundity.

Fecundity in this project was expressed as the relative fecundity, which represents the mature ova count per gram of body mass (Gaigher, 1969; De Villiers, 1991). In addition the relative fecundity was correlated to the fork length of the fish and presented as such.

In order to determine the spawning chronology and to establish whether the species spawned at different times the GSI and the ova diameters were used as suggested by Settles and Hoyt (1978).

3. Results.

3.1 The selected sites and the survey frequency

Figure 1 shows the location of the pilot site, the four selected breeding ecology sites (2, 3, 5 and 11) as well as the site at the Xikundu Fishway. The data from the Xikundu Fishway spans the period May to November 2004. The pilot site at Ha-Nesengani in the Luvuvhu River was surveyed for the period January 2005 to November 2005 while sites 2, 3, 5 and 11 were surveyed during June to October 2007.

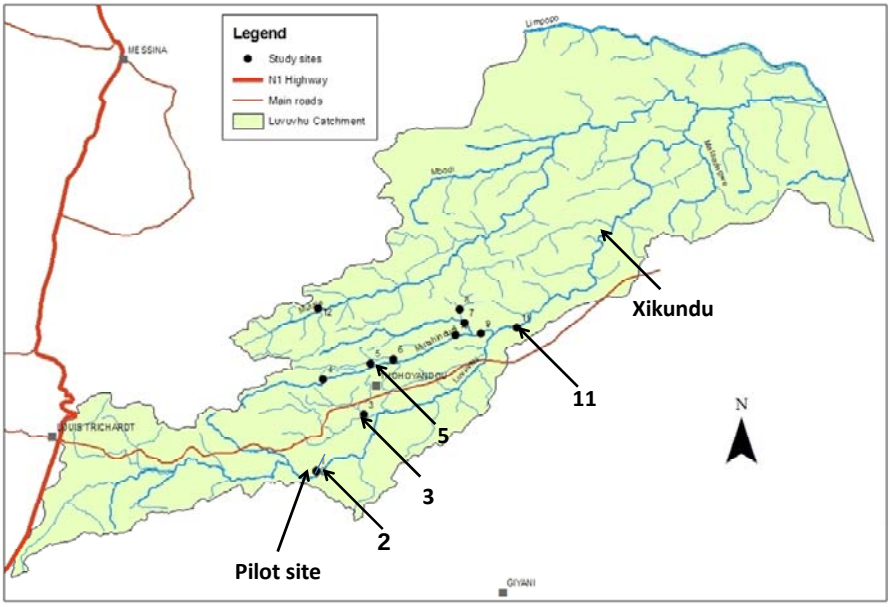

Figure 1: The sites in the Luvuvhu River that formed part of the study. (2 = Tshino in the Mutshindudi River, 3 = Crocodile Ventures in the Dzindi River, 5 = Tshivhulani in the Mutshindudi River and 11 = Tshifudi in the Luvuvhu River).

3.2 **Recruitment**.

The results obtained at the "pilot site" (Figure 2) show that during the September 2005 survey specimens in the smallest fork length class (11 – 20 mm) were collected for the first time. Of note is the absence of fish in the two smallest size classes in the May survey. This is an indication that breeding had occurred in the period between the previous survey in May and the survey in September. It should be noted that fish in the larger size class (21 – 30 mm) were present earlier in the year during the January and March surveys which is an indication of a spawning event prior to those surveys.

This agrees with findings of Fouché *et al.* (2005) in the Luvuvhu River who found specimens smaller than 20 mm in fork length during their September survey. Heath *et al.* (2005) reported that at the Xikundu fishway, gonadal growth peaked in September. There is general consensus that breeding is correlated with the onset of the spring rains (Bell-Cross and Minshull, 1988). According to Skelton (2001) the species breeds twice a year (summer and spring) to coincide with the rainy seasons. Based on the findings and the work of these authors it was decided to concentrate the breeding ecology component of this study in a period that would reflect both periods. Analyses of the length frequency distribution of small fish, less than 110 mm fork length, collected at the breeding ecology sites from June to October 2007 (Figure 3) show that

small fish in the 11-20mm class were collected in August, September and October with the highest percentage frequency in October.

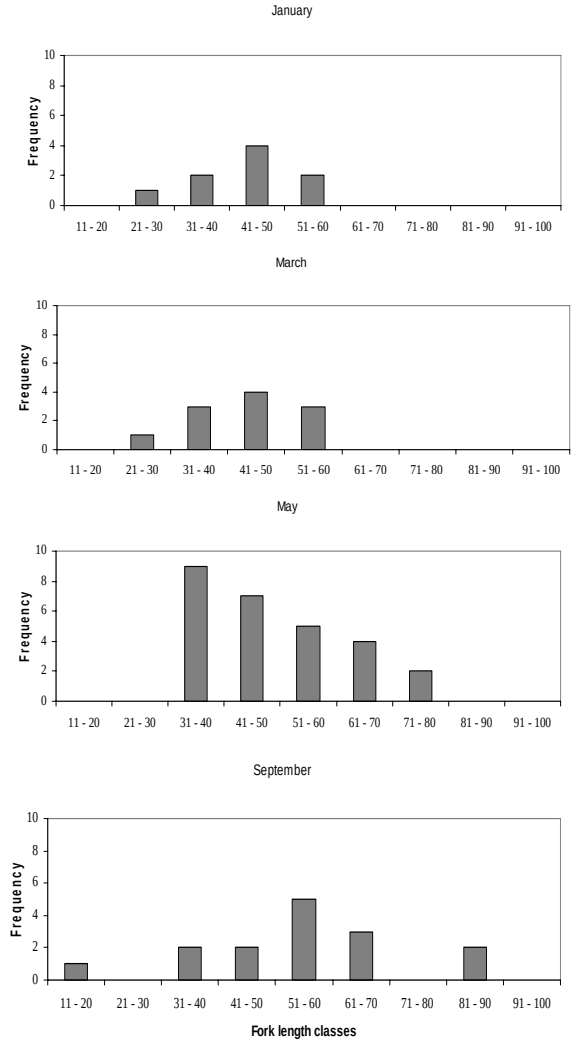

Figure 2: **Length frequency distribution of *Labeobarbus marequensis* specimens collected in the shallow biotopes at the Ha-Nesengani site (pilot study) in the Luvuvhu River in the pilot study during 2005.**

3.3 **Breeding biology**.

The results obtained with the analyses of the GSI values of the breeding ecology sites (Figure 4) are not conclusive although there is a clear indication of an increase in the GSI towards September and a possible decline towards October. However the results of the Xikundu Fishway survey (Figure 5) shows a distinct decline after the September survey. This clearly indicates that spawning had occurred. A second spawning event seems to have occurred when the peak and decline in the graph during March-April is considered.

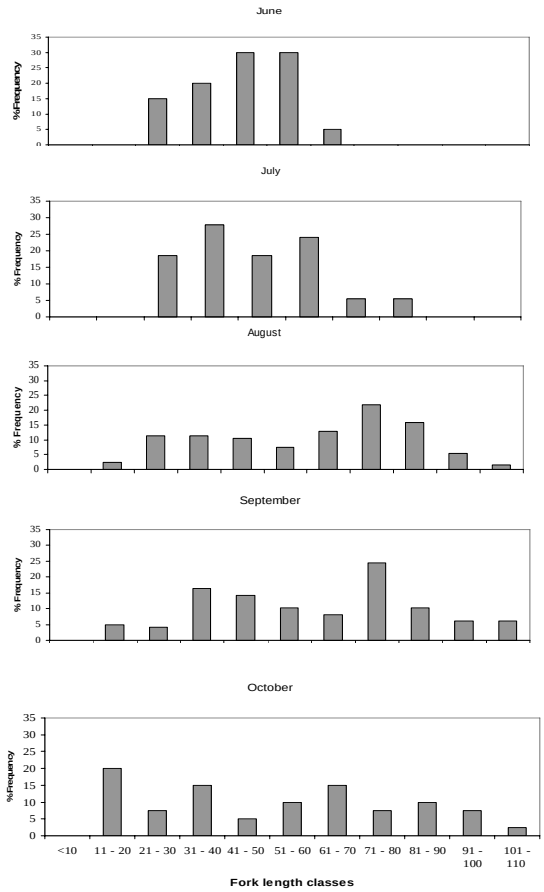

Figure 3: Percentage frequency of occurrence of *Labeobarbus marequensis* in the fork length classes smaller than 110 mm collected at sites 2, 3 5 and 11 in the Luvuvhu River during the period June 2007 to October 2007.

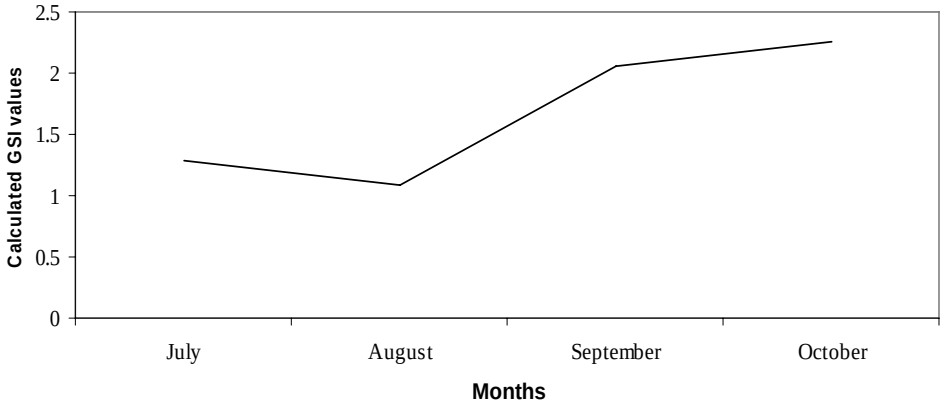

Figure 4: Calculated GSI values of all the specimens of *Labeobarbus marequensis* collected at the breeding sites in the Luvuvhu River during the period July to October 2007.

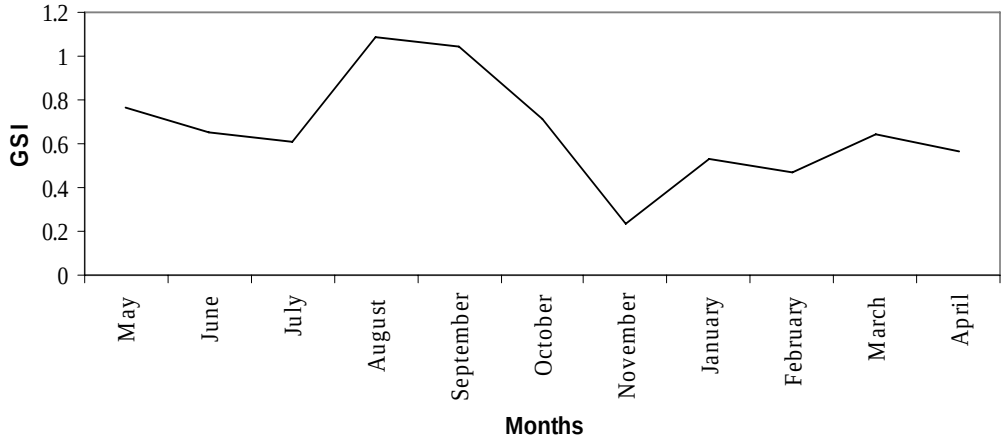

Figure 5: Seasonal changes in the Gonadosomatic Index of *Labeobarbus marequensis* > 80 mm in fork length collected in the Xikundu Fishway in the Luvuvhu River during the period May 2004 to April 2005.

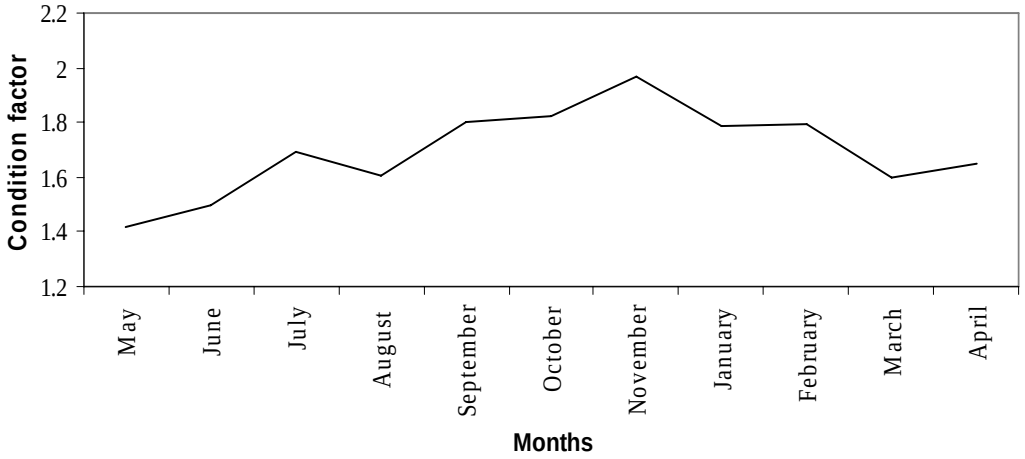

Figure 6: Seasonal changes in the condition (CF) of *Labeobarbus marequensis* (> 80mm fork length) collected in the Xikundu Fishway in the Luvuvhu River during the period May 2004 to April 2005.

The values of the calculated Condition Factor of the fish collected in the Xikundu Fishway (Figure 6) show that the condition of the fish increased steadily after the first spawning event that occurred prior to May 2004. This increase continued to November 2004 which was after the second spawning event which occurred from September 2004.

To establish length at sexual maturity the data of all the specimens of *L. marequensis* collected in all the aspects of this study were pooled. Figure 7 shows clearly that 50% or more of the males with a fork length of more than 90 mm had gonads that were classified as either maturing or fully matured.

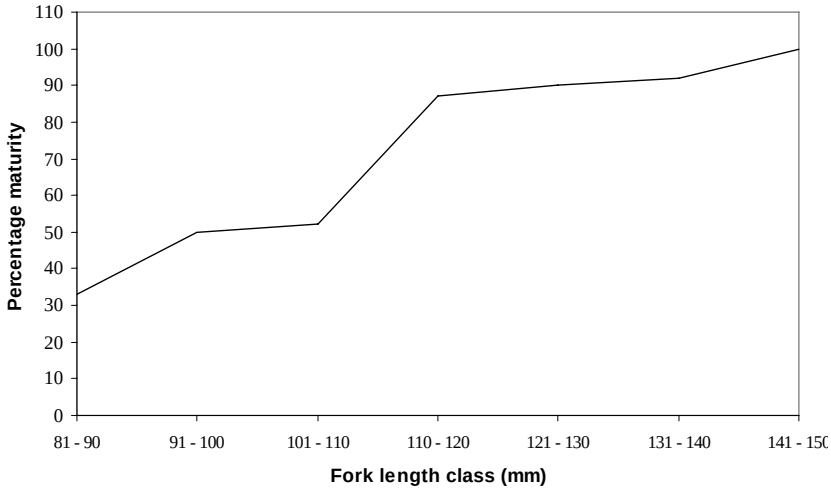

Figure 7: The length at sexual maturity of all male *Labeobarbus marequensis* collected in the Luvuvhu River and tributaries.

Due to low numbers of female specimens in some of the fork length classes, the length at sexual maturity results could not be graphically displayed. However, no sexually mature ovaries were observed in fish with fork lengths shorter than 120 mm. In the fork length classes between 121 and 140 mm "maturing" ovaries were observed in sixty percent of the specimens. Although the "maturing" and "mature" ovaries were observed in specimens in the 151 – 180 mm class, the majority of "mature" ovaries were observed in specimens with a fork length longer than 200 mm.

Measured egg diameters ranged from 0,125 to 2,25 mm and the microscopical investigation showed distinct morphological differences between "eggs" of various sizes. These morphological differences were used to classify the eggs into three different egg size classes. The smallest size class (from 0,125 up to 0,5mm in diameter) consisted of eggs where no distinctive features could be observed. In the second size class (diameters up to 1,0 mm) the cytoplasmic component had a grainy appearance. In the largest size class (eggs with a diameter up to 2,25 mm) a distinctive dark area was visible in the cytoplasm. The relative fecundity was calculated using maturing and mature eggs. Although this included specimens from the 161 – 170 fork length class the majority of the specimens were of a fork length longer than 270 mm. Table 1 shows that the mean relative fecundity was 44,7 ova per gram of body mass. It should be noted that in the majority of the fork length classes only one or two specimens were observed which could account for the difference between the averages.

The ovaries of the mature (class 3) females contained eggs of all three of the distinct egg size classes. This included oocytes that were smaller than 0,5 mm, maturing ova of between 0,5 and 1,0 mm and mature ova larger than 1,0 mm in diameter. Figure 8 shows that the composition of this "mixture", based on each egg size presented as a percentage of the total number of eggs, varied between the size classes with no distinct pattern or trend that could be identified. This mixture suggests that *L. marequensis* is a serial spawner with probably a prolonged spawning period. The prolonged spawning aspect is supported by the fact that juveniles that were classified as J_1 (11 – 20 mm) were collected over long periods at some of the breeding ecology sites (Table 2).

Table 6.14: The calculated average Relative Fecundity (RF) of mature (Maturity class 3) females of *Labeobarbus marequensis* collected in the Luvuvhu River during the period July to October 2007.

Fork length classes	Average RF based on egg classes 2 and 3	Average RF based on egg class 3
161-170	111.4	59.9
271 – 280	57.8	44.6
281 – 290	77.8	55.3
301 – 310	64.0	54.8
311 – 320	57.0	31.9
321 – 330	63.1	48.7
331 – 340	87.7	42.9
371 – 380	38.2	28.4
391 – 400	46.6	36.2
Mean	**67.0**	**44.7**

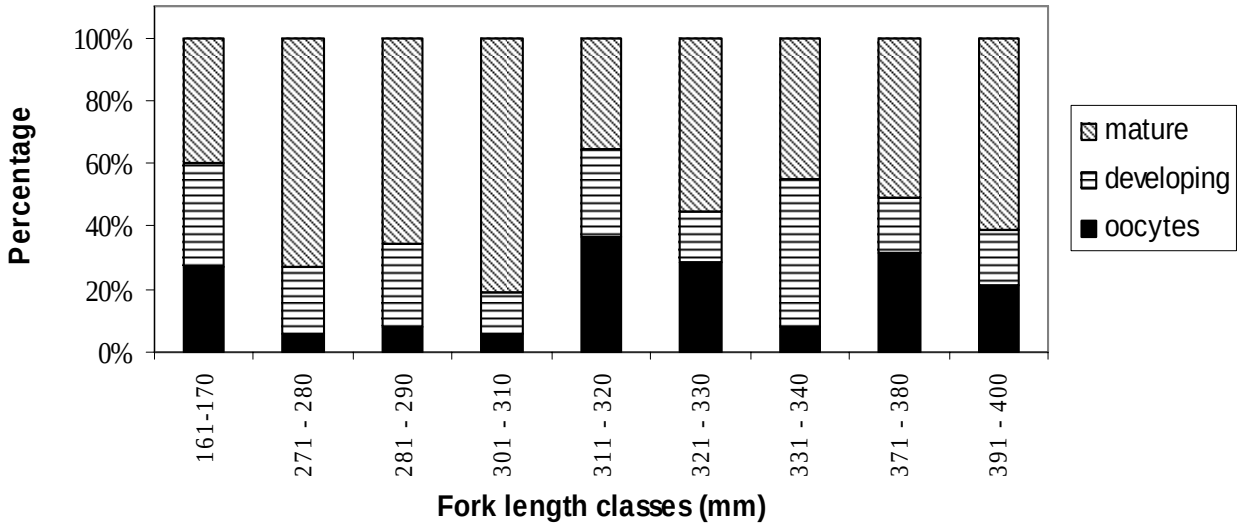

Figure 8: Calculated percentages of egg size classes recorded in female *Labeobarbus marequensis* in maturity class 3 (Mature) collected in the Luvuvhu River and tributaries in the period July to October 2007.

The best example is the site at Tshifudi (site 11) where J_1 juveniles were collected during the August, September and October 2007 surveys. At the Tshivhulani site (site 5) these juveniles were collected in September and October of the same year. The distribution in egg size, as illustrated by the histograms of four randomly selected mature females, displayed bi-modal distributions (Figure 9). This reconfirms to illustrate that the species is a serial spawner as the "number of modes in a size distribution of ova is often considered to represent the number of spawning individual females are capable of " (Bagenal and Braun in Tómmason *et al.*, 1984).

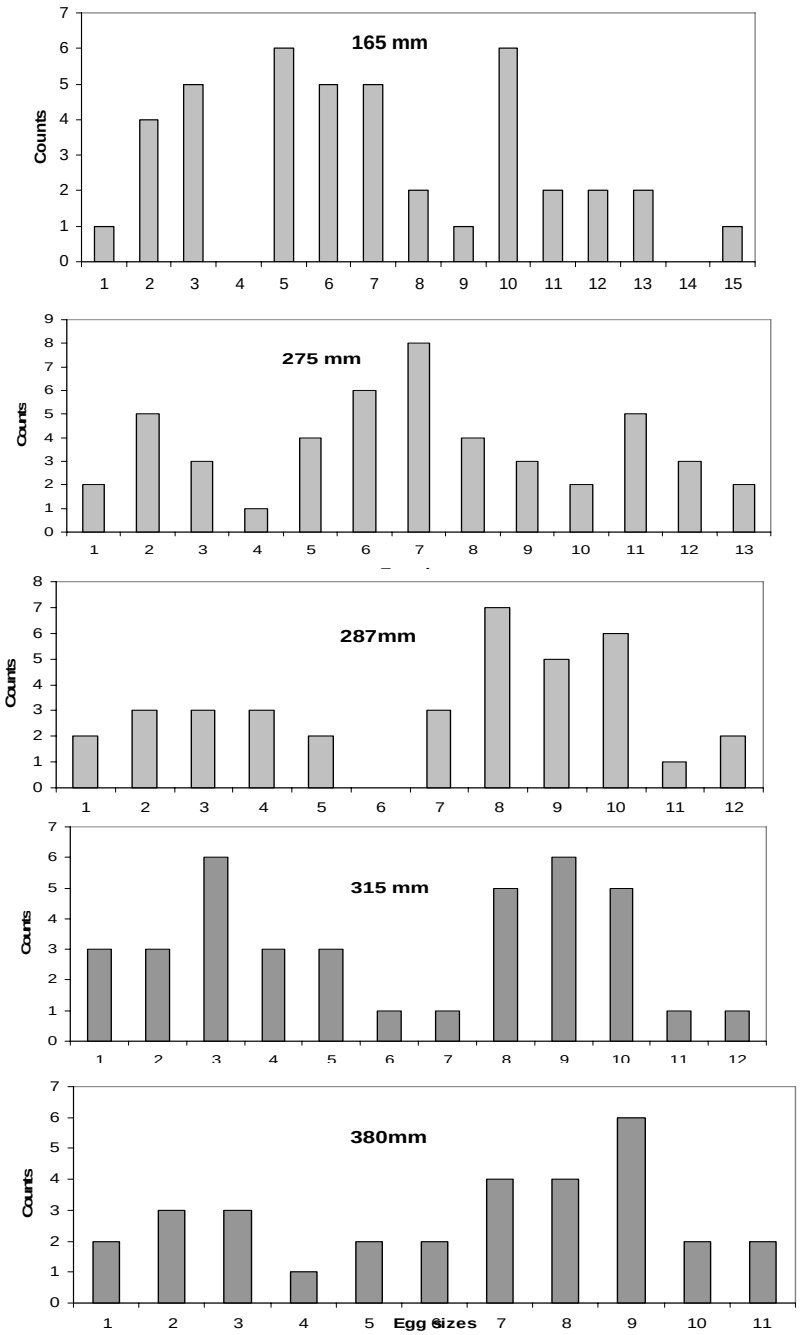

Figure 9: Histograms displaying the distribution in egg size counts of five "mature" *Labeobarbus marequensis* females collected in the Luvuvhu River in the period from July to October 2007. Each of the units of the x-axis represents a 0,125 mm interval, with unit 1 for example being eggs of 0 – 0,125 mm.

The results of the sampling within the identified "areas" in the breeding ecology site (Table 2) shows that the small juveniles belonging to fork length group J_1 displayed distinct seasonal patterns and habitat preferences. The seasonal patterns underpins the fact that spawning occurs twice per year as observed with the GSI analyses and it is observed that this size of fish were most abundant in what was regarded as breeding areas.

Table 2: Presence of specimens of the different fork length groups *Labeobarbus marequensis* collected during the period July to October 2007 in the identified "areas" related to breeding at the four sites in the Luvuvhu River system. (The abbreviations for the hydraulic biotopes are: B = breeding area, RI = riffle, RA = rapid, SP = shallow pool, P = pool. The length classes are: 2 = 51 – 80mm, 3 = 81 – 100mm, 4 = 101 – 120mm , 5 = 121 – 150mm, 6 = 151 – 200mm, 7 = 201 – 250mm, 8 = 251 – 320mm and 9 = > 321mm. Stanza 1 was subdivided in J_1 = 11 – 20mm, J_2 = 21 – 30 mm and 1 = 31 – 50mm.

Site name	Area	Velocity depth class	Hydraulic Biotope	July 2007	August 2007	September 2007	October 2007
Site 2 Tshino	1	SS	**B**				J_1
	2	FS	RI				2
	3	FS	RI			J_2, 1	
	4	FS	RI	J_2, 1			
	5	FS	RA	J_2, 1	1,2		
	6	SS	SP		J_2	J_2, 1	
Site 11 Tshifudi	8	FS	**B**	2	J_1, J_2	J_1, J_2	J_1
	9	FS	RI				
	11	SS	RI	J_2, 1,2			2
	13	FS	RI	2		2	2
	14	FS	RA			2,3	2,3
	15	SS	SP				J_1
	16	SS	SP	2		2	3
	17	SS	SP	2		2	
	20	SD	P	7		6,7,8	8,9
Site 5 Tshivhu-lani	21	SS	**B**		J_2	J_1, J_2	J_2
	22	SS	SP	J_2	J_2	1	
	23	FS	RI			J_2, 2	J_2, 1
	24	FS	RA			J_2, 2,3,4,5	J_1J_2 ,2
	25	SS	RI		J_2		J1
	26	FS	RI				4
	27	SD	P			5,6,8	
Site 3 Crocodile Ventures	28	SS	**B**		J_2	J_2	
	30	FS	RI	1,2		2	J_2
	31	SS	SP	1,2		1	
	32	FD	RA	2		1	2
	33	FS	RI	1,2		1,2	
	34	SS	**B**		1		J_2
	35	SD	P			6	3,5,6
	38	SS	**B**	J_2, 1			

Large females were collected in the slow flowing pools while the sexually mature males, sizes 2 and 3 in table 2, dominated the fast shallow rapids and riffles and it was concluded that this was an indication that spawning occurred in these biotopes and in particular those where the substrate was dominated by cobbles and small boulders.

4. Discussion

Length-frequency and modal progression analyses are usually part of the indirect methods of age determination as is illustrated in Weatherly and Gill (1989) who stated that "if reproduction in fish populations occurs such that there is a regular influx of new recruits over a relative short period of time, they will display a length-frequency distribution that features modes". A *proviso*

set by them was that if the sample included a broad size range and at least contain an adequate number of the youngest fish each new mode would reflect the influx of new recruits. The method using the time of capture of small juveniles to infer the time of first spawning since the previous summer has been used for South African yellowfish (Mulder, 1971; Hamman, 1974 and 1981; Tómasson *et al.*, 1984). Based on the findings of Göldner (1969) and Tómasson *et al.* (op cit) it was accepted for this study that in the case of *L. marequensis* specimens up to 20 mm in length would be about a month old and those up to 30 mm a month older.

The results of the "pilot study" component of this project showed that small specimens of the J_1 sub-group were collected in September which is evident of one spawning event. Analyses of the Xikundu data indicate spawning events that occurred prior to May and the again in early spring. This is supported by the analyses of the Gonadosomatic Index of the specimens collected at the Xikundu fishway. The selective nature of the fishway and the resultant absence of specimens of the J_1 and J_2 sub-groups should be borne in mind. The results of the "breeding ecology" component provide evidence of two spawning events that occurred. Although no specimens of the J_1 subgroup was collected during the July survey the presence of specimens of the J_2 subgroup are indicative of a spawning event that occurred two months prior to the survey, i.e. in May. The presence of J_1 subgroup specimens in August, September and October confirms the results obtained in the pilot and Xikundu studies. Based on these results it can therefore be deducted that the species spawn twice during a year and that each of the spawning event is an extended one. Analyses of the GSI of the fish collected in the Xikundu fishway and the resultant bi-modal pattern underpins (Settles and Hoyt, 1978) that the species spawn twice a year.

The results of this study have shown that breeding occurs at sites where flow of water occurs over boulders and cobbles. It was pointed out that it was essential that these breeding habitats should be in close proximity to both fast-deep biotopes (deep riffles and rapids) as well as slow-deep biotopes (pools). These deep habitats can be regarded as resting areas where specimens mature before breeding (Vlok, 1992).

The presence and utilization of nursery areas have been pointed out in this study. These are the areas where very small (J_1) juveniles occur (10 – 20 mm fork length). It was shown that over and above the fact that these nursery areas should have a cobble or boulder substrate for protection and shelter, the water velocity in these areas are very low or even non existent.

Analyses of the maturity classes linked to gonadal development showed that male *L. marequensis* collected in this study became sexually mature when their fork lengths exceeded 90 mm. This is slightly longer than the 70 mm observed by Gaigher (1969a) for male *L. marequensis* in the Incomati River. The results of the analyses of the observed gonadal maturity classes of the females in this study showed that although mature females with fork lengths shorter that 200 mm were observed, the majority of sexually mature females were observed in fish longer than 200 mm. This is substantially lower than the findings of Gaigher (1969) where the females with the highest maturity coefficients recorded were specimens exceeding 280 mm.

This mixture of egg sizes observed in the mature females (maturity class 3) suggests that *L. marequensis* is a serial spawner and it can be accepted that it probably has a prolonged spawning period. The bi-modal distribution in egg diameters confirms that is a serial spawner. Tómmason *et al.* (1984) found that *L. aeneus* displayed a uni-modal distribution while Gaigher (1976) reported that bi-modal distributions were observed in some specimens of *L. kimberleyensis*. As stated previously fractional or serial spawning and for that matter prolonged spawning periods, are often characteristic of fish that occur in areas where no clear distinction between seasons are

recorded. The area in which *L. marequensis* is distributed, which starts at the middle Zambezi River system (Jubb 1967) and stretches south to the Phongolo River system (Skelton, 2001) is an area where no clear distinction between seasons exist.

It can therefore be concluded that *L. marequensis* is a fractional spawner that spawns twice per year. These spawning events coincide with an increase in flow caused by the onset of rains. In spring and early summer the flow increase is accompanied by an increase in temperature. The moderate fecundity and relative large eggs of *L. marequensis* forms part of its adaptive capability. In order to breed the habitat should consist of a mixture of fast flowing water over coarse substrate and deeper habitat with low velocities. It was also observed that nursery areas, where the small juveniles survive, should be in close proximity to the actual breeding areas, which are situated in cobble and boulder areas where slow flow occurs.

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PHYSIOLOGICAL RESPONSE OF VAAL-ORANGE SMALLMOUTH YELLOWFISH (*LABEOBARBUS AENEUS*) TO CATCH-AND-RELEASE ANGLING INDUCED STRESS IN THE VAAL RIVER, SOUTH AFRICA.

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Abstract
The practice of catch and release (C&R) fishing has been widely promoted by angling fraternities (especially flyfishermen) as a popular conservation strategy and fisheries management tool and is currently considered an ecologically sustainable practice. To determine the physiological response of smallmouth yellowfish *Labeobarbus aeneus* to C&R angling, data were collected from June 2008 through to December 2008 (n=96) in the Vaal River, South Africa. Fish were collected using standard flyfishing techniques, anaesthetised in clove oil and blood drawn from the caudal veins; thereafter weighed, measured, revived and released. To serve as controls, 16 randomly selected fish were kept for 72 h in a 15 000 ℓ pool filled with river water. Blood plasma was analysed for concentrations of glucose, cortisol and lactate to determine the effects of angling duration, fish size, and water temperature. Larger fish were shown to be angled for a longer duration compared to smaller fish. Levels of glucose, at times, were affected by water temperature (influenced by time of year). Plasma glucose concentrations decreased with greater angling duration. Few individuals (n=12) showed significantly increased plasma cortisol concentrations. In extended capture fish (angled for more than 1 min) lactate concentrations were found to increase significantly above values for rapid capture fish (angled for less than 1 min). Rapid capture fish had lactate values similar to those of control fish. Control fish showed that baseline levels of cortisol and lactate were restored within 72 h of capture. When compared to results from other species this study shows that the physiological response is species specific, and that studies should be done on all targeted freshwater game fish species to ascertain the physiological stress imposed by C&R angling.

INTRODUCTION

A fish's response to a stressor involves all levels of organization from the cellular, to individual organisms, to population structures (Iwama *et al.*, 2004). To all living organisms this stress response is normal and of vital importance. Three categories can be distinguished within the general stress response of fish, firstly an initial neuroendocrine response (Gamperl *et al.*, 1994) resulting in the release of stress hormones, such as catecholamines and cortisol into circulation (Iwama *et al.*, 2004). Secondly, perturbations in the organism's biochemistry and physiology may occur, which are largely influenced by the aforementioned stress hormones. These result in blood chemistry and haematological changes (Barton *et al.*, 2002, Iwama *et al.*, 2004), such as increased glucose and lactate levels, which result from adjustments to metabolism, respiration, acid-base status and the immune function of the individual fish (Barton *et al.*, 2002). Finally, the tertiary response, which represents changes to whole animals and populations and diverts energy away from essential life processes such as growth and reproduction (Barton *et al.*, 2002, Iwama *et al.*, 2004).

For game fish one such potential stressor is capture by sport anglers. The increased popularity of freshwater game fishing in Southern Africa, and worldwide, highlights the importance in elucidating the response of these fishes to sport angling stress. One of these species, the Vaal-Orange smallmouth yellowfish, *Labeobarbus aeneus* is recognized and widely promoted (Bloomer *et al.*, 2007) as a popular sport angling fish (Groenewald, 1958; Jubb, 1961;

1962; 1973). They are considered the most important angling fish species in the Orange River system (Gaigher, 1976).

The aim of this investigation was to examine the response of smallmouth yellowfish to angling using blood plasma levels of glucose, cortisol and lactate as physiological stress biomarkers.

MATERIALS AND METHODS

Study area

The catchment area of the Vaal River is roughly 192 000 km^2 (Braune and Rogers, 1987) and is the main water source for South Africa's central regions. The Vaal River originates in the lake Chrissie area of the Drakensberg escarpment, from here the river flows in a west-south-westerly direction until it meets and merges with the Orange River close to Douglas (Bertasso, 2004). The Vaal River is approximately 900 km in length (Braune and Rogers, 1987) and its major tributaries drain the Eastern Drakensberg, the Witwatersrand and the Maluti mountains. Along its length, the Vaal River contains several of South Africa's major dams, namely, Grootdraai, Vaal Dam, Vaal Barrage, Bloemhof, Vaalharts and Douglas Weir (Bertasso, 2004).

The area studied contained many islands, smaller channels and numerous rapids, riffles and deeper pools, and was roughly 30 km south of Potchefstroom at Elgro River Lodge (Figure 1), and spanned 12 km of the river (Figure 2).

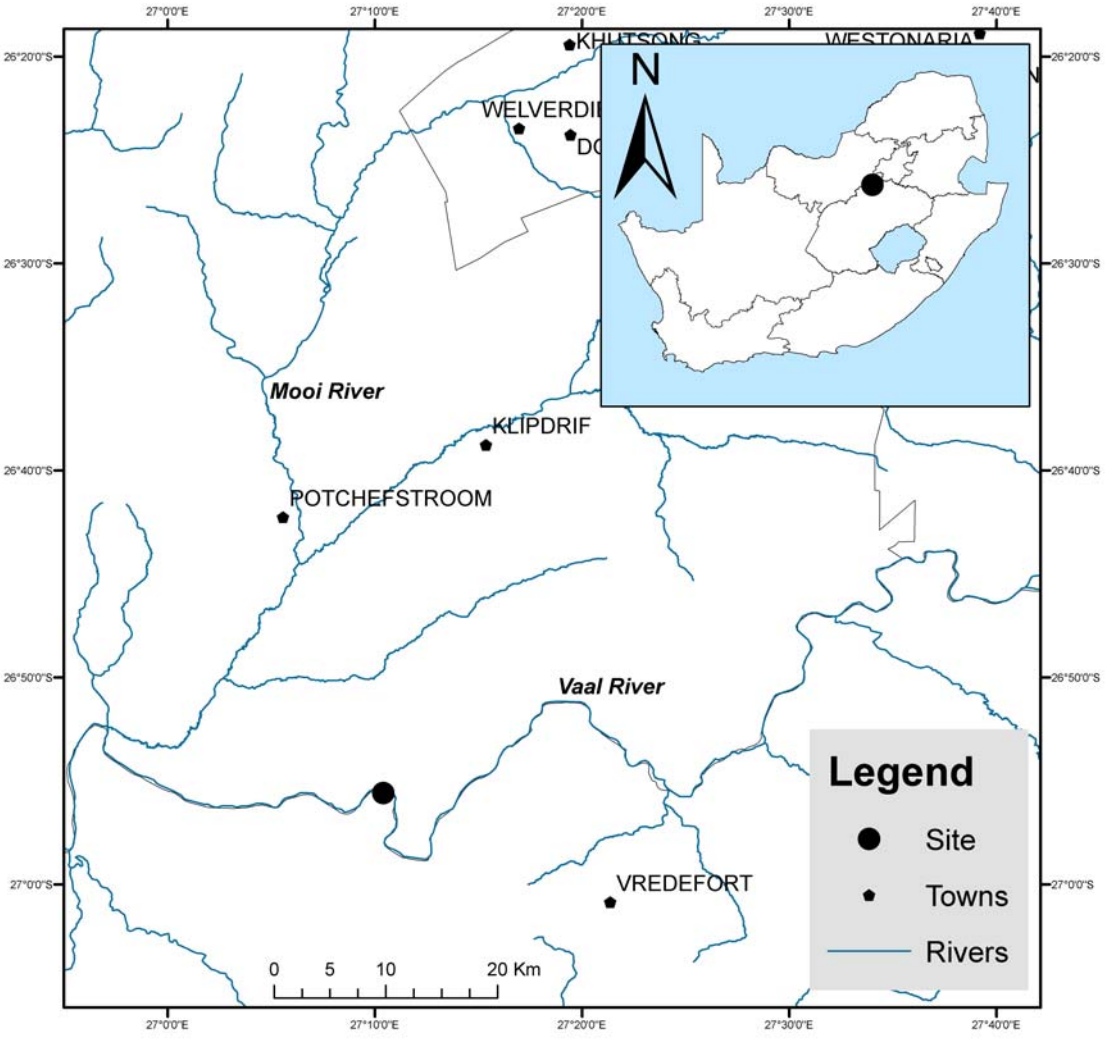

Figure 1: Map of the study area and surrounds in South Africa, the marker indicates the sampled area in the Vaal River.

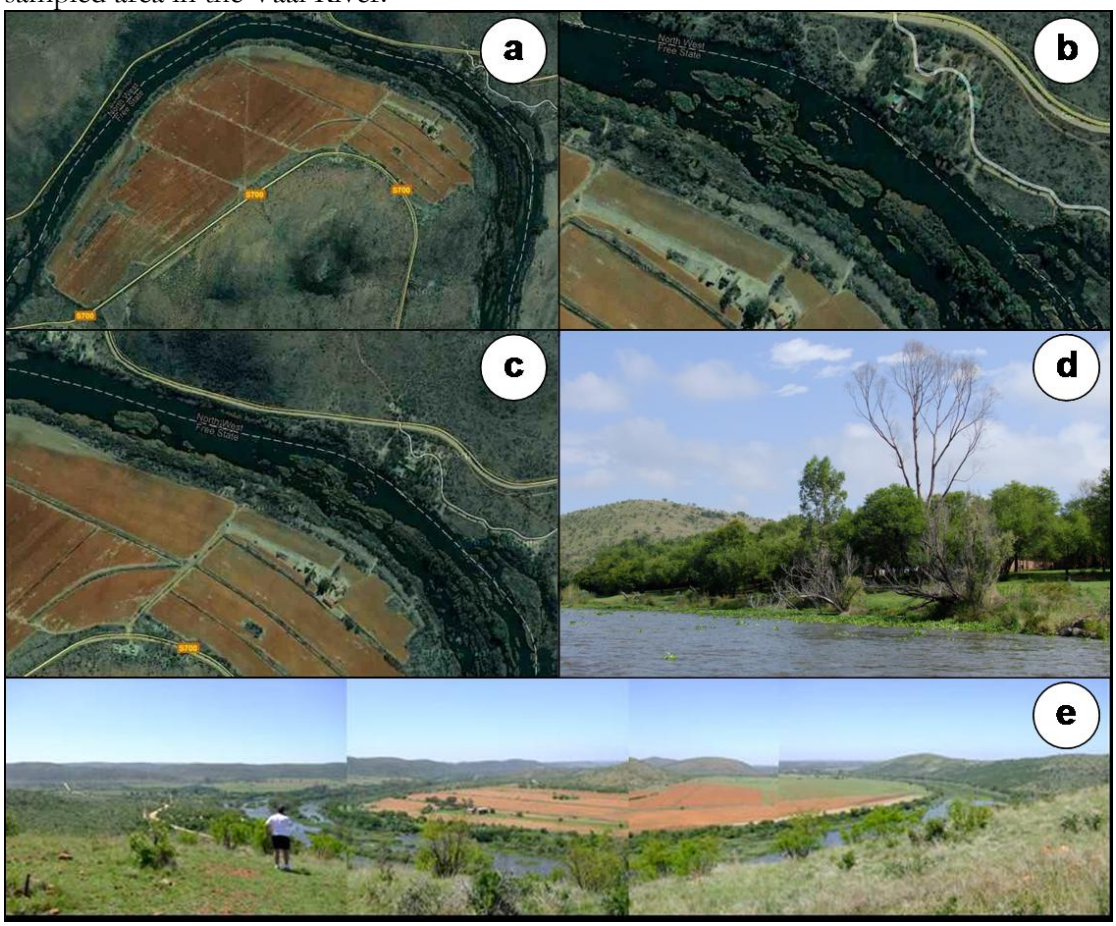

Figure 2: Photographs depicting sampling area in the Vaal River, a, b, c) satellite images (Google maps) showing the many islands and smaller channels in the area, d, e) photos showing the river as well as some of the surrounding vegetation.

Sampling

A total of 96 *L. aeneus* were captured in 2008 from June (winter) to December (summer) by means of fly-fishing in the middle reaches of the Vaal River (Figure 3 a, b, c) (North West Department of Agriculture, Conservation and Environment permit no. 000113 NW -08, and Free State Department of Tourism, Environmental and Economic affairs permit no. HK/P1/10965/001). Fly fishermen were encouraged to fish as normal and the primary gear setup used during this study was a 5/6 weight rod fitted with floating line and a 2X monofilament tippet. Fishermen used a variety of flies that were either recommended by professional guides or tried and tested patterns that had been developed independently. The fishing areas were dependant on the time of year (and thus changes in water temperature). During the colder winter months (June to mid September) deeper water such as pools were targeted, whereas shallower parts of the river, mainly in riffles and rapids, were targeted when the water was warmer during (mid September to December). When fishing the pools, angling was conducted from inflatable canoes (Figure 3d), and in shallower waters anglers waded through the water, no deeper than the mid-thoracic region. Anglers participating in this study consisted of a group of fly-fishermen with varying experience. The more experienced group of fishermen had been fishing for *L. aeneus* in this river system for more than 3 years (range 3 to 25

years), whereas the inexperienced anglers had < 2 years fishing experience. For each fish caught (Figure 3 e, f, g) the times to land fish and handling procedure (hook removal) were recorded. Landing time refers to the time from when the fish was hooked until it was landed (caught in the net); the handling time refers to the time from when the fish was netted by the angler, the hook removed (handling times were prolonged when anglers took photos of the fish they caught). Landing and handling times for each fish were combined to calculate total angling time. In addition to the timings (landing and handling times), general fish characteristics (mass and various length measurements: standard length SL, fork length FL and total length TL) were recorded (Figure 3h, i, j) after blood had been drawn. On completion of data collection, each fish was revived in flowing river water and released (Figure 3k).

Anaesthesia and Sampling procedure

Following capture, all fish were anaesthetised for 2 minutes in a 96 ℓ container containing 50 ℓ of fresh river water with a 32 mg/ℓ concentration of clove oil solution [1:9 ratio of clove oil mixed with ethanol (Anderson *et al.*, 1997; Meka and McCormick, 2005). Anaesthetised fish were removed from the container and 2 mℓ of blood was drawn from the caudal vein using sterile 1 mℓ syringes and 1½ inch 21 gauge needles. Blood was immediately transferred to 4 mℓ heparinised vacutainers and kept cool until centrifugation to separate the plasma supernatant. Plasma was placed in to 1½ mℓ eppendorf tubes, stored in liquid nitrogen in the field and then stored at -80°C on return to the laboratory, until analysis took place.

In addition to the timings (landing and handling times), general fish characteristics (mass and various length measurements: standard length SL, fork length FL and total length TL) were recorded after blood had been drawn. On completion of data collection, each fish was revived in flowing river water and released.

Figure 3: Photographs depicting fieldwork whilst sampling in the Vaal River, a) inflatable canoes fitted with containers (anaesthetisation) and used to carry sampling equipment, b) typical inflatable boat used by flyfishermen when fishing in deeper pools, c) wading fly-fishermen targeting *Labeobarbus aeneus* in shallow waters, d) fly-fisherman fishing from boat, e) angler with his catch, f) and g) two more specimens landed by fisherman, h, i, j) general measurements of specimen being taken and all relevant data being noted, k) fish being revived in flowing river water prior to release.

Sample Analysis

Plasma glucose and lactate were determined using Roche/Hitachi kit (model no. 11448668 216 [CV = 10.65%] and model no. 11822837 190 [CV = 9.12%] respectively, Mannheim, Germany). Plasma cortisol was determined through ELISA, using a research cortisol test kit (model no. 402710 [CV = 8.74%], Neogen Corporation, Lexington, Kentucky USA). The volumes required for the glucose and lactate analysis were adapted so that the reactions could take place in 300µl microplate wells. Plasma cortisol was determined through ELISA, using a research cortisol test kit (Model no. 402710 [CV=9.09%], Neogen Corporation, Lexington, Kentucky USA). Plasma glucose, cortisol and lactate assays were run on a Biotek microplate reader at wavelengths of 540nm (glucose) and 630nm (cortisol and lactate). Concentrations were calculated from the absorbances obtained, by means of equations provided, for cortisol a standard curve (0 – 10ng.mℓ $^{-1}$) was constructed. Physiological changes caused by both landing and handling times (form a part of exhaustive exercise and handling stress, respectively) have been shown for fish species (Meka and McCormick, 2005), these times were analysed separately as well as in combination. The time that fish were anaesthetised was not included during blood parameter analysis, as this time was kept constant (2 min) and clove oil imposes a negligible physiological effect with short exposure times (Wagner *et al.*, 2002). The most influential factors contributing to changes in the physiological response was considered to be both landing as well as handling time, because of the exhaustive nature of hooking and landing processes (Booth *et al.*, 1995; Meka and McCormick, 2005).

Control group

The control group consisted of sixteen randomly chosen fish. Following the initial blood drawing, fish were revived in fresh river water and kept in an aerated 96 ℓ insulated container filled with fresh river water. These control fish were then transported to the field laboratory (control pool) within 60 min and released into a 15 000 ℓ aquarium (pool) containing fresh river water. A 10 000 ℓ .h^{-1} water pump was used to aerate the water and simulate flowing waters. Twenty percent of the water in the control pool was replaced daily to provide fish with fresh river water (Smit *et al.*, 2009). Fish were left in a quiet condition for a 72 h period (Gustaveson *et al.*, 1991; Smit *et al.*, 2009), to allow the physiological stress response from capture to settle and emulate the condition of free swimming unstressed fish. Clove oil was added to the water to anaesthetise the fish and a further blood sample was taken and analysed as previously described. Samples obtained were used as a control value to examine the differences with values attained from captured fish.

Data analysis

All data were analysed using SPSS for windows v. 15 and were similar to that previously used (Smit *et al.*, 2009). All descriptive data are reported as mean ± SD. Pearson's Correlation Coefficient was used to examine the influence of fish mass on landing time. Fish were grouped by landing time which was divided into minute intervals (< 1 min, 1. – 2 min, 2 – 3 min, etc) and also grouped according to the water temperature they were caught at (11°C, 19°C, 22°C and 27°C). A one-way ANOVA was used to examine the plasma cortisol, plasma glucose and plasma lactate responses resulting from the different landing times and water temperatures. A one-way ANOVA was also used to determine whether the water temperature groups differed significantly with regard to the landing times of the captured fish in each group. Differences between groups were determined with the aid of an LSD *post-hoc* test.

RESULTS

Descriptives and Control Fish

Water temperature ranged from 11°C to 27°C depending on the time of year in which sampling took place. Mean total length (TL) and body mass of these fish were 504 ± 88 mm (217 – 666 mm) and 1.47 ± 0.68 kg (0.12 – 3.18 kg). Mean total angling time was 2 min 40 s ± 1 min 9 s (50 s – 7 min 27 s) with a mean landing time of 1 min 30 s ± 55 s (20 s – 5 min 56 s). A significant positive correlation was found between body mass and landing time ($r=0.446$, $p<0.05$) (Figure 4).

Following 72 h in an aquarium, the mean plasma lactate concentration for the control fish was 4.68 ± 1.67 $mMol.L^{-1}$ (2.07 – 7.93 $mMol.L^{-1}$). Blood lactate concentrations in this group were significantly higher following hook and line capture than the concentrations found in the same fish following 72 h in an aquarium ($P<0.05$); however glucose and cortisol levels from control fish were not significantly different to the post capture levels.

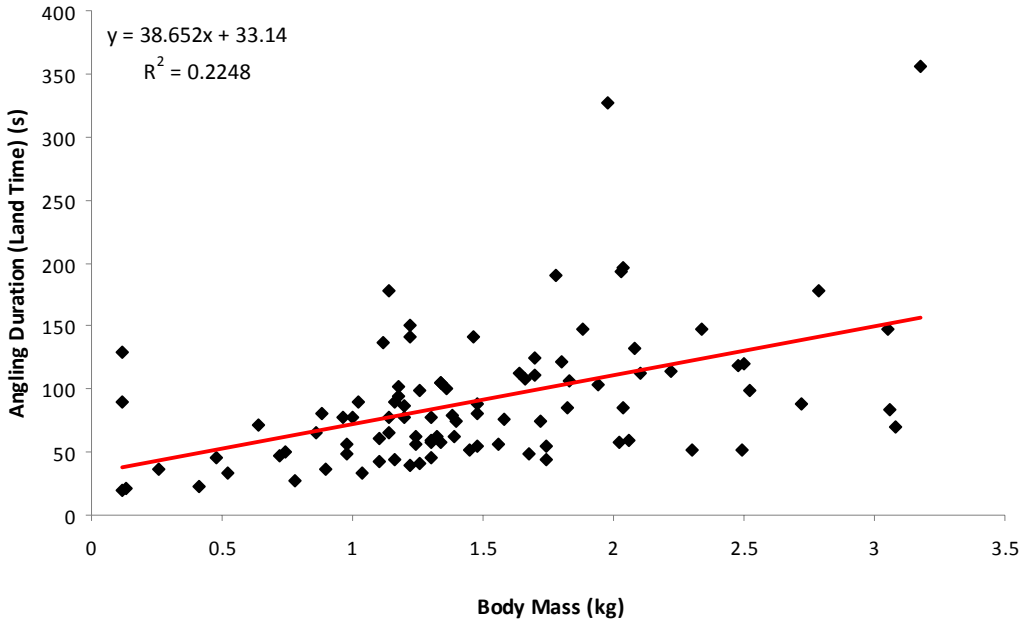

Figure 4: The relationship between smallmouth yellowfish body mass and landing time ($n=96$; $P<0.05$).

Water Temperature

Fish were grouped according to the water temperature in which they were caught at (11°C, 19°C, 22°C and 27°C). A one way ANOVA revealed that the landing time of the fish captured at the different water temperatures were not significantly different to each other ($F=1.736$, $P=0.165$). As the landing times of these groups were not significantly different from each other, the different blood parameters of each group could be compared with one another. The one-way ANOVA analysis further revealed that plasma glucose and plasma lactate were significantly different (Glucose – $F=7.985$, $P<0.00009$; Lactate – $F=7.776$, $P=0.0001$) when calculated using water temperature, while plasma cortisol was not ($F=1.419$, $P=0.243$). The LSD post-hoc analysis showed that mean glucose levels at 11°C and 27°C were not different ($P=0.99$), however they were significantly lower than the intermediate water temperatures of 19°C and 22°C ($P<0.05$), although the intermediate temperatures were also not significantly different to each other ($P=0.99$), (Figure 5). While mean cortisol levels generally increased with water temperature, none of the groups were significantly different to each other (Figure 6). Mean post-

capture plasma lactate concentrations also increased with increasing water temperature, the LSD post-hoc analysis revealed that the 27°C temperature group was significantly higher than all other water temperature groups (P<0.05) (Figure 7).

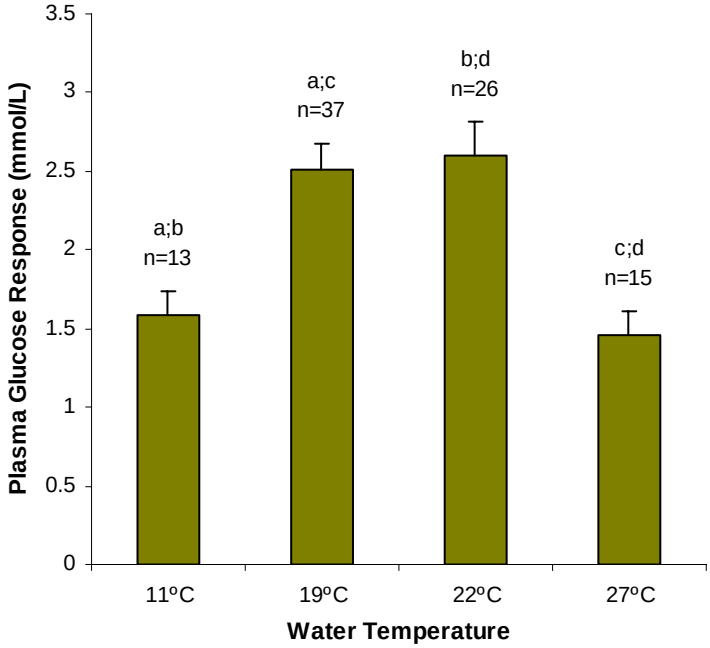

Figure 5: Plasma glucose response of smallmouth yellowfish angled during different water temperatures. Values are presented as mean ± SE; n=91. Means with common subscript differ significantly (P<0.05).

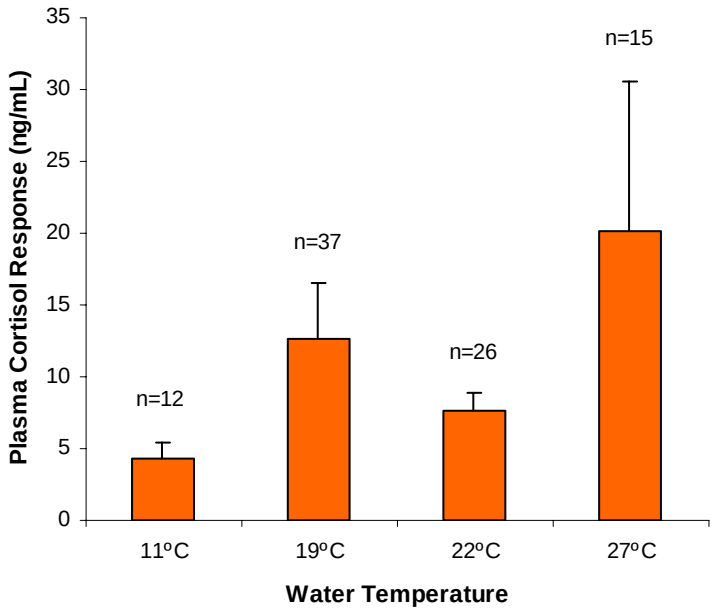

Figure 6: Plasma cortisol response of smallmouth yellowfish angled during different water temperatures. Values are presented as mean ± SE; n=96. Cortisol concentrations were not significantly different at varying water temperatures (P>0.05).

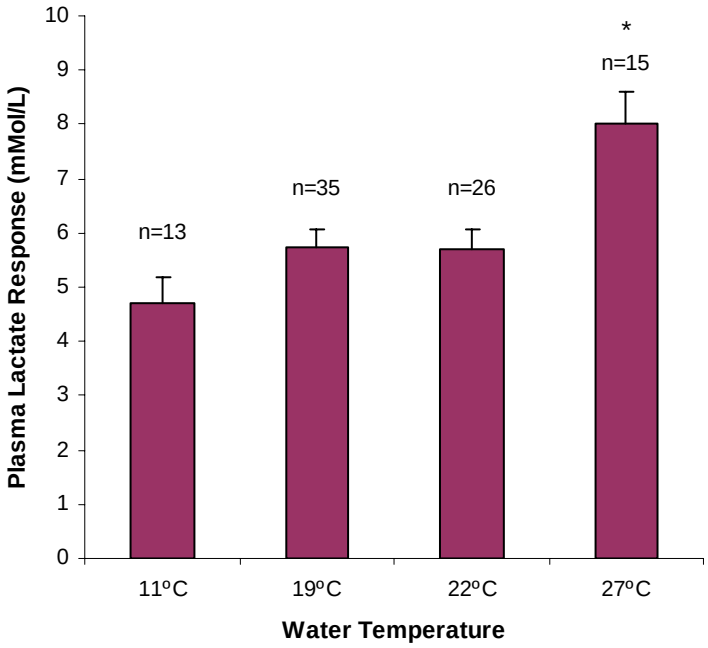

Figure 7: Plasma lactate response of smallmouth yellowfish angled during different water temperatures. Values are presented as mean ± SE; n=87, * denotes that blood lactate concentrations were significantly greater than the other temperature groups ($P<0.05$).

Landing Time

A one way ANOVA revealed that plasma glucose and plasma cortisol concentrations were not significantly different between groups when calculated using land time (glucose – $F=1.535$, $P=0.198$; cortisol – $F=0.471$, $P=0.757$). Mean plasma glucose for the different time intervals were however found to be negatively correlated to land time ($r^2=0.9106$); the longer fish were angled the lower the plasma glucose concentration (Figure 8), whilst plasma cortisol concentrations did not show any correlation ($r^2=0.0043$) (Figure 9). Although a few individuals (n=12) did show significantly ($P<0.05$) elevated plasma cortisol levels ranging from 18 – 160 $ng.mL^{-1}$, the remaining cohort had mean cortisol levels of 4.83 ± 3.94 $ng.m\ell^{-1}$.

Plasma lactate concentrations were found to be significantly different when grouped by land time ($F=4.005$, $P=0.005$) (Figure 10), and mean lactate concentrations for the various time intervals were found to have a strong positive correlatation ($r^2=0.9687$). LSD post-hoc analyses showed no difference between plasma lactate concentrations in the control group and rapid capture fish (< 1 min); the control group however was significantly different to the following groups: 1 – 2 min ($P<0.05$); 2 – 3 min ($P<0.05$); and > 3 min ($P<0.05$). Glucose ($r^2=0.0622$), cortisol ($r^2=0.0685$) and lactate ($r^2=0.0278$) concentrations showed no correlation to body mass.

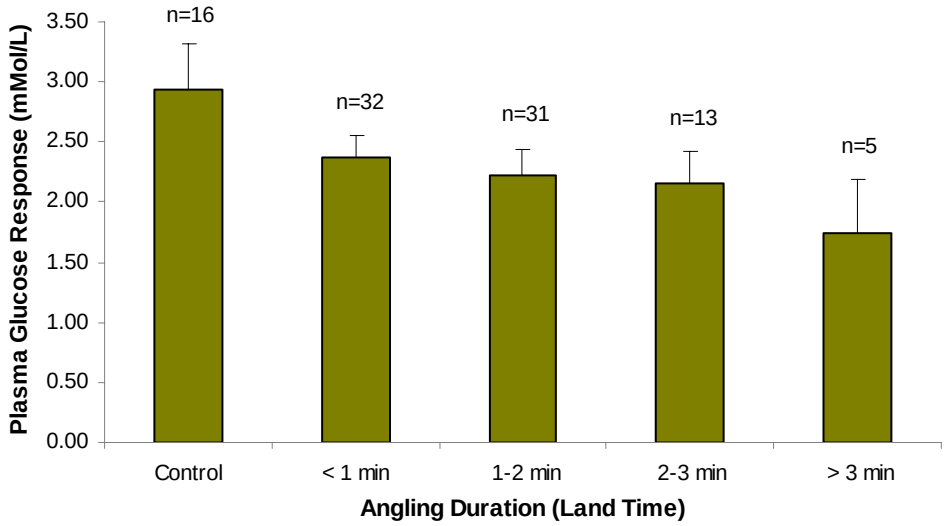

Figure 8: Plasma glucose response of control and angled smallmouth yellowfish during different time intervals. Values are presented as mean ± SE; n=97.

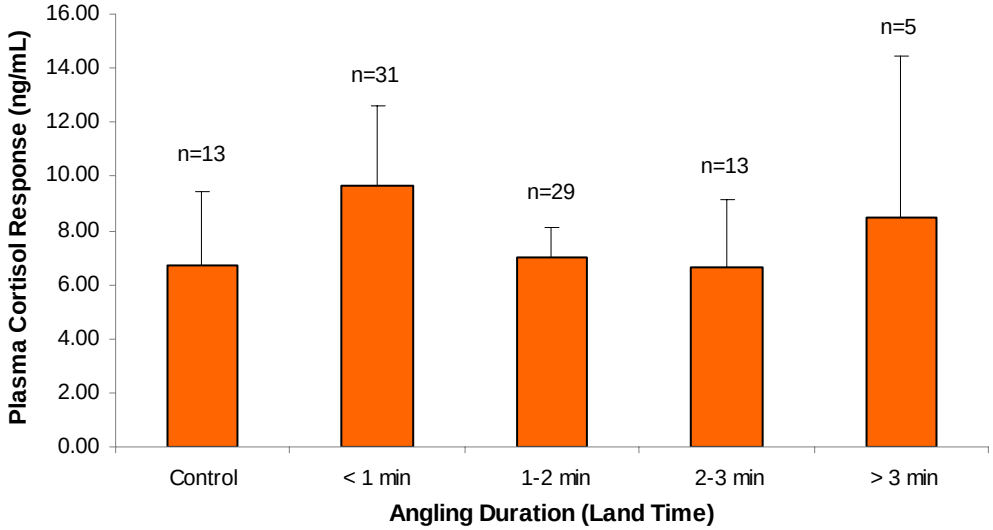

Figure 9: Plasma cortisol response of control and angled smallmouth yellowfish during different time intervals. Values are presented as mean ± SE; n=91.

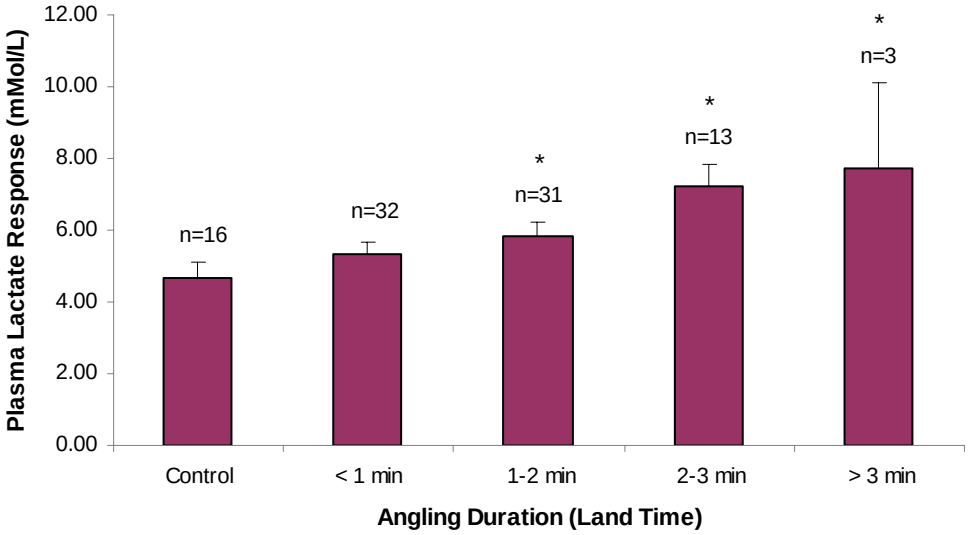

Figure 10: Blood lactate response of control and angled smallmouth yellowfish during different time intervals. Values are presented as mean ± SE; n=95. * denotes that blood lactate concentrations were significantly greater than the control group ($P<0.05$).

DISCUSSION

Effect of the angling period

The blood parameters tested from angled Vaal River smallmouth yellowfish exhibit decreased glucose, increased cortisol (in some individuals) and increased plasma lactate concentrations with increased angling time. According to Booth *et al.* (1995) the most physically demanding form of exercise stress in fish is capture by angling. Numerous studies have shown that the longer fish are angled the greater the subsequent physiological response, (Pankhurst and Dedual, 1994; Thorstad *et al.*, 2003; Meka and McCormick, 2005; Smit *et al.*, 2009), which may result in elevated mortality rates (Meka and McCormick, 2005). Exhaustion can result from extended angling durations and is characterised by increased lactate levels, this is further magnified if the fish is exposed to air and the gill lamellae collapse; consequently gas exchange is lost and CO_2 concentrations increase with a concomitant decrease in O_2 uptake (Casselman, 2005). Although all these factors may contribute to elevated levels of lactate, it is likely that the principal contributor to the physiological stress is the metabolic work done whilst hooked (Arlinghaus and Hallerman, 2007; Smit *et al.*, 2009).

The plasma lactate response of *L. aeneus* to angling duration was significantly greater than controls at every time interval, except at the 1 min time interval indicating that a large degree of metabolic stress is evident, even after short angling durations upwards of 1 min. Comparable results were shown by both Gustaveson *et al.* (1991) and Smit *et al.* (2009) in the response of largemouth bass and tigerfish, respectively. Tigerfish showed an immediate response with significantly higher blood lactate in fish angled for < 1 min and throughout the increasing time intervals when compared to controls. Largemouth bass angled for 1 min or more also had a significantly higher blood lactate level than control fish. Conversely, significant increases in lactate levels of angled rainbow trout were only found after 2 – 3 min from the start of angling (Meka and McCormick, 2005). Importantly Meka and McCormick (2005) used rapid angled fish (fish angled for < 2 min) as their control fish (these fish will likely already have elevated lactate levels) and were fished at lower water temperatures (~10 – 13°C).

The 16 control fish were kept successfully for 72 h and their plasma lactate levels were significantly lower than the post-capture levels (4.68 $mMol.L^{-1}$ vs. 5.74 $mMolL^{-1}$, respectively). Results also show that *L. aeneus* plasma lactate levels were significantly elevated within 1 – 2 min

(5.81 mMol.L^{-1}) after hooking when compared to control fish (4.68 mMol.L^{-1}). Smit *et al.* (2009) showed significantly elevated levels in less than 1 min (3.2 mMol.L^{-1}) after hooking when compared to control fish (1.6 mMol.L^{-1}). Control fish plasma lactate levels in this study are higher than in control tigerfish (Smit *et al.*, 2009). Meka and McCormick (2005) showed that rapid capture fish had lactate concentrations of ≤ 5 mMol.L^{-1}, which they suggested showed levels of free swimming fish (control fish). The significant increase in plasma lactate levels within 1 – 2 minutes of angling indicates that there is a severe metabolic response, likely the result of increased muscular work, following hooking (Smit *et al.*, 2009). The control values for plasma lactate reported here are higher than those reported for largemouth bass, 1.8 mMol.L^{-1} (Gustaveson *et al.*, 1991) and Coho salmon, 1 mMol.L^{-1} (Milligan and McDonald, 1988).

The mean cortisol value of the angled *L. aeneus* was low and showed no increase with angling time. Post capture values were also not significantly different from the control fish data, but were similar to rapid capture rainbow trout from the Alagnak River, which had cortisol concentrations of less than 11ng.mL^{-1}; these values were considered to reflect those of free-swimming natural fish populations (Meka and McCormick, 2005). Consequently we propose that the cortisol values found during this study are also reflective of free-swimming "unstressed" fish. A few individuals (n=12) did however show significantly elevated cortisol concentrations of 18 – 160 ng.mL^{-1}. This might indicate that for fish with non-elevated levels, blood drawing may have been done before the cortisol response could be measured. Cortisol release from the inter-renal tissue is a delayed reaction to an induced stress because the response is dependent on various pathways; consequently, it is conceivable that it may take some time before the response can be seen in the blood (Barton, 2002; Iwama *et al.*, 2004).

In this study glucose concentrations decreased as angling times increased, while Silbergeld (1974) found increased glucose concentrations in stressed fish. Although significant increases in plasma glucose have been observed within 5 minutes (Wydoski *et al.*, 1976), numerous controlled studies have found that significant changes in glucose may take up to an hour to manifest (Ristori and Laurent, 1984; Carey and McCormick, 1998). The decrease in glucose with angling time was not significantly different to the levels of control fish, Meka and McCormick (2005) similarly had no significant differences in glucose concentration with increased angling times. The lack of an increase in the glucose concentrations provides further support to the notion that the cortisol concentrations measured in this study are likely a reflection of resting values as greater circulating cortisol concentrations tend to result in higher glucose concentrations (Barton, 2002; Iwama *et al.*, 2004).

Based on the data from the control fish we are confident that lactate, cortisol and glucose levels in the control group returned to concentrations that are analogous to the resting/free swimming levels of the natural population. The establishment of baseline levels is critical to the study of the stress response (Iwama *et al.*, 2004).

Like Meka and McCormick (2005), we propose that the post capture lactate and cortisol levels found in this study represent the initial stages of a stress response caused by angling, and that the levels will continue to rise and will only peak some time after the initial stressor is applied (Barton, 2002; Iwama *et al.*, 2004), but subside after 72 h.

Effect of size (body mass)

As the body mass of the smallmouth yellowfish caught increased, so did the angling duration (r^2=0.2248). This has been shown for numerous species in many different studies, namely; tigerfish (Smit *et al.*, 2009), Atlantic salmon (Thorstad *et al.*, 2003) and rainbow trout (Meka and McCormick, 2005). Glucose, cortisol and lactate levels showed no correlation to increased body mass. Smit *et al.* (2009) also found that lactate concentrations of control fish data was independent of body mass and concluded that the metabolic stress caused by angling stress was the chief cause of elevated blood lactate levels (Meka and McCormick, 2005). Similarly we

attribute decreased plasma glucose and increased plasma cortisol and lactate levels in this study to the unavoidable metabolic stresses of angling. The stress response in fish from this study has been shown to be independent of body size, but dependant on angling duration. Fish that are angled for longer periods are generally larger individuals, these increased angling times result in larger increases in lactate and cortisol and decreases in glucose concentrations. This would suggest that the larger and oldest male and female individuals of the population would be placed under the greatest stress. These larger individuals would most likely be repeating spawners and deliver the largest contributions to the growth and replenishment of the population during spawning periods. The main season that *L. aeneus* are targeted by fly-fishermen is from mid-September to mid-April, these times correspond to their spawning season (Mulder, 1973; Tomasson *et al.*, 1984; Weyl *et al.*, 2009), which lasts from late-September through to mid-March, depending on the river water temperature and flow (Gaigher, 1976; Tomasson *et al.*, 1984). Angling stress has been shown to affect spawning behaviour and spawning success in many species (Cooke *et al.*, 2000) including largemouth bass and salmon, (Cooke *et al.*, 2002, Thorstad *et al.*, 2003). For smallmouth yellowfish the same may be true, but this requires further investigation.

Water Temperature

The water temperatures in this study ranged between 11°C and 27°C and represent the entire range of seasonal temperatures that these fish may be exposed to. Water temperature has been shown to inflict significant effects on post-capture levels of glucose, lactate and cortisol (Meka and McCormick, 2005). It has been suggested that temperature has a significant influence on the physiological responses to exhaustive exercise – such as angling (Kieffer *et al.*, 1994). In the current study, post-capture plasma glucose levels were shown to be lowest at the upper (27°C) and lower (11°C) temperatures (extremes), and highest at the intermediate temperatures of 19°C and 22°C respectively. Meka and McCormick (2005) found a significant correlation between glucose and temperature; in their study post capture glucose levels in rainbow trout were found to be increased with water temperature. The glucose concentrations shown in this study are likely non-indicative of the stress response, but may show the variation in the availability of energy during different times of the year and thus influenced by water temperature.

Post-capture plasma lactate levels reflected the range of water temperatures sampled. Fish angled at the coldest (11°C) temperatures showed mean plasma lactate values similar to control fish, whilst fish angled at intermediate (19°C and 22°C) temperatures showed mean lactate levels similar to fish angled for 2 minutes or less. Fish angled at the upper temperature extreme (27°C) showed mean plasma lactate levels similar to extended capture fish (i.e. fish angled for more than 2 minutes). Similarly rainbow trout (Meka and McCormick, 2005) and largemouth bass (Gustaveson *et al.*, 1991) exhibited increased lactate levels as water temperature increased. Both these studies showed that at all temperatures, increased angling duration caused lactate levels to increase, but also that lactate concentrations were highest at the warmest water temperatures compared to the cooler water temperatures. The temperature a fish is acclimated to may influence the anaerobic energy production in fish (Kieffer *et al.*, 1994). The lactate response found in fish from this study, show that fish angled at lower and intermediate temperatures have the smallest response, whilst fish angled at the upper temperatures have the greatest response to angling. Kieffer *et al.* (1994) observed similar results, in that post exercise fish acclimated to higher temperatures (18°C) showed lactate concentrations two-fold greater than fish acclimated to lower temperatures (5°C). Therefore fish angled at higher water temperatures are put under greater stress and as a result under greater risk of a wide range of sub lethal impacts and even mortality than fish angled at lower water temperatures.

Recovery, mortality and potential sub-lethal effects

Generally the required time for post-capture plasma cortisol and glucose levels to return to resting levels is 24 hours following an intense stress event (Barton *et al.*, 1986; Pickering and Pottinger, 1989; Pankhurst and Dedual, 1994; Iwama *et al.*, 2004; Meka and McCormick, 2005; Arlinghaus and Hallerman, 2007). Post exercise lactate levels have been shown to clear relatively quickly, ranging from 8 to 18 hours, (Kieffer *et al.*, 1994; Casselman, 2005). However, recovery times as well as the magnitude of the stress response are influenced by a number of factors; the severity and duration of the stress (Iwama *et al.*, 2004), water temperature, recovery conditions and genetic variation between populations (Pickering and Pottinger, 1989; Pankhurst and Dedual, 1994; Meka and McCormick, 2005). Therefore extended capture fish as well as fish angled at higher water temperatures, should presumably experience greater peak cortisol and lactate concentrations and thus require longer recovery periods than fish with shorter angling times and those fish angled at lower water temperatures.

Mortality from exhaustive exercise has been shown to manifest within several hours to several days post-capture (Dotson, 1982; Brobbel *et al.*, 1996; Wilkie *et al.*, 1996; Thorstad *et al.*, 2003; Meka & McCormick, 2005). The exact cause of post-capture mortality is not known; it has been suggested that an intracellular acid-base disturbance induced partly through lactic acid production in the muscle may contribute for which plasma lactate is an indirect index of muscle lactic acid production (Wood *et a*l., 1983). Increased plasma lactate levels have been shown to be associated with delayed mortality following exercise or hypoxia (Wood *et al.*, 1983; Ferguson and Tufts, 1992). However, neither a threshold for plasma lactate nor other blood parameters have been established as a predictive mortality index (Meka and McCormick, 2005). Intracellular acidosis as a result of exhaustive anaerobic exercise as well as the collapse of the gill filaments due to air exposure may cause mortality due to the physiological disturbance and the associated energy depletion (Arlinghaus and Hallerman, 2007). Even slight increases of cortisol of 10 $ng.mL^{-1}$ have been shown to lead to the mortality of fish because the fish are left susceptible to various pathogens such as *Saprolegnia*, bacterial fin rot and furunculosis, all of which are well known as stress related diseases (Arlinghaus and Hallerman, 2007). Temperature has also been shown to affect mortality in fish species namely bluegill *Lepomis macrochirus*, Rafinesque, 1819 (Muoneke, 1992) and cutthroat trout (Dotson, 1982) where mortality rates increased up to 10% with increased water temperatures, and this was also shown for numerous bass species (Casselman, 2005). No mortality studies have been done on any African or South African species. Mortality caused by catch and release fishing is frequently under-estimated by both the anglers as well as the fisheries managers. After reviewing 118 catch and release studies Casselman (2005) concluded that the average mortality arising from angling is around 16.2%, and therefore many anglers assume they are doing the right thing, and are not having an effect on the population; in reality many may die following release and have a marked impact on the population (Casselman, 2005).

The increased plasma cortisol and lactate levels shown in this study are indicative of the exercise and the eventual stress responses that may have generated certain post-capture sub lethal responses in individual *L. aeneus*. Many studies have demonstrated that fish may stop feeding following a stress event such as angling and this can result in decreased growth (Pickering *et al.*, 1982; McCormick *et al.*, 1998). According to Gregory and Wood (1999) this cessation of feeding and resultant decreased growth may be due to the effects of cortisol. In addition, other behavioural changes caused by the stress response may include avoiding predators, capturing prey (larger individuals of *L. aeneus*), as well as migration and habitat preference (rapids, riffles or deeper pools) (Iwama *et al.*, 2004). Behavioural changes may reflect adverse changes as to how an animal perceives and responds to its environment (Iwama *et al.*, 2004). The reproductive capacity of an individual or heavily fished population may decrease as energy used for such necessary life processes may be diverted in order to cope with the increased

energy demand due to the stressor and as such decrease recruitment and productivity (Barton, 2002). It has been shown that increased cortisol levels while being of adaptive value to fish paradoxically also suppresses the immune response of the fish, thus leaving fish susceptible to disease during the recovery period (Arlinghaus and Hallerman, 2007). Although the effects of air exposure have not been assessed during this study, it is important to note the important role it may play in the stress response of angled fish refer to section 2.4.3 of Chapter 2 for a more in depth discussion on the effects of air exposure.

CONCLUSIONS

The results obtained in this study directly apply to *L. aeneus* in the Vaal River, in the vicinity of Potchefstroom, but may be considered representative of other popular C&R populations throughout South Africa. Water temperature along with angling times were the influential factor in the range of glucose, cortisol and especially lactate levels in this study. This specific study presents information regarding the physiological effects of C&R fishing on only the second southern African species.

The results from *L. aeneus* differ to a certain extent with that of *H. vittatus*. This confirms once again that the physiological response to angling is specific and it is important that research focus on all targeted species and populations.

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OVERVIEW OF ACID MINE DRAINAGE AND RECENT GOVERNMENT ACTIVITY

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- The Witwatersrand has been mined for more than a century. The Witwatersrand Mining Basin is composed of the Far East Basin, Central Rand Basin, Western Basin, Far Western Basin, KOSH (Klerksdorp, Orkey, Stilfontein and Hartbeestfontein) and the Free State gold mines.
- It is the world's largest gold and uranium mining basin with the extraction from more than 120 mines of 43 500 tons of gold in one century and 73 000 tons of uranium between 1953 and 1995.
- The basin covers an area of 1600 km^2, and led to a legacy of some 400 km^2 of mine tailings dams and 6 billion tons of pyrite tailings containing low-grade uranium.
- The mineral pyrite (FeS_2) and other sulfur containing minerals are common. Mining gold inevitably involves exposing these pyritic materials to oxygen and water. In the deep gold mines, these materials are exposed in the voids created by the mining process. They also are brought to the surface as an unwanted waste product along with the gold, where they and other unwanted materials were separated from the gold and historically put in huge refuge piles known as tailings dams. Here too the pyritic materials were exposed to oxygen and water.
- Wherever pyrite can come into contact with oxygen and water a potential problem exists. This trio of pyrite, oxygen and water causes in the formation of AMD1.

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1 When pyrite is initially exposed to oxygen and water the following reaction can occur

$$4FeS_{2(s)} + 14O_{2(g)} + 4H_2O_{(l)} \rightarrow 4Fe^{2+}_{(aq)} + 8SO_4^{2-}{}_{(aq)} + 8H^+_{(aq)} \quad (1)$$

This can be stated as pyrite, oxygen, and water react to form dissolved ferrous ions (a.k.a. iron II), dissolved sulfate ions and acidity. Thus ferrous ions and acidic hydrogen ions are released into the waters that run off through the mine tunnels or refuge piles. The pH of the water will likely go down depending on just how often this reaction occurs. While dissolved, ferrous iron ($Fe^{2+}_{(aq)}$) and sulfate ions ($SO_4^{2-}{}_{(aq)}$) are colourless and the water may actually look crystal clear. In some AMD discharges, this is the condition of the water as it makes its way to the surface. Also note that this is not a particularly fast reaction just as the formation of rust takes a while to happen.

The next step in the process is for the ferrous iron to be oxidized to ferric iron as shown in the following reaction

$$4Fe^{2+}_{(aq)} + O_{2(g)} + 4H^+_{(aq)} \rightarrow 4Fe^{3+}_{(aq)} + 2H_2O_{(l)} \quad (2)$$

Aqueous ferrous (Fe^{2+}) ions react with oxygen and acidic hydrogen ions to form ferric (Fe^{3+}) ions and water. Note that oxygen needs to be present for this reaction to happen. Often this reaction doesn't happen to any great extent underground because of limited available oxygen. Also note that acidity is consumed in this process. This reaction rate is pH dependant with the reaction proceeding slowly under acidic conditions (pH 2-3) with no bacteria present and several orders of magnitude faster at pH values near 5. This reaction is referred to as the "rate determining step" in the overall acid-generating sequence.

- Tailings dams and waste rock dumps can never be maintained in completely reducing environment. It logically follows that there will be long term water risks.
- Waste from gold mines constitutes the largest single source of waste and pollution in South Africa.
- Acid Mine Drainage (AMD) is responsible for the most costly environmental and socio-economic impacts. This water has a low pH and a high acidity and contains toxic and radioactive heavy metals.
- Production of AMD may continue for many years after mines are closed and tailings dams decommissioned.
- AMD is not only associated with surface and groundwater pollution but also degradation of soil quality, harming aquatic sediments and fauna, and allowing heavy metals to seep into the environment.
- Radionuclides are concentrated in sediments downstream of their sources. Sequential extractions showed that these radionuclides are distributed in multiple phases within the sediment bodies of the Witwatersrand goldfields and that they may be re-mobilised by Acid Mine Drainage.
- Long-term exposure to AMD polluted drinking water may lead to increased rates of cancer, decreased cognitive function and appearance of skin lesions.
- Heavy metals in drinking water could compromise the neural development of the foetus which can result in mental retardation.

Equation 3 describes the next reaction where the ferric ions now hydrolyze in water to form ferric hydroxide. (Hydrolysis is a reaction in which water reacts with another reactant and which a hydroxyl group and a hydrogen ion are formed.)

$$4Fe^{3+}_{(aq)} + 12\ H_2O_{(l)} \ \text{---}> \ 4Fe(OH)_{3(s)} + 12H^{+}_{(aq)} \quad (3)$$

This process releases even more hydrogen ions into the aquatic environment and further reducing the pH. The ferric hydroxide formed in this reaction is also called "yellow boy", a yellowish-orange precipitate that turns the acidic runoff in the streams to an orange or red color and covers the stream bed with a slimy coating. Aquatic life dwelling on the bottom channel of the stream is soon killed off. If the pH is greater than 3.5 this precipitation reaction will occur.

Often the net effect of equations 1 through 3 is summarized in the following equation

$$4FeS_{2(s)} + 15O_{2(g)} + 14H_2O_{(l)} \ \text{---}> \ 4Fe(OH)_{3(s)} + 8SO_4^{2-}{}_{(aq)} + 16H^{+}_{(aq)} \quad (4)$$

Overall pyrite is oxidized releasing acidic hydrogen ions into the water and coating the stream bed with "yellow boy".

These reactions give a fair representation of how pyrite reacts to form pollution. However, a number of other reactions are also possible, mostly leading to the same kind of products. For example

$$FeS_{2(aq)} + 14Fe^{3+}_{(aq)} + 8H_2O_{(l)} \ \text{---}> \ 15Fe^{2+}_{(aq)} + 2SO_4^{2-}{}_{(aq)} + 16H^{+}_{(aq)} \quad (5)$$

involves pyrite reacting with ferric ions and water producing ferrous ions, sulfate ions and acidity. What happens in any particular environment is largely dependant on the conditions existing in that environment. One such factor is the presence of a bacterium known as *Thiobacillus ferroxidans* which likes acidic conditions and can greatly enhance the rate of oxidation of iron and sulfur containing compounds.

- If indeed the extent of "… *problems related to mining waste may be rated as second only to global warming and stratospheric ozone depletion in terms of ecological risk"* (EEB, 2000), then the Witwatersrand gold mining area of South Africa is at serious risk.
- In 2002 in the Krugersdorp-Randfontein area water has started to decant from the flooded West Rand Mine Basin, the smallest of the Mine Basins within the Witwatersrand goldfields, into the Tweelopiespruit and the Wonderfonteinspruit. An unqualified volume of AMD furthermore escapes downstream into the Zwartkrans compartment via the Tweelopiespruit, mostly subsurface. The Zwartkrans compartment hosts the very sensitive Cradle of Humankind World Heritage site.
- Groundwater contamination with the chemical characteristics of West Rand Goldfield mine water has been detected at a number of sites in the dolomitic aquifer of the Zwartkrans Compartment. 11 491 people use the groundwater in the Zwartkrans Compartment for domestic use; 2 654 Ha are under irrigation using borehole water and 458 Ha are under irrigation using river water.
- The combination of the pH and redox driven reactions resulted in a measured uranium concentration of 16mg/l of the Robinson Lake, the source of the Tweelopiespruit and resulted in the NNR declaring the lake a radiation area. It furthermore resulted in the Tweelopiespruit being classified as a Class V River, that is, an acutely toxic river.
- The Department of Water Affairs and Forestry issued a Directive on 29 March 2005 to the three mining companies operational within the West Rand. The Mines failed to comply with the terms and conditions of the Directive and semi-toxic water continued to be discharged into the Tweelopiespruit from 2005 to 2010. 100 tons of salt are discharged daily into the Tweelopiespruit.
- Results indicate that U-levels in water resources of the whole Wonderfonteinspruit catchment increased markedly since 1997 even though U-loads emitted by some large gold mines in the Far West Rand were reduced. This apparent contradiction is explained by the contribution of highly polluted water decanting from the flooded mine void in the West Rand.
- Of particular concern is the fact that U-levels in the Wonderfonteinspruit are comparable to those detected in the Northern Cape which had been geostatistically linked to abnormal haematological values related to increased incidences of leukaemia observed in residents of the area.
- Since the 21st of January, 2010 between 12 and 30 Mega Litres of untreated AMD are decanting uncontrolled into the Tweelopiespruit and seeps into the Wonderfonteinspruit. 12.5 Mega Litres of semi-treated AMD are discharged into the Tweelopiespruit.
- The chronic effects of AMD on humans, such as mutagenicity, teratogenicity and estrogenicity, have not been assessed.
- The R6.9 million that the honourable Minister of Water and Environmental Affairs has recently donated to address the environmental emergency within the West Rand Mine Basin is currently being used, grounded upon physical (real) evidence, to purchase massive volumes of lime, which is added where the untreated AMD (the current volume is 30 Mega Litres) is flowing into the Krugersdorp Game Reserve. This results in the heavy metals, including U, precipitating in the Hippo Dam (the first receptor in the Krugersdorp Game Reserve). Since the iron is not removed, it results in secondary chemical reactions with resultant pH shocks. The acidification causes these heavy metals in the Hippo Dam to become mobilized and solubilized. The pH of the last dam in the Krugersdorp Game Reserve, namely the Aviary Dam, after the water has flowed through wetlands, is 4.

- There are opposing academic views regarding the impact of the AMD on the dolomite in the Zwartkrans Compartment which hosts the Cradle of Humankind World Heritage Site. Garfield Krige, an expert, found that:

  It has been calculated that the sulphuric acid in each 1 Ml of mine void water will dissolve a volume of dolomite (carbonate rock) of approximately 317 litres. In April 2009 the mine void water, containing sulphuric acid, will have been flowing into the Zwartkrans compartment for 8 years. The corresponding void in the dolomite that has been formed so far, amounts to a staggering 16.7 Ml (i.e. 16 700 m^3). Although this void space will be spread over a large area, most of it will be concentrated in the area where the water in the Tweelopiespruit first comes into contact with the dolomite. This is also the area where the N14 road crosses the Tweelopiespruit. This road is in serious danger of collapse due to sinkhole formation! A gravity survey and drilling/grouting (if needed) operation should be implemented immediately to safeguard the lives of people using this section of the N14 road.

  Over the last 8 years the sulphate concentration in many of the boreholes in the Cradle of Humankind World Heritage Site has also increased significantly, indicating that the plume of pollution is spreading rapidly through the groundwater aquifer. Sulphate concentrations in excess of 1 500 mg/l have been recorded in boreholes used for domestic purposes. These water users are presently unaware of the potential poisoning of their water supply and should be provided with a clean source of water before people/animals using this water become ill. In 2006 the pollution plume was already recorded in boreholes well beyond the Sterkfontein caves along the Blaauwbankspruit valley (also referred to as the "Valley of the Ancestors)."

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STATUS OF YELLOWFISH POPULATIONS AND RIVER HEALTH PROGRAMME IN THE NORTH WEST PROVINCE – 2010. **PART 1**: PROVINCIAL REPORT

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Abstract

Four *Labeobarbus spp* and *Barbus rapax* occur in four Water Management Areas in the North West province.

Little research specific to yellowfish is conducted in the province except for the work in the Vaal River. The efforts of the province regarding aquatic monitoring are focused on the River Health Programme, and some results are presented.

Severe pollution and flow threats are experienced in the "work horse" rivers originating in industrial areas, namely the Vaal and Crocodile Rivers, while rural rivers experience problems caused by dams and erratic water release regimes, alien vegetation and limited mining activities. However, there are some near-pristine rivers in the upper reaches and these are of high biodiversity value.

Introduction

Four water management areas (WMA) are present in the North West Province, namely the Upper, Middle and Lower Vaal River WMA's in the south feeding into the west flowing Orange River and the Crocodile West and Marico WMA feeding into the east flowing Limpopo River in the north. The Vaal River WMA's harbour two different yellowfish species and the Marico/Crocodile WMA contains two yellowfish species and the papermouth.

Species present

Labeobarbus kimberleyensis and *L. aeneus* in the west flowing Vaal River system.
L. marequensis, L. polylepis and *B. rapax* in the east flowing Marico/Crocodile River system.

Table 1: Occurrence of yellowfish in NW dams

	Labeobarbus kimberleyensis	*L. aeneus*	*L. marequensis*	*Labeobarbus polylepis*	*Barbus rapax*
Taung Dam	**X**	**X**			
Koster Dam		**X (introduced)**			
Lindleyspoort Dam			**X**		**X**
Vaalkop Dam			**X**		**X**
Roodekopjes Dam			**X**		**X**
Molatedi Dam			**X**		**X**
Hartebeespoort Dam			**X**	**X**	**X**

Status of species

Labeobarbus kimberleyensis - Vulnerable (VU A1c)* (IUCN, 2004).
*(A = Reduction in population size; 1 = an observed, estimated, inferred or suspected population size reduction of >50% over the last 10 years or three generations & c = a decline in area of occupancy, extent of occurrence and/or quality of habitat.)

L. kimberleyensis is also listed as a Threatened or Protected Species under the regulations of the National Environmental Management: Biodiversity Act.

The other species are not listed, but catch restrictions are imposed.

Sub-populations present: Unknown
Sub-populations status: Unknown

Threats
Annexure A reports on the anthropogenic impacts on the rivers in the NW Province which pose a serious threat to aquatic biota.

Another cause for concern is the illegal distribution and stocking of fish species, including yellowfish, as the introduction of *L. aeneus* into Koster Dam clearly illustrates. This practice not only results in the introduction of species alien to specific ecosystems, but can also be a source of genetic pollution and disease.

Man-made impoundments reduce natural spawning sites, which may cause different species to congregate at the remaining suitable sites at the inflow of the river. This can lead to hybridization, as is suspected between *L. aeneus* and *L. kimberleyensis* in Taung Dam.

Conservation measures to conserve yellowfish resource
Conservancies – Orange Vaal River Yellowfish Conservation and Management Association

Stockings – None by NW DACERD, but illegal stocking by private individuals have been reported (*Labeobarbus aeneus* in Koster Dam).

Education and awareness – Wetland Awareness Campaign by North West Wetland Forum, Crocodile (West)/Marico State of the Rivers Report and Poster.

Legislation – New provincial angling license conditions have been promulgated on 15 April 2009 (Provincial Gazette Extraordinary no. 6619).

Monitoring - The National River Health Programme (RHP) is included in the Strategic Plan of NW DACE. Although not aimed specifically at yellowfish, the programme monitors the biodiversity at selected sites with different indices (including SASS5 and VEGRAI) and also (but currently to a lesser extent) includes fish surveys. A progress report is attached (Annexure A)

Research – No yellowfish-specific research is done by NW DACERD. J.H. Koekemoer is conducting a Ph.D. study on fish population structures in Hartebeespoort Dam, Lindleyspoort Dam and Koster Dam (see results under "Species present").

The University of Johannesburg and the Endangered Wildlife Trust are conducting research on yellowfish in the Vaal River.

Intermediate Ecological Reserve determinations are in progress for the all four Water Management Areas in NW (commissioned by DWA).

Action plan & Progress Report - The Conservation Plan for the Crocodile (West) and Marico Rivers will be integrated in provincial biodiversity conservation strategy and bioregional plans.

Value of yellowfish resource to anglers and subsistence fishers
No data available.

Concluding remarks

The rivers in North West are, as in the rest of South Africa, under severe threat from urban development, mining and agriculture. This has a severe impact on yellowfish populations, but fortunately there are still several river reaches in the higher lying areas that are in near pristine condition and with high biodiversity values.

The NW province is a stronghold for *L. marequensis* and thanks to research projects and conservation endeavours of FOSAF and the Orange Vaal River Yellowfish Conservation and Management Association, *L. kimberleyensis* and *L. aeneus* receive attention. There is concern regarding the status of *L. polylepis* and a more intense survey of its preferred habitat is required.

Acknowledgements

Paul Fouche is thanked for conducting two fish surveys for the RHP in the North West Province and for the training given to our field staff. Johan Koekemoer is thanked for making his preliminary data available to NW DACE for this report.

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PART 2: SUMMARY OF THE PROVINCIAL RIVER HEALTH PROGRAMME PROGRESS REPORT, NORTH WEST PROVINCE: **PART 2**

JANUARY 2005 TO MARCH 2010

Compiled by: Hermien Roux, SNCS, March 2010

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1. Introduction

The purpose of this document is to provide a brief report on the progress of the Provincial River Health Programme (RHP) in the North West Province since 2005. The origin and background of this programme will also be discussed. Progress with the monitoring programme in the different biomonitoring regions, linkages to other projects and a summary of products will be provided. This is a working document and is updated annually in March and September. The other RHP reports submitted during the year are available from the author.

2. Background

The River Health Programme is a sub-programme of the National Aquatic Ecosystem Health Monitoring Programme (NAEHMP), the national custodians are: The Department of Water Affairs and Forestry (DWAF or since 2009 Department of Water Affairs and Environment), Department of Environmental Affairs and Tourism (DEAT-old name) and the Water Research Commission (WRC), that provide strategic guidance and direction to the Programme. The Programme is administered and coordinated by Department of Water Affair's Directorate: Resource Quality Services and have up to 2009, been assisted by the CSIR to fulfill this role. There has been no change made to these roles and responsibilities since the amalgamation of DWAF and DEAT to form the Department of Water and Environment in 2009.

The River Health Programme (RHP) was initiated on a national basis in 1994 in response to the need to monitor, assess and report on the ecological state of river ecosystems based on their biological condition in relation to anthropogenic influences. The RHP is coordinated on a national level and implemented on a provincial level throughout the country. It is accepted that different approaches may be taken in the provincial implementation of the programme depending on the perceived requirements of provincial stakeholders, the types of rivers in the province and the scientific, technical and organizational capacities of the various role players. The basic requirements of the national programme must, however, be fulfilled i.e. standardized selection of sampling sites and biomonitoring techniques should be followed, data formats should be uniform, data stored at a centralized point and the provincial initiatives should be long term. Biological data collection and reporting forms a major part of the programme. The recent publication provides guidance to the Provincial programmes: DWAF (2008) National Aquatic Ecosystem Health Monitoring Programme (NAEHMP): River Health Programme (RHP) Implementation Manual. Version 2. ISBN No. 978-0-621-383343-0, Department of Water Affairs and Forestry, Pretoria, South Africa.

At the provincial level, in the North West Province, the RHP is implemented and maintained by its key stakeholders and their efforts are coordinated by a Provincial Champion, who is currently a representative of NW-DACERD. Other stakeholders include/ed: Finnish Environment Institute (SYKE), DWA (RQS, North West Regional Office, RDM and Kimberley regional office), CSIR, SANBI, NW University, UNIVEN, UFS, Golder & Associates, Blue Science, Cleanstream, Water for Africa, Albany Museum, Rustenburg Municipality, SIBU (Sannieshof ratepayers association) NW Wetland forum, Working for Wetlands, Yellowfish Working Group and the Orange Vaal River Yellowfish Conservation & Management Association (OVRYCMA). The partnership with various organizations conducting studies in the province is mutually beneficial to the provincial RHP and to conservation efforts on a National scale. The Provincial Champion (DACERD) is managing and coordinating the RHP in the province and report back to DWA on a regular basis. The introduction of a quarterly e-communication during 2007 by the National Programme whereby the Provincial Champions provide feedback is a useful communication tool.

The River Health Programme monitors and assesses the biological and habitat integrity of rivers (through evaluation of, for example, aquatic invertebrates, diatoms and riparian vegetation). These assessments enable reports on the ecological state of river systems to be produced in an objective and scientifically sound manner.

Why monitor?

- We have legal obligations (National Water Act and various other conservation and environmental legislation, NEMA, NEMBA) to monitor the ecological condition of natural resources.
- If you have to manage something, you have to know where, how much of it and in what condition it is.
- Assess the general ecological state
- Assess impacts
- Assess compliance with ecological objectives/ regulatory standards
- Trend detection (in other words, directional changes in attributes of drivers and biota)

2.1 Overview of the River Health Programme in the North West Province:

In 2005 the River Health Programme was implemented and an aquatic biomonitoring programme was established. Hermien Roux was responsible for the biomonitoring programme and Tharina Boshoff was the Champion until September 2007 when Hermien Roux was appointed as the RHP Champion.

The North West team is responsible for biomonitoring in parts of four water management areas (WMA), namely; Crocodile (West) and Marico, Upper-, Middle- and Lower Vaal Water Management Areas (see Figure 1). The WMA's are further subdivided into 7 biomonitoring regions. The Crocodile West and Marico is divided into four biomonitoring areas: Marico and Molopo; Western Crocodile (Elands river and tributaries), Middle Crocodile (Hex and Sterkstroom) and the Eastern Crocodile (Crocodile, Pienaars, Tolwane and tributaries). The Lower, Middle and Upper Vaal each form a separate biomonitoring region.

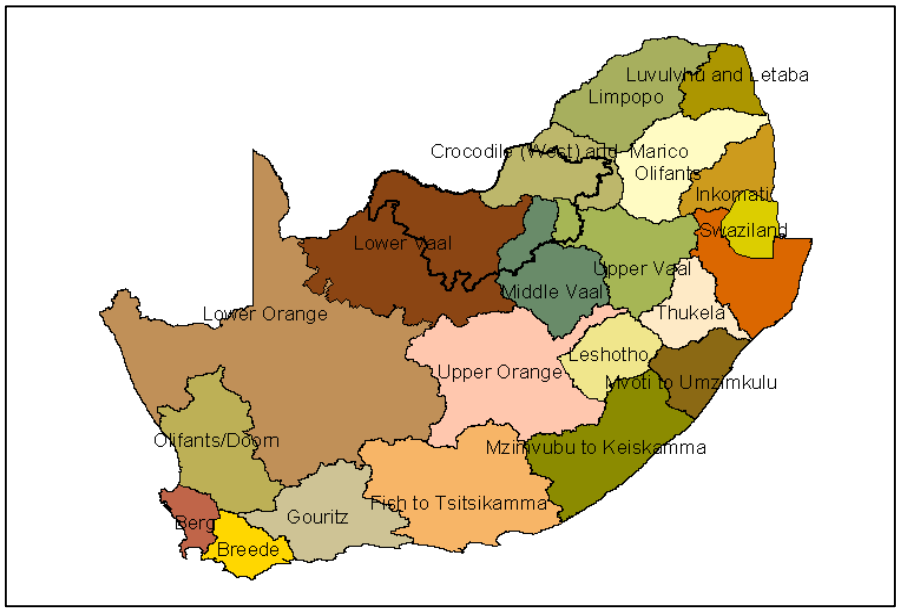

Figure 1: Water Management Areas in the North West Province

2.1.2. Outline of the main focus areas and achievements of the provincial programme

2009-2010 Data analysis phase:

- Focus on data analysis, threats and advise on remediation- ongoing

Threat:

Report to NW-DACERD and DWA: Kareespruit and Klein Maricopoort Dam sewage

Molopo eye water abstraction- report to DWAF

Sannieshof sewage situation- advice provided

Recommendations on the sewage effluent threat to Barberspan Nature Reserve and Ramsar site. Submitted to NWP&T Board. Internal Report North West

- Focus on providing support and data for Ecological reserve determinations in the Crocodile West and Marico-ongoing
- Involvement in SASS5 accreditation days as provincial auditor-ongoing
- Lodge specimens at appropriate institutions-ongoing
- Assist with Updated National programme, sites monitored in Marico WMA with national team (SASS5, fish, RHAM)
- RHAM for selected sites in the Marico River and tributaries to determine habitat and flow (Jan 10)

2010:

- Focus on RHAM for all sites monitored
- Focus biomonitoring in NFEPA priority areas
- Support to flow determination studies- Molopo River-April 10
- Support to Harts River pollution studies (SASS5 and background)-March 10
- Support to Ecological Reserve determinations
  Observed flow in the Klein Marico River and tributaries and a summary of SASS5 results for relevant sites. Submitted to Golder and Associates as part of the Ecological Flow determination project commissioned by DWA. Internal Report North West DACERD (Jan 10)
- Support to National site monitoring
- Support to macro invertebrate habitat preference rating study-May 10
- Revise monitoring cycle
- Involvement in SASS5 accreditation days as provincial auditor
- Focus on the establishment of reference conditions-ongoing
- Lodge specimens at appropriate institutions

2.1.3. Biomonitoring indices used

Biota in riverine ecosystems reflect both the present and past history of the water quality at a particular point in the river, allowing detection of disturbances that might otherwise be missed (Eekhout et al., 1996). Aquatic communities (e.g. fish, riparian vegetation, macro-invertebrates) can integrate and reflect the effects of chemical and physical disturbances that occur in river ecosystems over extended periods of time. These communities can provide a holistic and integrated measure of the integrity or health of the river as a whole (Barber-James, 2001; Roux, 2001). Walmsley et al. (2001) stated that indicators could provide measurements of the success of integrated water resource management.

Methods have been developed for the bioassessment of the integrity of aquatic systems that are based on some or other aspect of a single species, but most are based on the attributes of whole assemblages of organisms. Examples of such indicators include the Fish Assemblage Integrity

Index (Kleynhans, 1999), the Riparian Vegetation Index as well as the South African Scoring System, better known as SASS (Chutter, 1998). Although some methods have been available for many years, biomonitoring has only recently become a routine tool in the management of South Africa's inland waters (Davies & Day, 1998). The SASS biomonitoring system has gained a large body of support as a rapid and fairly accurate system of evaluating ecosystem health and is currently in its fifth revised state, namely SASS 5 (Dickens and Graham, 2002).

The Rapid Habitat Assessment method (RHAM) is a process to collate relevant habitat information in a cost-effective manner for Ecological Water Resource Monitoring (EWRM) monitoring (DWA, 2009). This method involves the delineation of habitat units and taking predefined measurements across different cross-sections. Flow discharge for the specific biomonitoring point is one of the valuable results obtained from this method. The application of the RHAM consists of a range of sequential steps which are described in the flow diagram:

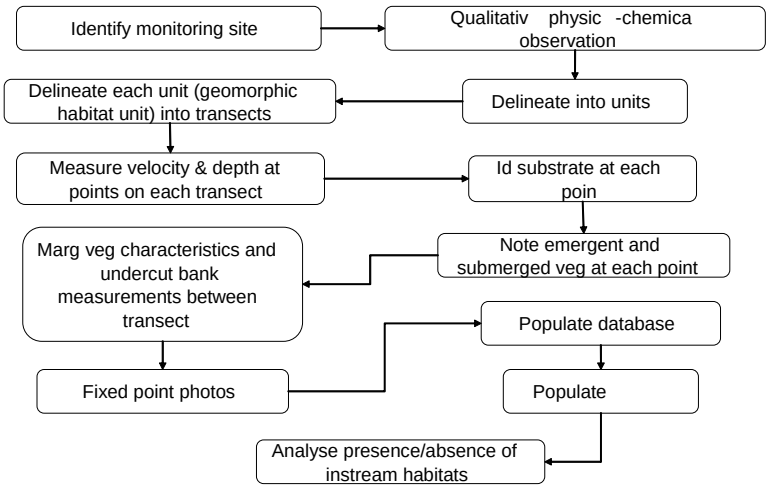

Table 1 provides a summary of the biological indicator indices that are used in the RHP. The person responsible and the activity status are also mentioned. There are other indices that also form part of aquatic monitoring, these are not used due to capacity constraints. The two main indices currently used in the NW RHP are the Index of Habitat Integrity (IHI) and SASS5. The use of the RHAM for habitat flow relationships looks promising.

Table 1: Summary of major indices used in the North West River Health Programme

Tools	Used in NW RHP	Reason
SASS5 (South African Scoring System 5) and **MIRAI** (Macro Invertebrate Rapid Assessment Index)	Yes	Accredited person: H. Roux
VEGRAI (Riparian Vegetation Response Assessment Index)	Yes for 07-08 NO for future	Botanist (started 2007): Focus on other important issues (Red data plants) staff limitations
FRAI (Fish Response Assessment Index)	NO but Sometimes	No Staff
IHI (Index of Habitat Integrity)	Yes, selected rivers but $ for future? Yes 05-08	H. Roux and consultants
IHAS (Invertebrate Habitat Assessment System)	No future, other tools better	H. Roux
GAI (Geomorphologic Driver Assessment Index) and **HAI** (Hydrological Driver Assessment Index)	No- basic info No- basic info	H. Roux
PAI (Physico-chemical Driver Assessment Index)	No, basic water quality data and samples	H. Roux
Diatoms	Yes	Field staff (collect) J. Taylor (ID analyze) H. Roux will try rapid method from 2010
Basic site information and database	Yes	H. Roux
RHAM (Rapid Habitat Assessment Method)	Yes	H. Roux will try rapid method from 2010

Data from the various indices are analysed to provide an indication of the ecological status or class of the rivers/ biomonitoring sites in the province. The ecological status of a river is defined as the "totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna" (adapted from Iversen et al 2000). Ecological components include:
Hydro-morphology (Geomorphology and Hydrology) (Driver); Water quality (Driver); Physical habitat (Driver);
Biological groups (Biological responses of fish, riparian vegetation and aquatic invertebrates).

The river type (geomorphology very important) and the resilience, adaptability and fragility of the biota will influence how responses to changes are analysed. The importance of the different driver metrics will thus change as the river type changes (weighting and ranking of metrics).

The cause and effect relationship becomes very important during reserve determination, monitoring of the reserve in terms of monitoring compliance and systematic conservation planning. The present condition of the drivers needs to be assessed and interpreted in terms of

the biological habitat and then the biological responses compared to a reference condition → Ecostatus approach. All of the indices use the same classification system for the Ecostatus approach. The results from the indices can be represented as A (Blue) to F (Black) categories, based on the degree of impacts or deviation from reference condition:

ECOLOGICAL CATEGORY	EC NAME	ECOSTATUS NAME = EC	COLOUR
A	Natural	Unmodified natural	Blue
B	Good	Largely natural with few modifications	Green
C	Fair	Moderately modified	Yellow
D	Poor	Largely modified	Red
E	Seriously modified	Seriously modified	Purple
F	Critically modified	Critically or extremely modified	Black

3. Progress

The planning and establishment of an aquatic biological monitoring programme commenced in 2005. Historically the North West Province did not have a well established aquatic monitoring programme. One of the first steps in the establishment of a biomonitoring programme is site selection.

3.1 Site selection

The sites were derived from a combination of the existing sites surveyed in the past, mostly by DWAF during 2004 and new sites identified. The site selection process involved active searching (maps and ground searching) and GIS work to evaluate the sites in relation to environmental variables. The sites are selected to represent certain river types and to evaluate anthropogenic impacts. The distribution of sites in the Province is depicted in Figure 2; the absence of sites in the western parts is due to a lack of flowing water. Biomonitoring sites have to meet certain habitat criteria and should preferably be easily accessible. Aerial survey data assisted in the identification of suitable habitat types for the application of the SASS5 methodology in selected rivers. It would be advantageous to have aerial data for all of the rivers in the province.

A River Health site code is assigned to each site. This code is used to link the data to the biomonitoring point and is used for data capture to the National Rivers Database and for water quality analysis by DWAF. There are currently 179 biomonitoring sites in the North West Province. It is important to note that there are different types of sites and not all of the sites are part of the continuous monitoring programme. The National sites are in a process of verification and some have been monitored during August 2009. Reference sites are in the process of being identified but a lack of historical data in most of the Water Management Areas has prevented reference site establishment in some areas.

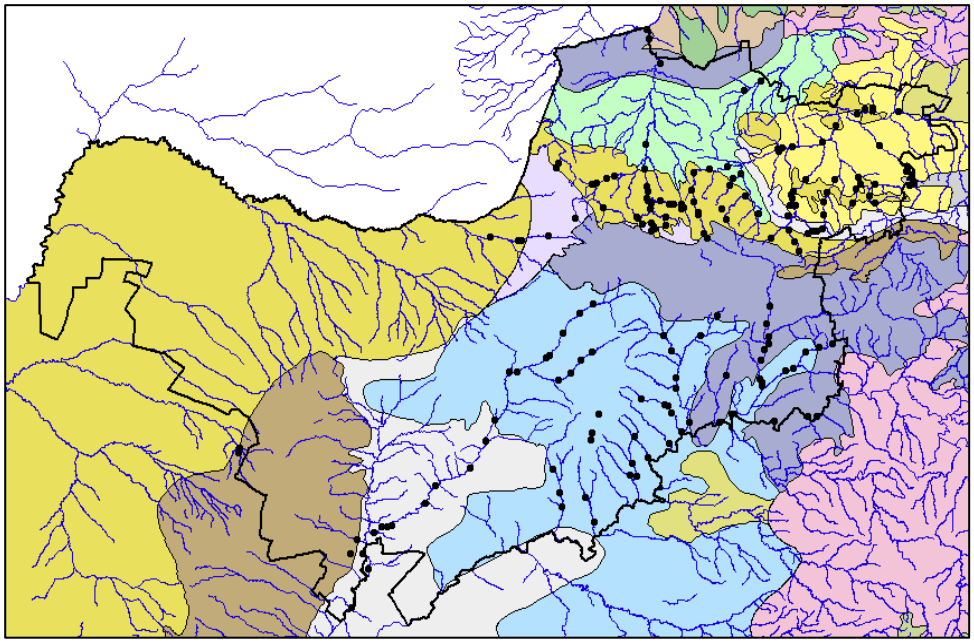

Figure 2: Distribution of biomonitoring sites and Ecoregions in the Province

3.2 Monitoring

In total 179 RHP sites are monitored across the province. These sites are registered on the National Rivers Database and on the DWA Water Management System database. There are currently 290 of SASS5 (South African Scoring System version 5) and Site Information data captured on the National Rivers Database for monitoring results since 2005. Each site is monitored at least twice a year, every second year, if environmental parameters are favourable for the application of SASS5. Diatoms are collected and analyzed by the North West University (Jonathan Taylor). Basic water quality parameters are measured and water quality samples collected and analyzed by DWA RQS. The botanist was training to do the Riparian Vegetation analyses and has completed the preliminary evaluations at some of the biomonitoring sites (40 sites). She is unable to continue with VEGRAI due to other project commitments.

The SASS5 procedure requires that the practitioner is accredited every three years to ensure data credibility and repeatability of the methodology. The correct identification of the aquatic invertebrates is vital for the application of the biomonitoring technique. Annual biomonitoring plans are distributed to the RHP team and relevant stakeholders to encourage shared resources. Feedback is also provided to stakeholders after each biomonitoring fieldwork session. Field data forms are completed at each site, scores calculated and data captured to MS Excel spreadsheets and to the National Rivers Database. Data analysis is done as per requirements for reporting purposes. For purposes of this report, the main index used for the different sites is SASS5 and the Ecological category is derived through the MIRAI and biological bands where limited data was available. Water quality analysis received from DWA RQS is not reported on but is available from the author.

The monitoring results from the Ecological Reserve determination process (mostly 2009 and 2010) will be distributed as soon as all of the data analyses and report writing are finalized. Preliminary results are available from the author. The final reports are due in April 2010.The

results from the different biomonitoring will be discussed separately and major issues identified will be discussed.

3.2.1 Upper Vaal Water Management Area

The Mooi River originates in a dolomitic area upstream from Klerkskraal Dam in the Upper Vaal Water Management Area, see Figure 3. The groundwater in the area is widely utilised for irrigated agriculture. The SASS5 data are from two surveys in 2006 (May and October), biomonitoring was planned for 2008 but kilometre restrictions by NW-DACE prevented the surveys. The 2009 surveys were cancelled due to the wrist operation of the aquatic scientist.

The upper reaches of the river above and below the Klerkskraal Dam comprise wetlands. The Klerkskraal Dam distributes water to farmers downstream of the dam for irrigation purposes. This substantially reduces both the variability and volume of water that occurs in the system downstream of the dam. No releases are being made from the Klerkskraal Dam for the Ecological Reserve. The biological data reflects this and the area upstream from Potchefstroom is in an overall C Ecological category and the IHI category is overall a D, mostly due to old unrehabilitated diamond mines and crop farming, see Table 3. The sites are all situated in the Highveld Ecoregion.

The Wonderfonteinspruit and Loopspruit are two tributaries of the Mooi River that originate east of the Mooi River. Mine water contamination (including heavy metals and radioactive substances) from the Wonderfonteinspruit is a serious concern, no suitable SASS5 habitat exists but water samples were collected in the Wonderfonteinspruit at site C2WOND-WONDE. There are rehabilitation plans for the Wonderfonteinspruit and the Water Research Commission conducted a risk assessment of metals and metalloids in the Wonderfonteinspruit Catchment and published the Report, entitled "*An Assessment Of Sources, Pathways, Mechanisms And Risks Of Current And Potential Future Pollution Of Water And Sediments In Gold-Mining Areas Of The Wonderfonteinspruit Catchment*" in 2006. The mean values for the Wonderfonteinspruit samples were found to significantly exceed not only natural background concentrations, but also levels of regulatory concern for cobalt, zinc, arsenic, cadmium and uranium, with uranium and cadmium exhibiting the highest risk coefficients. This potential for downstream contamination was identified as a specific concern for the water supply of the City of Potchefstroom. Potchefstroom is located downstream of the Wonderfonteinspruit, from which more than 400 000 people derive their drinking water via the Boskop Dam. The remediation action plan is a co-operative initiative by the Department of Water Affairs, the National Nuclear Regulator, the Federation for a Sustainable Environment, the Mining Interest Group and the Chamber of Mines.

Peat mining takes place in the Gerhard Minnebron wetland; diamond mining and prospecting has taken place in areas below Klerkskraal Dam and has impacted on the riverbed and riparian zone. The Loopspruit SASS5 data indicate serious sewage pollution and flow problems (site C2LOOP-KOKOS), the Ecological category is predominantly F. The IHI category is mostly D, return flows from flood irrigation and cattle carcasses dumped in the river were observed. The raising of the Klipdrift Dam (site C2LOOP-KLIPD) in the middle reaches enhances the deterioration by reducing flow events.

Potchefstroom Dam and town are situated in the lower reaches of the Mooi River, adding additional habitat modifications to the river. The SASS5 data indicate a C/D category (sites

C2MOOI-MEULS and C2MOOI-MOOIR) and a reduction in sensitive taxa, the IHI category is D.

The Vaal River is a heavily utilised system and is impacted by various activities in Gauteng, North West and Free State provinces. The primary impact on the river system is the deterioration of water quality as a result of salinisation and eutrophication of the system, and flow modification. These impacts negatively influence the yellowfish populations in the river. The SASS5 biomonitoring data indicate a low C Ecological category; the water quality deteriorated below Parys during October 2006 and recovered through the Vredefort Dome area, the overall IHI results in a C category. The seasonal flow of the river is heavily impacted by increased return flows and unnatural releases from the Barrage area for downstream water users. Aquatic weeds further deteriorate the available habitat for aquatic biota and water hyacinth is of particular concern.

This WMA is in the process of an Ecological Reserve determination and results should be available by the end of 2010. The Mooi River was identified as an important fish sanctuary area by the SANBI NFPA project (2009/2010), the upstream areas of this river must be protected and the ecological reserve implemented. There are Working for Wetlands rehabilitation actions that commenced in the upper catchment during 2009.

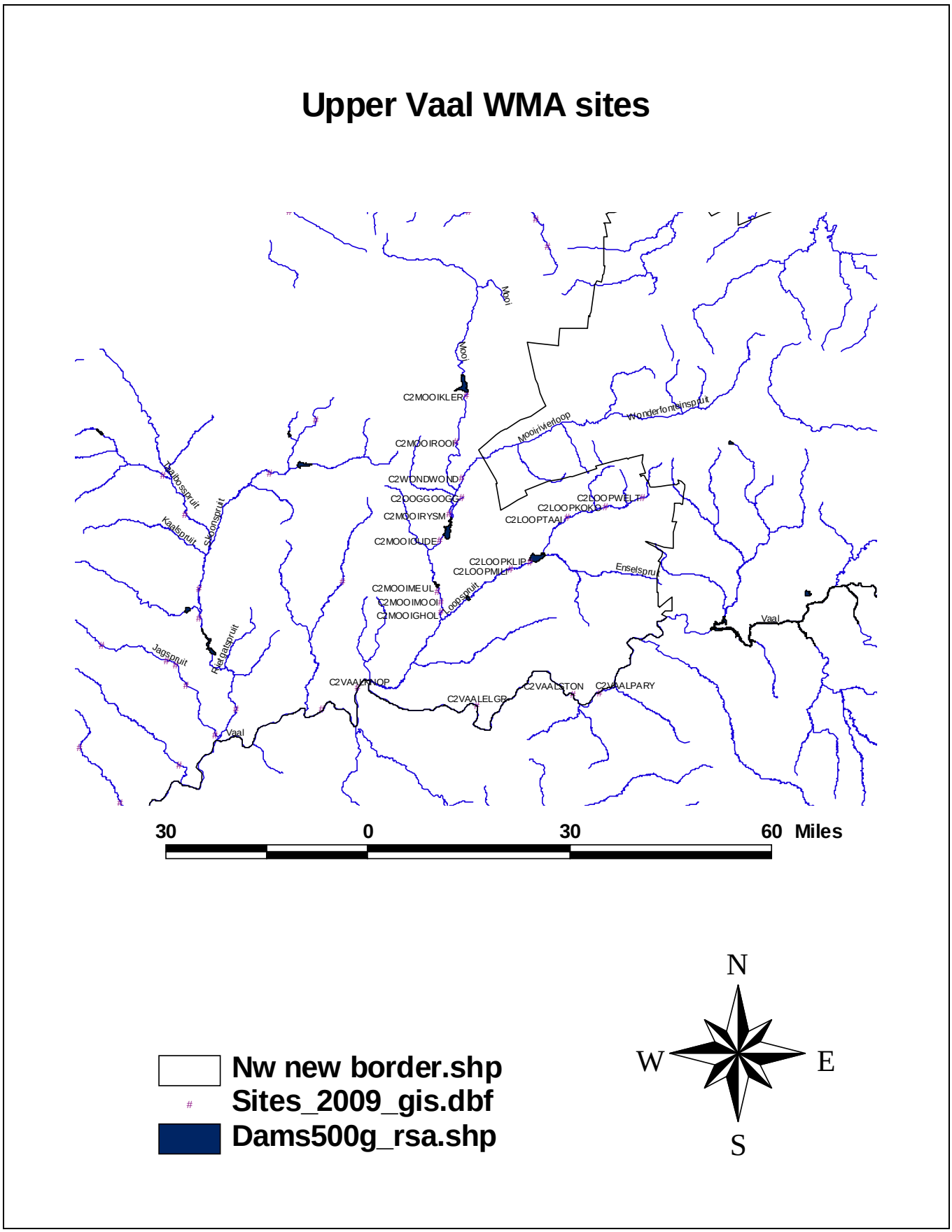

Figure 3: SASS5 sites in the Upper Vaal WMA

Table 3: Summary of Index of Habitat Integrity and SASS5 Ecological category results for the Upper Vaal

RHP Site Code	River Name	Tributary	IHI Instream 2007	IHI Riparian 2007	Survey dates	SASS	No Taxa	ASPT	Survey dates	SASS	No Taxa	ASPT
C2MOOI-KLERK	Mooi		D	D	15/05/2006	123	27	4.56	03/10/2006	92	22	4.18
C2MOOI-ROOID	Mooi		D	D	15/05/2006	79	19	4.16	Visit on 03/10/2006, river dry	x	x	x
C2WOND-WONDE	Mooi	Wonderfontein spruit	C	D	15/05/2006	x	x	x	03/10/2006	x	x	x
C2OOGG-OOGGE	Mooi	Oog van Gerhard Minnebron	C	C	16/05/2006	141	25	5.64	03/10/2006	134	25	5.36
C2MOOI-RYSMI	Mooi		C	D	16/05/2006	129	25	5.16	Visit on 03/10/2006, very high water levels	x	x	x
C2MOOI-OUDED	Mooi		E	F	16/05/2006	115	22	5.23	Visit on 04/10/2006, access problems	x	x	x
C2MOOI-MEULS	Mooi		D	D	16/05/2006	56	14	4	04/10/2006	144	30	4.8
C2MOOI-MOOIR	Mooi		D	D	19/05/2006	91	21	4.33	04/10/2006	109	22	4.95
C2MOOI-GHOLF	Mooi		D	D	Visit on 19/05/2006, water levels very high	x	x	x	Visit on 04/10/2006, very high water levels	x	x	x
C2LOOP-WELTE	Mooi	Loopspruit			17/05/2006	105	22	4.77	02/10/2006	121	26	4.65
C2LOOP-KOKOS	Mooi	Loopspruit	D	C	17/05/2006	27	8	3.38	02/10/2006	29	8	3.63
C2LOOP-TAAIB	Mooi	Loopspruit	C	C	Visit on 19/05/2006, no veg	x	x	x	Visit on 02/10/2006. no veg	x	x	x
C2LOOP-KLIPD	Mooi	Loopspruit	F	F	17/05/2006	46	13	3.54	Visit on 02/10/2006, increasing dam wall no water	x	x	x
C2LOOP-MILIT	Mooi	Loopspruit	D	D	17/05/2006	x	x	x	Visit on 02/10/2006, increasing dam wall no water	x	x	x
C2VAAL-PARYS	Vaal		C	C	18/05/2006	130	24	5.42	05/10/2006	110	25	4.4
C2VAAL-STONE	Vaal		C	C	18/05/2006	136	25	5.44	Visit on 05/10/2006	x	x	x
C2VAAL-ELGRO	Vaal		C	C		x	x	x	05/10/2006	126	27	4.67
C2VAAL-KNOPF	Vaal		D	D	Visit on 18/05/2006, high water levels	x	x	x	Visit on 05/10/2006	x	x	x

3.2.2 Middle Vaal Water Management Area

This water management area is characterized by various seasonal rivers. The only river that could be sampled during February and November 2007 was the Skoonspruit and one site on the Vaal River, see Figure 4. This water management area is thus fairly data deficient and difficult to discuss. The dolomitic eyes and associated peat wetlands should be monitored from a wetland conservation perspective. The Skoonspruit River originates north of the town of Ventersdorp as a dolomitic eye. Peat wetlands are associated with these upper reaches, see Figure 4. It contributes to the flow in the upper parts of the catchment and flows south to the confluence with the Vaal River. The IHI and SASS5 data indicate a high C Ecological category in the upper reaches of the Skoonspruit (site C2SKOO-VENTE), see Table 4. The sites are all situated in the Highveld Ecoregion.

The topography is gentle sloping. A wetland system occurs in the middle reaches of the river, in the vicinity of the confluence with the Taaiboschspruit and upstream from the Johan Neser Dam. Water abstraction is a major impact upstream from the Johan Neser Dam. The SASS5 data reflect the water abstraction and thus flow limitations as the Ecological categories are high E/F (major sedimentation buildup due to lack of flow) and C during different biomonitoring surveys. The IHI results indicate a C/D category, also mainly attributed to flow alterations. The Johan Neser Dam receives return flow from the mining areas.

The biomonitoring point at Uraniumville (C2SKOO-URANI) is situated below sewage treatment facilities. The SASS5 data indicate an E/F category, mainly attributed to water quality impacts from nutrient enrichment. The corresponding IHI results are a D category, with river and riparian modifications resulting from development as the main contributors.

This WMA is in the process of an Ecological Reserve determination and results should be available by the end of 2010.

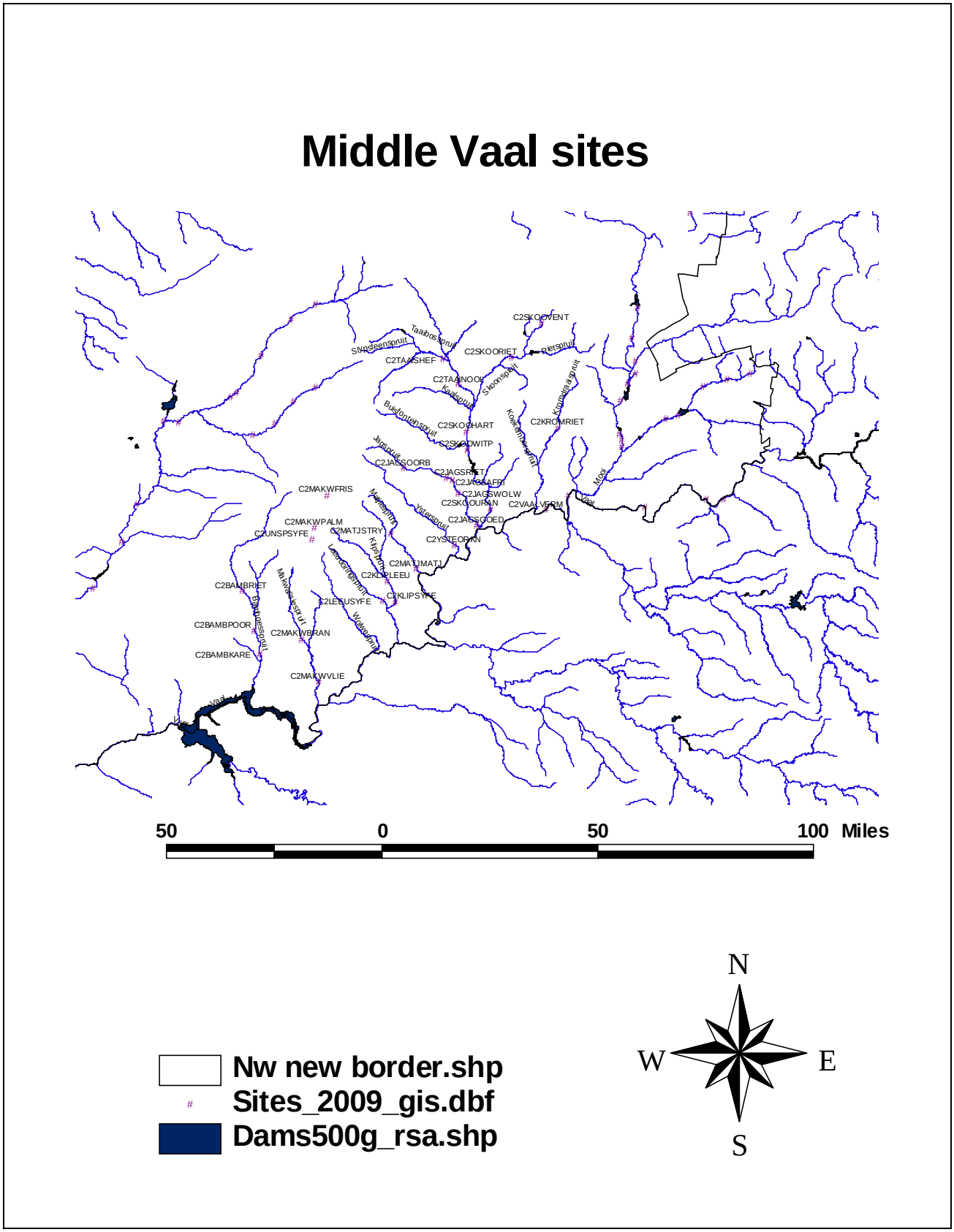

Figure 4: SASS5 sites in the Middle Vaal WMA

Table 4: Summary of Index of Habitat Integrity and SASS5 Ecological category results for the Middle Vaal

RHP Site Code	River Name	Tributary of	IHI Instream 2007	IHI Riparian 2007	Survey dates	SASS	No Taxa	ASPT	Survey dates	SASS	No Taxa	ASPT
C2VAAL-VERMA	Vaal				19/02/2007	100	20	5	28/11/2007	111	23	4.83
C2SKOO-VENTE	Skoonspruit	Vaal	C	C	21/02/2007 No flow	x	x	x	26/11/2007	164	33	4.97
C2SKOO-RIETS	Skoonspruit	Vaal	C	D	20/02/2007 Pools	x	x	x	26/11/2007	101	23	4.39
C2SKOO-HARTB	Skoonspruit	Vaal	C	C	20/02/2007 No Flow	x	x	x	27/11/2007	118	25	4.72
C2SKOO-WITPO	Skoonspruit	Vaal	D	D	20/02/2007 No Flow	x	x	x	No SIC on 27/11/2007	x	x	x
C2SKOO-URANI	Skoonspruit	Vaal	D	D	19/02/2007	35	11	3.18	27/11/2007	37	10	3.7

3.2.3 Lower Vaal Water Management Area

The sites in this water management area are distributed across three different Ecoregions: Highveld, Ghaap Plateau and Southern Kalahari. The Harts River originates south of Lichtenburg, the upper parts of this river are highly seasonal as indicated by Table 5. The wetlands and pans in this arid WMA must be mapped and monitored from a conservation perspective.

There are major impacts from farming and diamond mining in the river channels. The Harts River forms part of a major irrigation scheme and water transfers are made from the Vaal River. It is unfortunate that an aerial survey and IHI was not done for this water management area. There are several seasonal tributaries and rivers in this Water Management Area, see Figure 5.

The Harts River is under severe pressure from untreated sewage discharges and overflowing sewage treatment facilities in the Lichtenburg, Biesiesvlei, Sannieshof and Schweizer Reyneke areas. This nutrient enrichment is a direct threat to the ecology of Barberspan Reserve that is also a declared Ramsar site. The sites sampled upstream from Barberspan as part of a risk assessment study indicate dissolved oxygen problems and the SASS data results in a low C/D Ecological category in March 2010. Nutrient plumes from sewage pollution were observed moving downstream, through water quality analysis, and the oxygen concentration variations from very low to super saturated indicates the high algal activity.

The site downstream from the Taung Dam (C3HART-TOLGA) is in a B/C Ecological category and no ecological flow releases are made. The C Ecological category was during very low flow conditions in April 2007 and the improved category B was after rain in December 2007. The situation in and below Taung deteriorates to a C/D Ecological category (sites C3HART-HOSPI and C3HART-TASUN) sewage enrichment and urban runoff are contributing factors. The lower class was in April 2007 and the slight improvement was in December 2007 after rain. The sites

upstream from the major irrigation area shows an improvement from the sites in Taung, these sites are in a high C Ecological category (C3HART-MOTSW, C3HART-PAMPI).

This WMA is in the process of an Ecological Reserve determination and results should be available by the end of 2010. Wetland areas parallel to the Harts River downstream from Taung are important features of the river system.

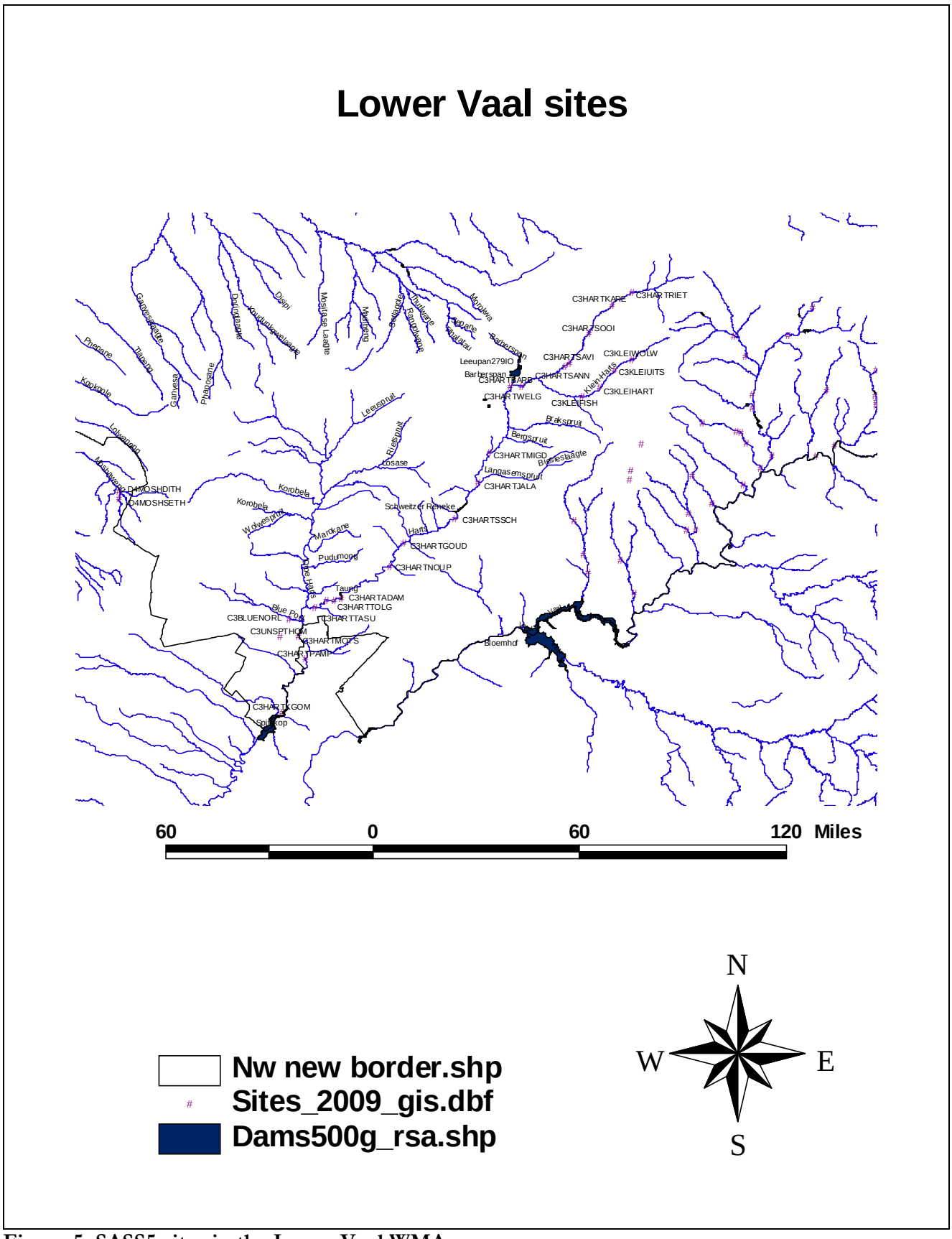

Figure 5: SASS5 sites in the Lower Vaal WMA

Table 5: Summary of Index of Habitat Integrity and SASS5 Ecological category results for the Lower Vaal

RHP Site Code	River Name	Tributary	IHI Instream 2007	IHI Riparian 2007	Survey dates	SASS	No Taxa	ASPT	Survey dates	SASS	No Taxa	ASPT
C3HART-WELGE	Harts	Vaal			Dry on 18/04/2007	x	x	x	Dry on 07/12/2007	x	x	x
					16/03/2010	61	14	4.4				
C3HART-LEEUS	Harts	Vaal			16/03/2010	82	18	4.6				
C3HART-TOLGA	Harts	Vaal			17/04/2007	99	20	4.95	06/12/2007	138	31	4.45
C3HART-HOSPI	Harts	Vaal			17/04/2007	43	9	4.78	06/12/2007	98	22	4.45
C3HART-TASUN	Harts	Vaal			17/04/2007	63	16	3.94	06/12/2007	79	20	3.95
C3HART-MOTSW	Harts	Vaal			Very low flow on 16/04/2007	x	x	x	05/12/2007	119	28	4.25
C3HART-PAMPI	Harts	Vaal			16/04/2007	121	25	4.84	05/12/2007	109	24	4.54
D4MOSH-SETHA	Garam okwena	Moshaweng			16/04/2007	102	23	4.43	Not in Province	x	x	x

Crocodile West and Marico Water Management Area (biomonitoring regions separate)

3.2.4 Molopo

The Molopo River originates east of Mafikeng from a dolomitic eye and flows through the Mafikeng town complex towards the Botswana border, see Figure 6. Water is abstracted directly from the Molopo dolomitic eye for domestic use in Mafikeng. Monitoring and maintaining this dolomitic eye is important from an ecological and social aspect. The extensive peat wetlands and underground water connections do not create ideal SASS5 habitat. The E/F Ecological category at D4MOLO-BUHRM is only a reflection of the habitat limitations and not the water quality, see Table 6. Rehabilitated wetland areas in the Mafikeng Nature Reserve, where alien vegetation has been removed, and bank and bed stabilisation works have been undertaken play an important ecological function in the river system.

Major water abstractions take place in and downstream of Mafikeng from various dams. No release mechanisms or operating rules exist to release water from the major dams in the system. The sewage treatment facility upstream from the site D4MOLO-MAFIK is responsible for the very low E/F Ecological category. Nutrient enrichment of the system is a serious threat. The importance of wetlands for water quality purification is noted by the improvement at site D4MOLO-LOMAN (D/ EF).

The Ecological category below Modimola dam (D4MOLO-MODIM) improves to a C. Erosion of the catchment and lack of ecological flow releases impact on the seasonal river reach downstream. The wetland rehabilitation that commenced in 2009 in the vicinity of Modimola dam will assist in the reduction of erosion in this area. The Molopo River will receive attention from a project initiated as part of an Orange River study during April 2010.

Marico River and tributaries

The Marico River system comprises of the Groot Marico and Klein Marico rivers. The Klein Marico River includes the Molemane and Kareespruit tributaries, see Figure 7.

The Molemane comprises extensive wetlands (including peat) and underground systems. The site (A3MOLE-OTTOS) at Ottoshoop is situated downstream from a predator farm. The site lacks some of the suitable SASS5 habitat and was in a high C Ecological category during March 2007. Possible nutrient enrichment from the predator farm deteriorated the class to an E/F in August 2007. The Molemane River originates from a dolomitic eye. Water is diverted from the dolomitic eye for domestic use. The upper parts of the river are impacted by a number of weirs and structures that are used for diversion of water and recreational purposes. This extensive wetland area should receive formal conservation protection and the water use of the associated dolomitic compartment should be critically evaluated.

The Kareespruit below the Zeerust golf course (A3KARE-GHOLF) and upstream from the sewage treatment facility (A3KARE-RAILW) is in a D/ EF Ecological category. The situation deteriorates below the sewage treatment facility to an E/F class (A3KARE-ABJAT). Raw sewage discharges and other nutrient inputs have severely deteriorated the water quality in the Klein Maricopoort Dam. The dam acts as a nutrient trap and the site downstream from the dam (A3KMAR-KALKD) improves to a C/D category. The upper reaches of the Klein Marico River are seasonal and the reaches below the Klein Maricopoort Dam receive no ecological flow releases. A detailed report of the sewage discharge situation is available from the author. The limited flow contributions made by the Klein Marico River are discussed in a report available from the author. Water abstraction from the dolomitic compartments that feeds the tributaries could contribute to the limited surface flow.

The Groot Marico River System originates on the plateau, south of the town Groot Marico. The upper reaches are dominated by a number of dolomitic eyes and tributaries that cut through the mountains south of Groot Marico. This creates deeply incised gorges that are fairly inaccessible for agricultural development and are therefore relatively un-impacted. Water abstraction from the underground aquifers for irrigation in the Grootpan and Lichtenburg areas are a threat to the flow maintenance from the dolomitic eyes. A detailed report regarding rehabilitation considerations and water abstractions is available from the author.

The Groot Marico River includes the upper and lower Marico River and the following tributaries in the upper reaches, see Table 6:

- Rietspruit (A3RIET-RENOS is in a B Ecological category, the lack of habitat prevents this site from reaching an A Ecological category, situated 10 m downstream from a dolomitic eye). This river together with Bokkraal se Loop contributes approximately 0.29 m^3/s flow as measured by DWA on 29/09/2009
- Kaaloog se Loop (A3KAAL-GROOT and A3KAAL-RIETS indicate an A/B Ecological category); during the 2009 Ecological Reserve determination process, the overall present ecological status (this includes fish, vegetation, hydrology, invertebrates and water quality) for this river was determined as a B and the flow determined during the reserve study was 0.4 m^3/s (July 2008) and 0.47 m^3/s (April 2009). The DWA flow determination was 0.22 m^3/s (on 29/09/2009) and this reading is questioned as the RHAM determinations (on 29/01/2010) done during SASS biomonitoring resulted in 0.462 m^3/s.
- Bokkraal (A3BOKK-BOKKR and A3BOKK-WATER indicate an A/B Ecological category). Bokkraal se Loop together with Rietspruit contributes approximately 0.29 m^3/s flow as measured by DWA on 29/09/2009. The RHAM flow determinations for A3BOKK-BOKKR done (on 25/01/2010) indicate a flow of 0.191 m^3/s and the RHAM for A3BOKK-WATE 0.256 m^3/s. It is thus highly likely that the DWA readings are an under estimation of the flow contributions.

- Ribbokfontein se Loop (A3RIBB-SYFER indicate an E/F Ecological category, this river is seasonal and reflected by the class.)
- Draaifontein (B Ecological category in the upper reaches and D/E downstream, this is also mainly flow related)
- Van Straatensvlei (B/C Ecological category, some negative impacts from alien vegetation in the wetland areas and dairy farming)
- Polkadraaispruit (The Ecological categories varies between sites but the overall category is a B/C), major impacts include farming and alien plants.

All of the tributaries have been identified as biodiversity special features and have also been included in the targeted river reaches for ensuring that 20% of all types of aquatic ecosystems are conserved. These areas have also been identified as conservation priorities and fish sanctuaries in the SANBI NFPA project during 2009.

The upper reaches of the Groot Marico River, up and downstream from the town, are in an A category at A3GMAR-KOEDO and at A3GMAR-WONDE. During the 2009 Ecological Reserve determination process, the overall present ecological status (this includes fish, vegetation, hydrology, invertebrates and water quality) for this river reach was determined as a B. The flow at A3GMAR-KOEDO was measured during the reserve determination fieldwork as 0.6 m^3/s (July 2008) and 1.02 m^3/s (April 2009). The flow measured using the RHAM method (on 28/01/2010) resulted as 0.781 m^3/s. The site further downstream at A3GMAR-VERGE resulted in a RHAM measured flow of 1.566 m^3/s.

Water abstraction for irrigation reduces the Ecological category to B/C further downstream at A3GMAR-DOORN. The site below Groot Marico Bosveld Dam reflects the importance of ecological flow maintenance. This site (A3GMAR-RIEKE) was in an overall C Ecological category for 2005 and 2007 but good rain in January, February and March 2008 increased the flow sufficiently that a B class was reached during April 2008. During the 2009 Ecological Reserve determination process, the overall present ecological status (this includes fish, vegetation, hydrology, invertebrates and water quality) for this river reach was determined as a C/D. The flow determinations was done at 0.045 m^3/s (July 2008) and 1.0 m^3/s (April 2009) during the reserve process. The RHAM flow discharge measurements indicated 0.055 m^3/s on 27/01/2010. The implementation of the ecological reserve and the construction of a fish ladder at the dam will enhance the ecological class for this reach.

The river downstream from the Groot Marico Bosveld Dam only flows seasonally due to water abstraction (site A3GMAR-UITKY in a D class due to lack of flow). Molatedi Dam and the Tswasa weir are the other water abstraction points. Water is exported to Botswana at the Tswasa weir. The sites A3GMAR-TSWAS and A3GMAR-DERDE are both in B classes during good flow conditions and deteriorate to C Ecological categories when flow is reduced. During the 2009 Ecological Reserve determination process, the overall present ecological status (this includes fish, vegetation, hydrology, invertebrates and water quality) for this river reach was determined as a C.

The Ngotwane River is also a tributary of the Groot Marico River and is fed by a dolomitic eye close to the town of Dinokana. The dolomitic eye supplies drinking water to the town, the Ecological category downstream from the eye (A1NGOT-DINOK) varies according to flow A/B. Downstream at A1NGOT-PUANE, the reduced flow, urban and rural impacts deteriorates the river to a C class.

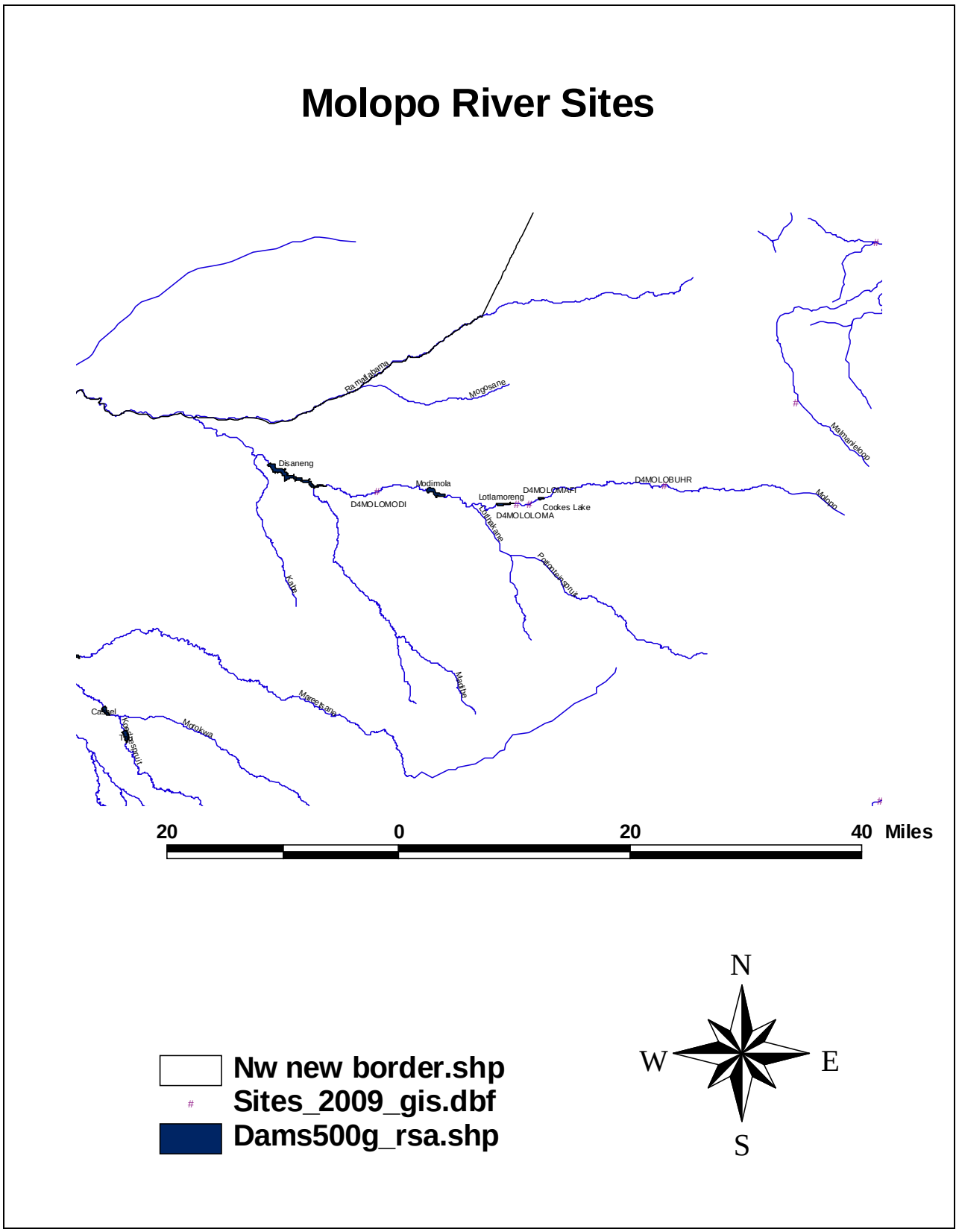

Figure 6: Molopo River Sites

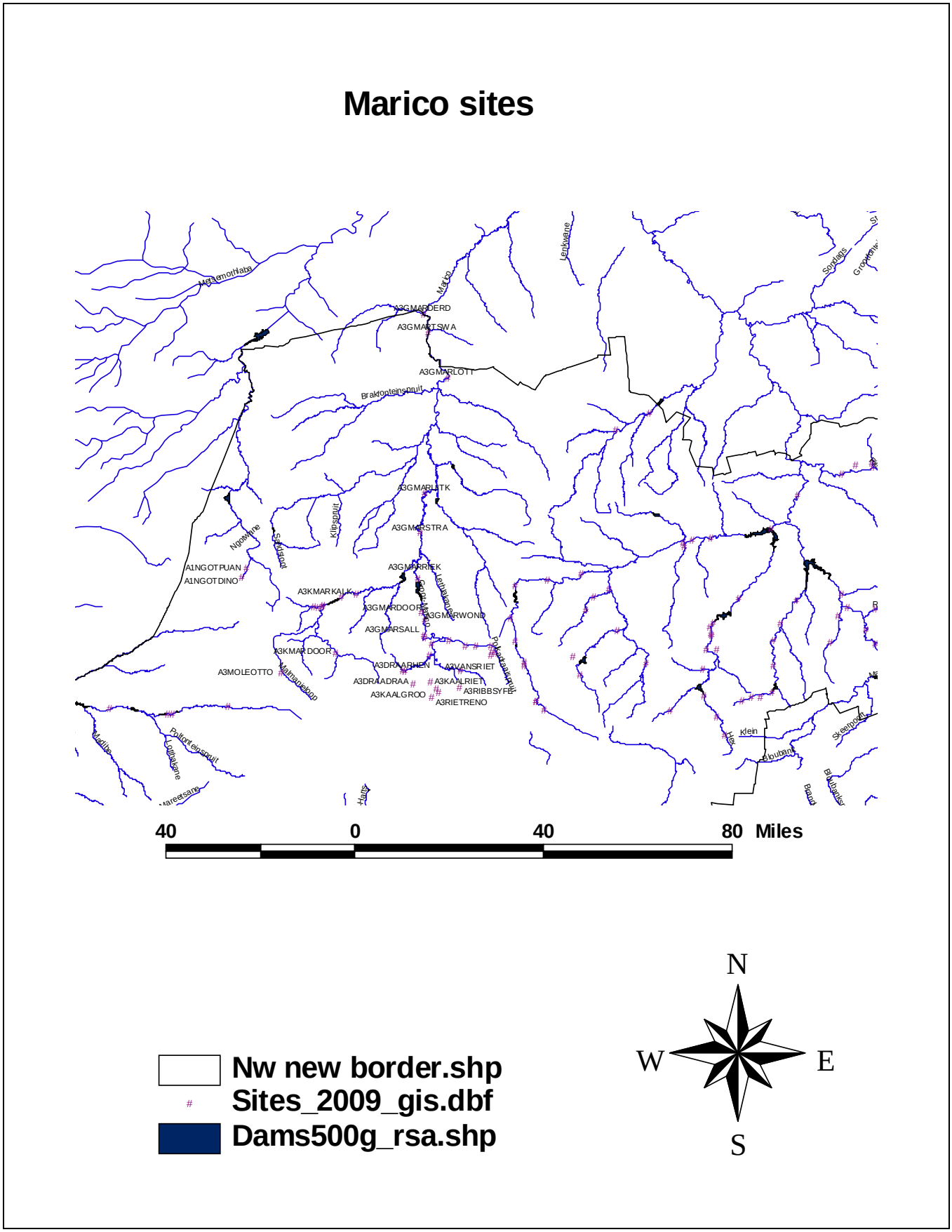

Figure 7: Marico River Sites

Table 6: Summary of Index of Habitat Integrity and SASS5 Ecological category results for Molopo, Marico River and tributaries (2005, 2007, 2008, 2010)

RHP Site Code	River Name	Tributary	IHI Instream 2007	IHI Riparian 2007	Survey dates	SASS	No Taxa	ASPT	Survey dates	SASS	No Taxa	ASPT
D4MOLO-BUHRM	Molopo		C	C	18/04/2005	83	21	3.95				
D4MOLO-MAFIK	Molopo		D	D	18/04/2005	36	11	3.27	20/06/2005	10	5	2
					14/09/2005	18	7	2.57	21/11/2005	16	7	2.29
					16/03/2007	18	7	2.57				
D4MOLO-LOMAN	Molopo		F	F	18/04/2005	63	16	3.94	20/06/2005	34	10	3.4
					14/09/2005	26	9	2.89	21/11/2005	39	11	3.55
									30/08/2007	20	6	3.33
D4MOLO-MODIM	Molopo		C	D	18/04/2005	66	16	4.13	20/06/2005	64	15	4.27
					14/09/2005	60	14	4.29				
					16/03/2007	26	8	3.25				
A3RIET-RENOS	Rietspruit	Groot Marico	C	C	21/04/2005	145	26	5.58	25/07/2005	96	19	5.05
					20/09/2005	172	27	6.37	25/11/2005	200	34	5.88
					08/03/2007	189	33	5.73	27/08/2007	191	30	6.37
					10/04/2008	162	29	5.59				
A3KAAL-GROOT	Kaaloogse loop	Groot Marico	B	B	21/04/2005	129	24	5.38	21/07/2005	88	15	5.87
					20/09/2005	201	28	7.18	25/11/2005	262	41	6.39
					08/03/2007	249	40	6.23	21/08/2007	246	39	6.31
					10/04/2008	294	47	6.26				
A3KAAL-RIETS	Kaaloogse loop	Groot Marico	A	A	21/04/2005	186	31	5.64	21/07/2005	147	24	6.13
					19/09/2005	279	41	6.8	24/11/2005	245	38	6.45
					08/03/2007	277	43	6.44	22/08/2007	204	32	6.38
					08/04/2008	267	42	6.36	2010/01/29	273	40	6.8
A3BOKK-BOKKR	Bokkraalse loop	Groot Marico			Poplar felling on 08/03/2007	x	x	x	21/08/2007	208	34	6.12
					10/04/2008	213	35	6.09	2010/01/25	211	35	6
A3BOKK-WATER	Bokkraalse loop	Groot Marico			08/03/2007	255	41	6.22	21/08/2007	264	42	6.29
					10/04/2008	264	43	6.14	2010/01/25	274	43	6.4
A3RIBB-SYFER	Ribbokfontein se loop	Groot Marico	B	B	21/04/2005	83	19	4.37	22/07/2005	66	13	5.08
A3DRAA-DRAAI	Draaifontein	Groot Marico	B	C					22/07/2005	177	30	5.9
					22/09/2005	177	33	5.36				
									No Veg 23/08/2007	91	16	5.69
A3DRAA-RHENO	Draaifontein	Groot Marico	B	C					27/07/2005	169	28	6.04
					21/09/2005	201	35	5.74	29/11/2005	236	40	5.9
									23/08/2007	161	30	5.37

RHP Site Code	River Name	Tributary	IHI Instream 2007	IHI Riparian 2007	Survey dates	SASS	No Taxa	ASPT	Survey dates	SASS	No Taxa	ASPT
A3VANS-RIETF	Vanstraatensvlei	Groot Marico	B	C	22/04/2005	134	27	4.96	22/07/2005	100	23	4.35
									28/11/2005	156	33	4.73
					05/03/2007	173	32	5.41	24/08/2007	179	31	5.77
A3DRAA-BRONK	Draaifontein	Groot Marico	B	C	21/04/2005	80	18	4.44	21/07/2005	74	16	4.63
					07/03/2007	106	24	4.42	22/08/2007	158	32	4.94
RHP Site Code	**River Name**	**Tributary**	**IHI Instream 2007**	**IHI Riparian 2007**	**Survey dates**	**SASS**	**No Taxa**	**ASPT**	**Survey dates**	**SASS**	**No Taxa**	**ASPT**
A3GMAR-KOEDO	Groot Marico		B	C	26/04/2005	260	41	6.34	21/07/2005	173	27	6.41
					19/09/2005	285	41	6.95	24/11/2005	224	35	6.4
					06/03/2007	299	46	6.5	22/08/2007	261	39	6.69
					08/04/2008	242	37	6.54	2010/01/28	269	41	6.6
A3POLK-SWART	Polkadraaispruit	Groot Marico	B	C	25/04/2005	109	20	5.45	25/07/2005	45	12	3.75
					21/09/2005	103	20	5.15	28/11/2005	79	18	4.39
					05/03/2007	120	20	6	No veg 24/08/2007	51	13	3.92
A3UNSP-RIETV	Tributary of Polkadraaispruit	Groot Marico			25/04/2005	144	26	5.54	22/07/2005	90	15	6
					21/09/2005	157	26	6.04	28/11/2005	174	33	5.27
A3POLK-VLEID	Polkadraaispruit	Groot Marico	B	C	25/04/2005	62	14	4.43	26/07/2005	72	14	5.14
					21/09/2005	88	19	4.63				
					05/03/2007	112	21	5.33	24/08/2007	98	20	4.9
A3UNSP-BOKKR	Tributary of Polkadraaispruit	Groot Marico			25/04/2005	115	22	5.23				
A3POLK-DOORD	Polkadraaispruit	Groot Marico	B	B	25/04/2005	79	18	4.39	25/07/2005	44	11	4
					21/09/2005	92	22	4.18	29/11/2005	47	14	3.36
A3UITV-STERK	Uitvlugspruit	Polkadraaispruit			25/04/2005	134	25	5.36	26/07/2005	118	22	5.36
					21/09/2005	123	22	5.59	29/11/2005	198	32	6.19
					06/03/2007	143	25	5.72	27/08/2007	134	24	5.58
A3POLK-TWYFE	Polkadraaispruit	Groot Marico	C	D	25/04/2005	131	22	5.92	26/07/2005	120	23	5.22
					21/09/2005	114	21	5.43	29/11/2005	203	34	5.97
					06/03/2007	151	25	6.04	27/08/2007	166	29	5.72
A3GMAR-VERGE	Groot Marico		C	C	26/04/2005	196	31	6.32	26/07/2005	180	28	6.43
					19/09/2005	256	39	6.56	24/11/2005	245	37	6.62
					13/03/2007	243	40	6.08	22/08/20	247	38	6.5

RHP Site Code	River Name	Tributary	IHI Instream 2007	IHI Riparian 2007	Survey dates	SASS	No Taxa	ASPT	Survey dates	SASS	No Taxa	ASPT
									07			
					2010/01/28	284	42	6.8				
A3GMAR-SALLI	Groot Marico		C	C	26/04/2005	141	24	5.88	26/07/2005	166	27	6.15
					16/09/2005	280	43	6.51	23/11/2005	222	34	6.53
A3GMAR-WONDE	Groot Marico		C	C	26/04/2005	208	34	6.12	22/06/2005	249	39	6.38
					16/09/2005	247	39	6.33	23/11/2005	310	49	6.33
					07/03/2007	279	46	6.07	Fire 23/08/2007	268	43	6.23
					08/04/2008	249	40	6.23				
A3GMAR-DOORN	Groot Marico		C	D	26/04/2005	136	23	5.91	22/06/2005	191	32	5.97
					16/09/2005	250	38	6.58				
					ALL WATER DIVERTED BY WEIR on 07/03/2007	x	x	x	No Veg 23/08/2007	160	26	6.15
A3GMAR-RIEKE	Groot Marico		E	E	20/04/2005	115	22	5.63	22/06/2005	124	24	5.17
					16/09/2005	145	26	5.58	23/11/2005	151	27	5.59
					07/03/2007	115	23	5	27/08/2007	119	22	5.41
					07/04/2008	173	31	5.58	2010/01/27	160	26	6.2

RHP Site Code	River Name	Tributary	IHI Instream 2007	IHI Riparian 2007	Survey dates	SASS	No Taxa	ASPT	Survey dates	SASS	No Taxa	ASPT
A3KMAR-DOORN	Klein Marico	Groot Marico	B	B	Seasonal							
A3MOLE-OTTOS	Molemaneloop	Klein Marico	B	C	16/03/2007	181	34	5.32	20/08/2007	85	18	4.72
A3KARE-GHOLF	Kareespruit	Klein Marico	D	D	27/04/2005	69	17	4.06	27/07/2005	88	21	4.19
					22/09/2005	104	23	4.52	02/12/2005	70	19	3.68
A3KARE-RAILW	Kareespruit	Klein Marico	D	D	27/04/2005	63	15	4.2	26/07/2005	62	16	3.88
					22/09/2005	79	20	3.95	02/12/2005	100	21	4.76
					15/03/2007	90	19	4.74				
A3KARE-ABJAT	Kareespruit	Klein Marico	D	C	27/04/2005	18	7	2.57	27/07/2005	4	3	1.33
					22/09/2005	8	4	2	02/12/2005	20	6	3.33
					RAW SEWERAGE on 15/03/2007	x	x	x				
A3KMAR-N4ROA	Klein Marico	Groot Marico	D	C								
A3KMAR-KALKD	Klein Marico	Groot Marico	E	F	27/04/2005	104	24	4.33				
					15/03/2007	137	25	5.48	29/08/2007	141	29	4.86
A3KMAR-NOOIT	Klein Marico	Groot Marico	C	D	27/04/2005	64	14	4.57				

RHP Site Code	River Name	Tributary	IHI Instream 2007	IHI Riparian 2007	Survey dates	SASS	No Taxa	ASPT	Survey dates	SASS	No Taxa	ASPT
A3GMAR-STRAA	Groot Marico		D	D								
A3GMAR-UITKY	Groot Marico		C	C	07/04/2008	76	16	4.75				
A3GMAR-LOTTE	Groot Marico		D	D	19/04/2005	21	4	5.25				
A3GMAR-TSWAS	Groot Marico		E	E	19/04/2005	140	32	4.38	21/06/2005	115	26	4.4
					22/11/2005	144	29	4.97	12/03/2007	115	25	4.6
									09/04/2008	120	26	4.62
A3GMAR-DERDE	Groot Marico		C	C	19/04/2005	111	25	4.44	21/06/2005	116	27	4.3
					15/09/2005	70	14	5	22/11/2005	136	28	4.86
RHP Site Code	**River Name**	**Tributary**	**IHI Instream 2007**	**IHI Riparian 2007**	**Survey dates**	**SASS**	**No Taxa**	**ASPT**	**Survey dates**	**SASS**	**No Taxa**	**ASPT**
A1NGOT-DINOK	Ngotwane	Groot Marico			02/12/2005	248	40	6.2	15/03/2007	210	34	6.18
					20/08/2007	197	34	5.79	11/04/2008	211	34	6.21
A1NGOT-PUANE	Ngotwane (Mmaphanyane)	Groot Marico			02/12/2005	84	18	4.67				
					20/08/2007	83	19	4.37	11/04/2008	117	21	5.57

3.2.5 Elands River and tributaries

The Elands River originates south of the town of Swartruggens in an extensive wetland area and flows in a northerly direction and then north east to the Vaalkop Dam, see Figure 8. The upper reaches of the catchment are dominated by slate mining activities and is in a B/C Ecological category, see Table 7. Sediment from some of the slate mines are not sufficiently retained and cause deterioration to a C/D Ecological category at A2UNSP-TRIBU. The upper reaches are steeply sloped while the middle and lower reaches are gentle sloping. Overgrazing in the middle and lower reaches of the catchment contributes to sediment deposition and degradation of the catchment.

The Swartruggens Dam and Lindleyspoort Dam supply water for domestic, agricultural and mining activities. The situation below Swartruggens Dam and in Swartruggens (A2ELAN-SWART) is in a D/EF Ecological category. The discharges from the Swartruggens sewage treatment facilities cause nutrient enrichment at A2ELAN-NOOIT. The area below Lindleyspoort Dam is intensively used for agriculture and no ecological flow releases are made, resulting in a low C/D Ecological category.

The Selons River is a highly seasonal tributary in the middle reaches. The Koster River is a tributary of the Selons. The Koster Dam does not release ecological flow. The Ecological category upstream from the dam at A2KOST-NAAUW is in a D/EF category, mainly due to flow and nutrient enrichment problems. The Dwarsspruit is an important tributary of the Selons from a fish diversity perspective. The Ecological categories of the Dwarsspruit are B/ high C.

The Laregane River is a tributary of the lower Elands. This river originates from mining areas and is in a C Ecological category at A2LARE-HARTB. The lower Elands consist mainly of deep sandy pools with very little flow. The water quality has also deteriorated as a result of erosion and high sediment loads occur in the river's middle to lower reaches. *Sesbania* have infested large parts of the river and the resulting deposition of seeds in the Vaalkop Dam basin could potentially create problems.

This WMA is in the process of an Ecological Reserve determination and results should be available by the end of 2010, preliminary results are available from the author.

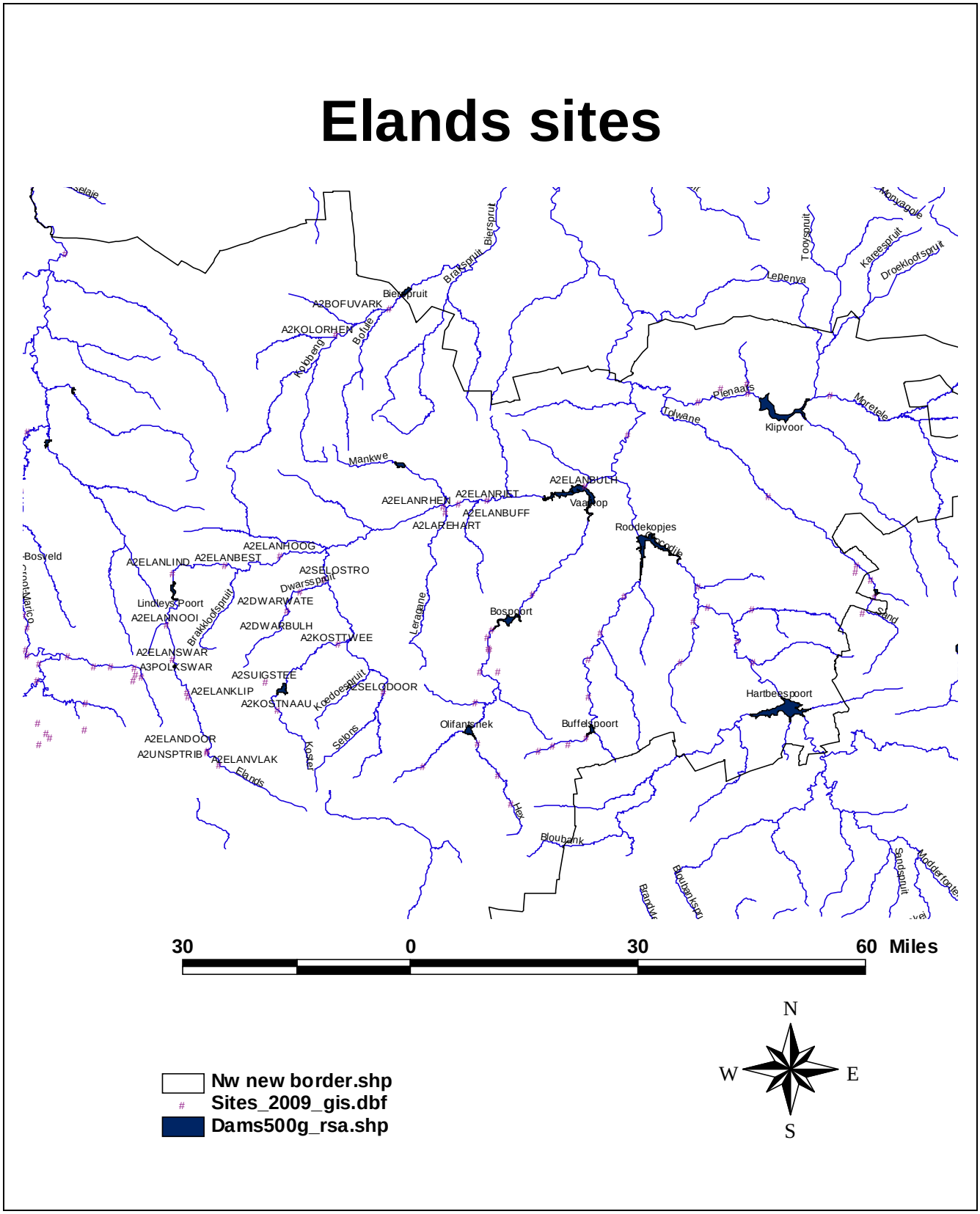

Figure 8: Elands River Sites

Table 7: Summary of Index of Habitat Integrity and SASS5 Ecological category results for Elands River and tributaries (Western Crocodile)

RHP Site Code	River Name	Tributary	IHI Instream 2007	IHI Riparian 2007	Survey dates	SASS	No Taxa	ASPT	Survey dates	SASS	No Taxa	ASPT
A2ELAN-VLAKF	Elands	Crocodile	C	C	26/06/2006	137	26	5.15				
A2UNSP-TRIBU	Tributary of Elands	Elands			26/06/2006	102	19	5.37	Bridge construction 29/11/2006	x	x	x
					17/07/2008	141	23.00	6.13				
A2ELAN-DOORN	Elands	Crocodile	C	D	26/06/2006	186	33	5.64	29/11/2006	171	32	5.34
					17/07/2008	121	20.00	6.25				
A2ELAN-KLIPB	Elands	Crocodile	C	C	26/06/2006	142	26	5.46	29/11/2006	168	30	5.6
					18/07/2008	179	33.00	5.42				
A2ELAN-DOORK	Elands	Crocodile	C	C	30/06/2006	141	22	6.41	30/11/2006	205	36	5.69
					18/07/2008	179	33.00	5.42				
A2ELAN-SWART	Elands	Crocodile	D	E	28/06/2006	73	13	5.62	30/11/2006	84	22	3.82
A2ELAN-NOOIT	Elands	Crocodile	C	D	28/06/2006	112	23	4.87	30/11/2006	90	22	4.09
					18/07/2008	50	13.00	3.85				
A2ELAN-LINDL	Elands	Crocodile	D	E	28/06/2006	85	19	4.47				
A2ELAN-BESTE	Elands	Crocodile	C	D					28/11/2006	111	25	4.44
					16/07/2008	118	26.00	4.54				
A2ELAN-HOOGE	Elands	Crocodile	C	C	29/06/2006	102	21	4.86				
					16/07/2008	71	16.00	4.44				
A2ELAN-RHENO	Elands	Crocodile	C	C								
A2ELAN-BUFFE	Elands	Crocodile	B	C								
A2LARE-HARTB	Laregane	Elands			29/06/2006	111	23	4.83	27/11/2006	105	23	4.57
A2ELAN-RIETS	Elands	Crocodile	C	C	29/06/2006	117	25	4.68				
A2ELAN-BULHO	Elands	Crocodile	D	D								
A2KOST-NAAUW	Koster	Selons			27/06/2006	75	15	5	29/11/2006	70	16	4.38
					17/07/2008	81	20.00	4.2				
A2SUIG-STEEN	Suigsloot	Koster							29/11/2006	148	30	4.93
A2DWAR-BULHO	Dwarsspruit	Selons			27/06/2006	142	24	5.92	28/11/2006	139	30	4.63
					16/07/2008	131	25.00	5.24				

A2DWAR-WATER	Dwarsspruit	Selons			27/06/2006	111	22	5.05	Total removal of riverine vegetation 30/11/2006	x	x	x

3.2.6 Hex and Sterkstroom Rivers

The Hex River originates south of the Rustenburg complex and flows north to the Vaalkop Dam, see Figure 9. The Olifantsnek Dam is situated in the upper reaches of the Hex River. The confluence of the Hex and Klein Hex is in the Olifantsnek Dam.

The upper reaches of the Hex River is in a B/ high C Ecological category (A2HEX-BUFFE, A2HEX-LEEUW and A2HEX-OLIFA), the main impacts result from water abstraction and farming activities. The Waterkloofspruit originates in the Kgwasane Mountain Reserve from an important mountain catchment wetland system. The biomonitoring site (A2WATE-WATER) is located close to Rustenburg and indicate a high B Ecological category, see Table 8.

Below Rustenburg heavy infestations of alien vegetation, flow modifications, urban runoff and mining are the major impacts on the river. The area upstream from Bospoort Dam at A2HEX-PAARD is in an E/F Ecological category, below the dam at A2HEX-ROOIW in a D/ low C. This river is degraded and contributes to water quality problems in Vaalkop Dam.

The Sterkstroom is a tributary of the Crocodile River that has its origin in the Magaliesberg. The upper reaches result in A/B Ecological categories (A2STER-RIETF, A2STER-KROMR and A2UNSP-KROMR). The upper reaches must be conserved and an Index of Habitat Integrity should be done. The agricultural activities in the vicinity of Buffelspoort Dam reduce the Ecological category to a C (A2STER-BUFFE). The combination of reduced flow and mining impacts downstream from Buffelspoort Dam results in Ecological categories of D(A2STER-WAAIK) and E/F (A2STER-ZWART). The water quality that enters the Roodekopjes Dam is thus not of a good quality.

This WMA is in the process of an Ecological Reserve determination and results should be available by the end of 2010, preliminary results are available from the author.

The preliminary Ecostatus result from the Hex River site (EWR6 and RHP site A2HEX-ROOIW) indicates that the overall category is D.

IHI				Driver	PES & REC Category	Trend	AEC Up	AEC down
instream		riparian		Hydrology	D	Decreasing	D	
				Water quality	D	Decreasing	C/D	
				Geomorphology	C/D	stable	C	
				Response components	**PES & REC Category**	**Trend**	**AEC Up**	**AEC Down**
				Fish	D	Decreasing	C/D	
				Aquatic invertebrates	C	Decreasing	C	
				Instream	C/D	Decreasing	C	
				Riparian vegetation	E	Decreasing	D/E	
				Ecostatus	D	Decreasing	C/D	

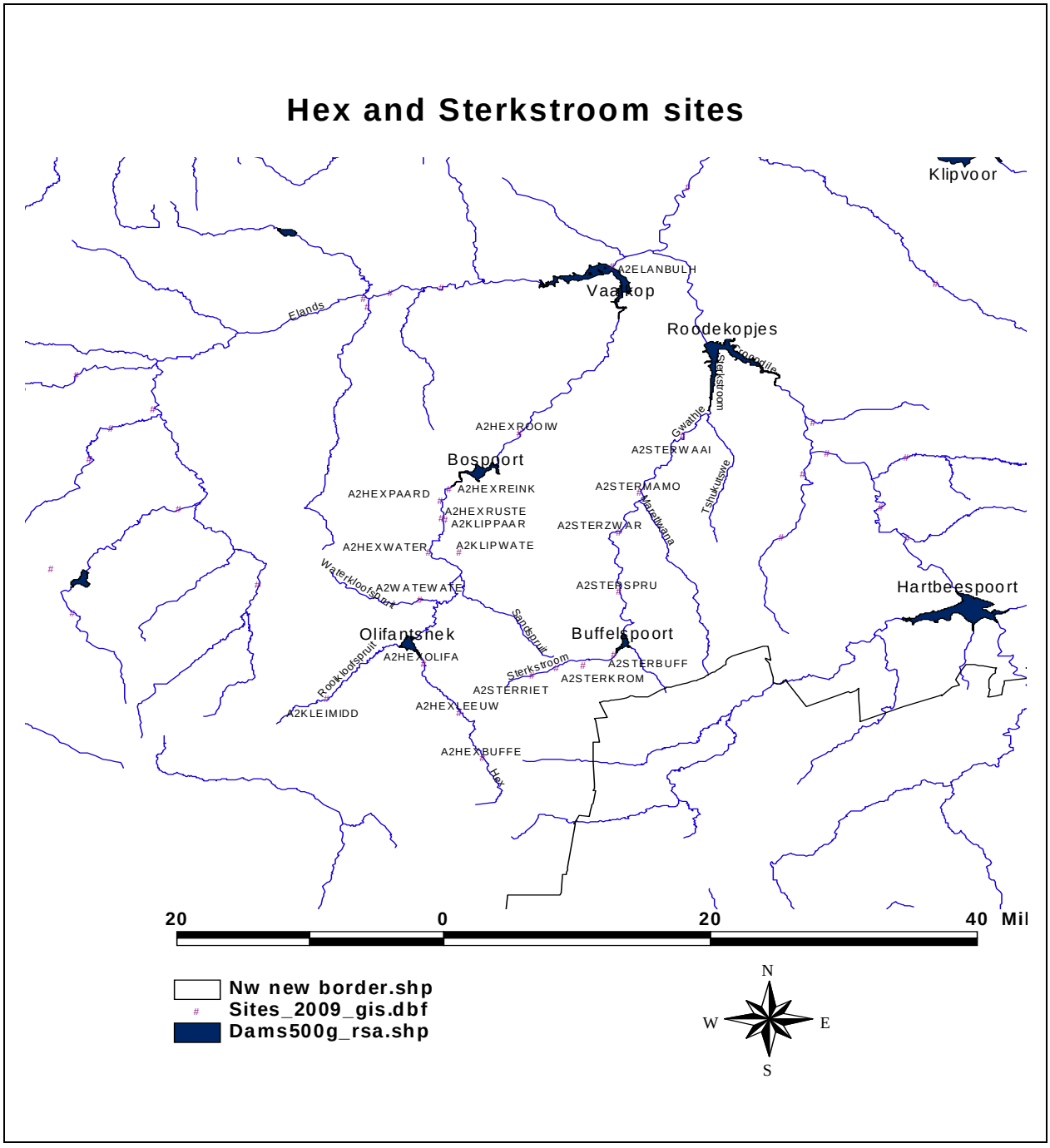

Figure 9: Hex and Sterkstroom River Sites

Table 8: Summary of Index of Habitat Integrity and SASS5 Ecological category results for Hex and Sterkstroom Rivers (Middle Croc)

RHP Site Code	River Name	Tributary	IHI Instream 2007	IHI Riparian 2007	Survey dates	SASS	No Taxa	ASPT	Survey dates	SASS	No Taxa	ASPT
A2HEX-BUFFE	Hex	Elands	B	C	07/09/2006	111	20	5.55	09/06/2008	164	26	6.31
A2HEX-LEEUW	Hex	Elands	B	C					09/06/2008	164	26	6.31
A2HEX-OLIFA	Hex	Elands	C	C	07/09/2006	151	28	5.39	09/06/2008	126	23	5.48
A2KLEI-MIDDE	Rooikloof spruit	Hex	C	C								
A2WATE-WATER	Waterklo ofspruit	Hex			07/09/2006	170	27	6.3				
A2HEX-WATER	Hex	Elands	C	D								
A2HEX-RUSTE	Hex	Elands	D	D								
A2HEX-PAARD	Hex	Elands	C	C					08/09/2006	45	11	4.09
A2HEX-REINK	Hex	Elands	F	F								
A2HEX-ROOIW	Hex	Elands	D	F	23/08/2006	66	15	4.4	11/06/2008	92	20	4.6
A2STER-RIETF	Sterkstroom	Crocodile			21/08/2006	205	33	6.21	10/06/2008	130	21	6.19
A2STER-KROMR	Sterkstroom	Crocodile			21/08/2006	153	24	6.38				
A2UNSP-KROMR	Tributary of Sterkstroom	Sterkstroom			21/08/2006	98	17	5.76	10/06/2008	142	22	6.45
A2STER-BUFFE	Sterkstroom	Crocodile			21/08/2006	110	19	5.79	10/06/2008	116	20	5.8
A2STER-SPRUI	Sterkstroom	Crocodile			22/08/2006	70	14	5	10/06/2008	70	13	5.38
A2STER-ZWART	Sterkstroom	Crocodile							10/06/2008	43	10	4.3
A2STER-MAMOG	Sterkstroom (Gwathle)	Crocodile			22/08/2006	59	14	4.21				
A2STER-WAAIK	Sterkstroom (Gwathle)	Crocodile			22/08/2006	76	17	4.47				

3.2.7 Crocodile River and tributaries

The Crocodile River originates in Gauteng in Johannesburg and flows in a northerly direction through Hartbeespoort Dam and then north westwards, supplying water to agricultural and mining activities in the North West Province, see Figure 10.

The Crocodile River and tributaries are in a D/EF Ecological category (see Table 9) with the exceptions of:

- The Ramogatla tributary at A2RAMO-KLIPK, this site was in a B class (September 2006) and has since deteriorated to a C (December 2006) and D (May 2008).
- The Tolwane at A2TOLW-NOOIT, this site was in a C class (September 2006) and has deteriorated to an EF (December 2006 and May 2008).
- The Pienaars downstream from Klipvoor Dam at A2PIEN-BUFFE, this site was in a high C (September 2006), B (December 2006) and high C (May 2008).

This WMA is in the process of an Ecological Reserve determination and results should be available by the end of 2010, preliminary results are available from the author. The planned inter-basin transfers will further negatively affect this river system that already has to deal with more discharges from Gauteng.

The overall Ecostatus category for the Crocodile River as determined through the Ecological Reserve process in the section upstream from Hartbeespoort Dam (EWR1) results in a D and summarized as follow:

IHI				Driver	PES & REC Category	Trend	AEC up	AEC down
instream		riparian		Hydrology	D	Increasing	D	
				Water quality	D/E	Decreasing	D	
				Geomorphology	C	Decreasing	C	
				Response components	**PES & REC Category**	**Trend**	**AEC Up**	**AEC down**
				Fish	D	Stable	D	
				Aquatic invertebrates	D	Stable	C	
				Instream	D/E	Stable	C/D	
				Riparian vegetation	D	Stable – decreasing	D	
				Ecostatus	D	Decreasing	D	

The Crocodile River site (EWR3) downstream from Hartbeespoort Dam results in an Ecostatus of C/D

IHI				Driver	PES & REC Category	Trend	AEC Up	AEC down
instream		riparian		Hydrology	D	Stable	C/D	D/E
				Water quality	D/E	Decreasing	D	F
				Geomorphology	E	stable	E	E
				Response components	**PES & REC Category**	**Trend**	**AEC Up**	**AEC Down**
				Fish	E	Stable	D	E
				Aquatic invertebrates	D	Negative	C	D/E
				Instream	D/E	Stable	D	E
				Riparian vegetation	B/C	Stable	B/C	C
				Ecostatus	C/D	Stable	C	D

The Pienaars River directly downstream from Klipvoor Dam (EWR 5 and RHP site A2PIEN-IFR2) results in an Ecostatus of D.

IHI				Driver	PES & REC Category	Trend	AEC Up	AEC down
instream		riparian		Hydrology	D	negative	D	
				Water quality	D	negative	C/D	
				Geomorphology	E	Negative	E	
				Response components	**PES & REC Category**	**Trend**	**AEC Up**	**AEC Down**
				Fish	D	negative	C/D	
				Aquatic invertebrates	C/D	negative	C	
				Instream	D	Stable	C	
				Riparian vegetation	D	Negative	C	
				Ecostatus	D	negative	C	

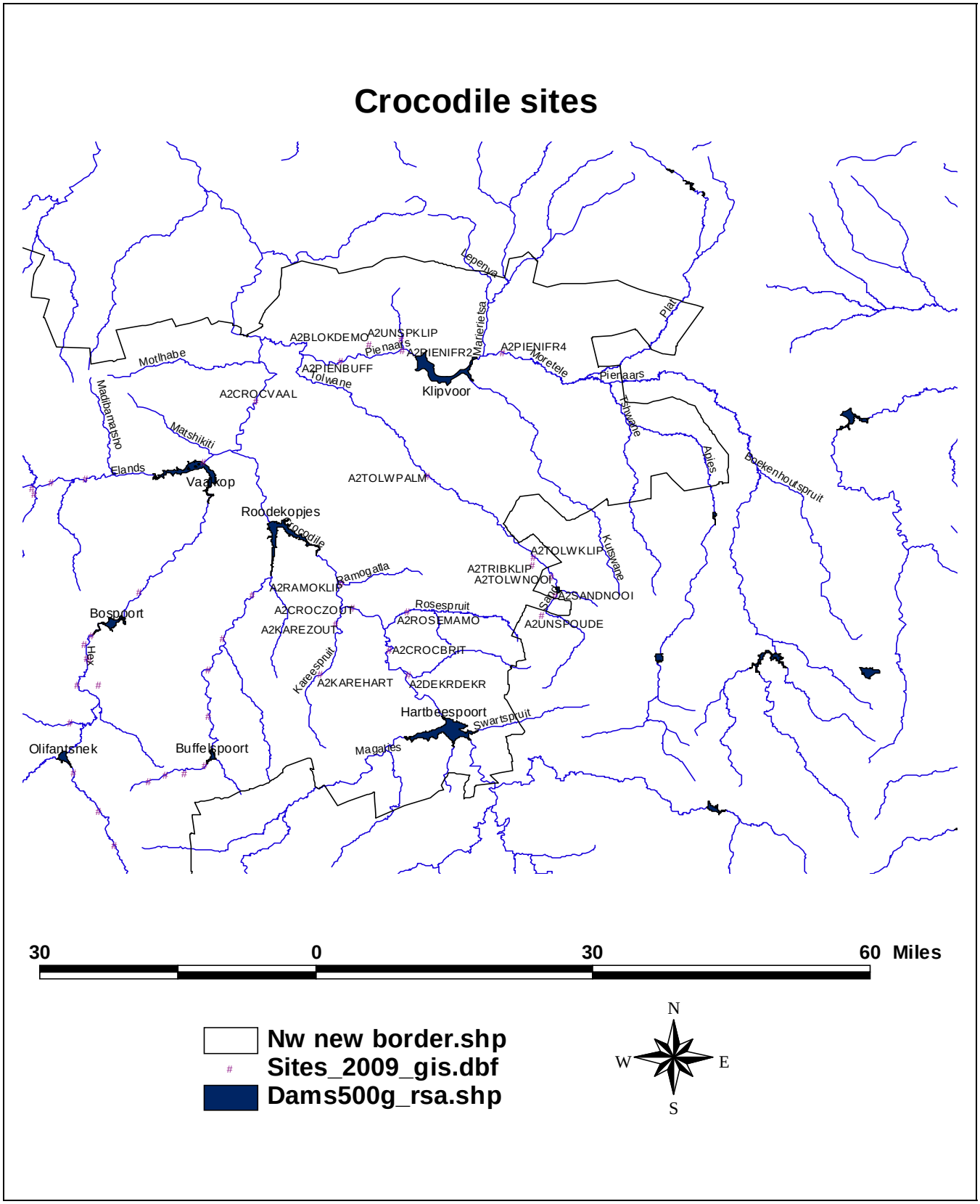

Figure 10: Crocodile River Sites

Table 9: Summary of Index of Habitat Integrity and SASS5 Ecological category results for Crocodile River and tributaries (Croc East)

RHP Site Code	River Name	Tributary	IHI Instream 2007	IHI Riparian 2007	Survey dates	SASS	No Taxa	ASPT	Survey dates	SASS	No Taxa	ASPT
A2DEKR-DEKRO	De Kroon Spruit	Crocodile	D	D								
A2CROC-BRITS	Crocodile		E	D								
A2ROSE-MAMOG	Rosespruit	Crocodile							11/12/2006	75	17.00	4.41
					15/05/2008	36	7.00	5.14				
A2CROC-ZOUTP	Crocodile		C	D	04/09/2006	79	18.00	4.39	11/12/2006	67	15.00	4.47
A2KARE-HARTB	Kareespruit	Crocodile			12/05/2008	34	9.00	3.78				
A2KARE-ZOUTP	Kareespruit	Crocodile			04/09/2006	69	15.00	4.6				
A2RAMO-KLIPK	Ramogatla	Crocodile			04/09/2006	138	27.00	5.11	11/12/2006	102	20.00	5.1
					12/05/2008	72	15.00	4.8				
A2CROC-VAALK	Crocodile		C	D	06/09/2006	31	9.00	3.44	12/12/2006	77	19.00	4.05
					15/05/2008	102	23.00	4.43				
A2SAND-NOOIT	Sand	Tolwane			05/09/2006	67	16.00	4.19	No work, serious safety concerns 13/12/2006	x	x	x
A2TOLW-NOOIT	Tolwane	Pienaars (Moretele)			05/09/2006	118	24.00	4.92	13/12/2006	65	17.00	3.82
					14/05/2008	66	13.00	5.08				
A2TOLW-PALMI	Tolwane	Pienaars (Moretele)							13/05/2008	87	16.00	5.44
A2PIEN-IFR2	Pienaars (Moretele)	Crocodile			06/09/2006	51	11.00	4.64	12/12/2006	59	15.00	3.93
A2PIEN-BUFFE	Pienaars (Moretele)	Crocodile			06/09/2006	120	22.00	5.45	12/12/2006	181	32.00	5.66
					13/05/2008	120	22.00	5.45				

4. Conclusion

Most of the river systems in the Province have been impacted by human activities and therefore the habitat integrity has deteriorated. Most rivers can be considered to be in a moderately to largely modified state (category C to D). Integrity of a largely natural state (category A) is rarely found in the assessed rivers. Improved management and rehabilitation actions are required in the modified rivers to implement improvements and to prevent further degradation. Conservation actions are required for the largely natural rivers as they support unique biodiversity features and subsequent ecological goods and services.

The continued monitoring and reporting of the status of the aquatic ecosystem in the province is essential in this water scarce area.

Challenges

- Only one person is responsible for project management, implementation, fieldwork, data capture, analysis and reporting
- Availability and appointment of experts to do biomonitoring of fish.
- Availability and appointment of support staff to assist with the aquatic invertebrates, habitat integrity, and riparian vegetation monitoring.
- Low/no flow of rivers in dry seasons and high flow in wet seasons, causing a discontinuation in the planned monitoring programme.
- Application of biomonitoring indices can only be done by experts.
- Server access problems prevented the direct capture to the National Rivers Database. Problem solved in June 2008.
- Kilometre restrictions during 2007, 2008, 2009, 2010.
- Lack of strong enforcement to prevent further degradation of river systems
- Implementation and monitoring of the Ecological Reserve

Opportunities

- Informed decisions, based on scientific data, can be made on issues related to river- and catchment management.
- A reliable database is being developed to support State of Environment reporting in the province.
- Biomonitoring training provided to staff members and other partners (Universities and DWA staff).
- To develop and implement a biomonitoring programme that will support integrated water resource management
- The integration of freshwater and terrestrial conservation planning

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BIOASSESSMENT OF THE LOWER VAAL RIVER

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1. INTRODUCTION

The Vaal River is an important water resource with a number of significant tributaries along its length. It originates from the Drakensberg escarpment at Sterkfontein Beacon near Breyten, Mpumalanga Province. The Vaal River is regulated through the Vaal Dam (Vaal-Barrage Dam) in the Gauteng Province and Bloemhof Dam in the North West Province. It flows 1 415 km southwest to its confluence with the Orange River at Douglas, Northern Cape. Most of the tributaries of the Vaal River downstream from the Vaal Dam are in a critical state of ecological decline (DWAF 2006). Upstream and downstream of the Vaal Dam it is also impacted by a large number of agricultural, industrial and mining activities such as coal mining. In the middle Vaal River (especially between Kromdraai and Bloemhof Dam) the topography tapers down to a slope of about 0.28 m/km (DWAF 2004).

Previously in South Africa, the quality of water was primarily determined by carrying out chemical analysis of water and measuring physical variables (Roux *et al.* 1993). Chemical analysis can give very accurate measures of the amounts of individual substances in the water of a river but it only considers the water passing at the moment of collection (Davies and Day 1998) and is thus only accurate at the time the sample is taken (Bertasso 2004). Furthermore, chemical and physical water analysis is expensive and requires skilled and trained personnel. With the above in mind, alternative methods for determining the quality of water sources are continuously being investigated. One of the alternative methods is biological monitoring. Biological monitoring provides a bigger picture of both the past and the present conditions in a river. This is because the organisms that are living in a river must have been able to survive whatever conditions the river has been subjected to in the recent past (Davies and Day 1998) and the integrity or health of the biota provides a direct and integrated measure of the health of the river as a whole.

Aquatic biota relies mostly and completely on the water bodies. The composition of communities of aquatic organisms is responds to the nature of the physical and chemical environment in which they live (Chutter 1998). The physical and chemical quality of water is defined by so many parameters that it is often impossible to determine which single parameter, or combination of parameters, causes the observed biological responses. A multitude of factors determine the health of a river ecosystem e.g. its geomorphologic characteristics, hydrological and hydraulic regime, chemical and physical water quality, and nature of the in-stream and riparian habitats (WRC 2001). It is impractical to monitor each of these factors in detail. The River Health Programme (RHP) is therefore focusing on selected ecological indicators that are representative of the larger ecosystem and are practical to measure. Since resident aquatic communities reflect the effects of chemical and physical impacts in a time-integrated manner, they are regarded as good indicators of overall ecological integrity. Fish also received attention as indicator organisms in South Africa, especially the intolerance of certain species to particular environmental conditions (Kleynhans 1999).

The purpose of the RHP is to gather information regarding the ecological state of river ecosystems in South Africa (WRC 2001), to enable reporting in an objective and scientific manner. Government and Conservation Agencies use this information for assessing and managing rivers.

2. AIM AND OBJECTIVES

- To bio-assess the ecological status of the Lower Vaal River in terms of water quality and invertebrates
- To assess the potential impacts and where possible recommend mitigation measures.

3. STUDY AREA

The Vaal River system is the principal tributary of the Orange River. The Vaal River has been altered through the construction of weirs, impoundments, canals, etc. in trying to provide enough water to users. It is also currently threatened by invasive alien plants occurring in and along the river

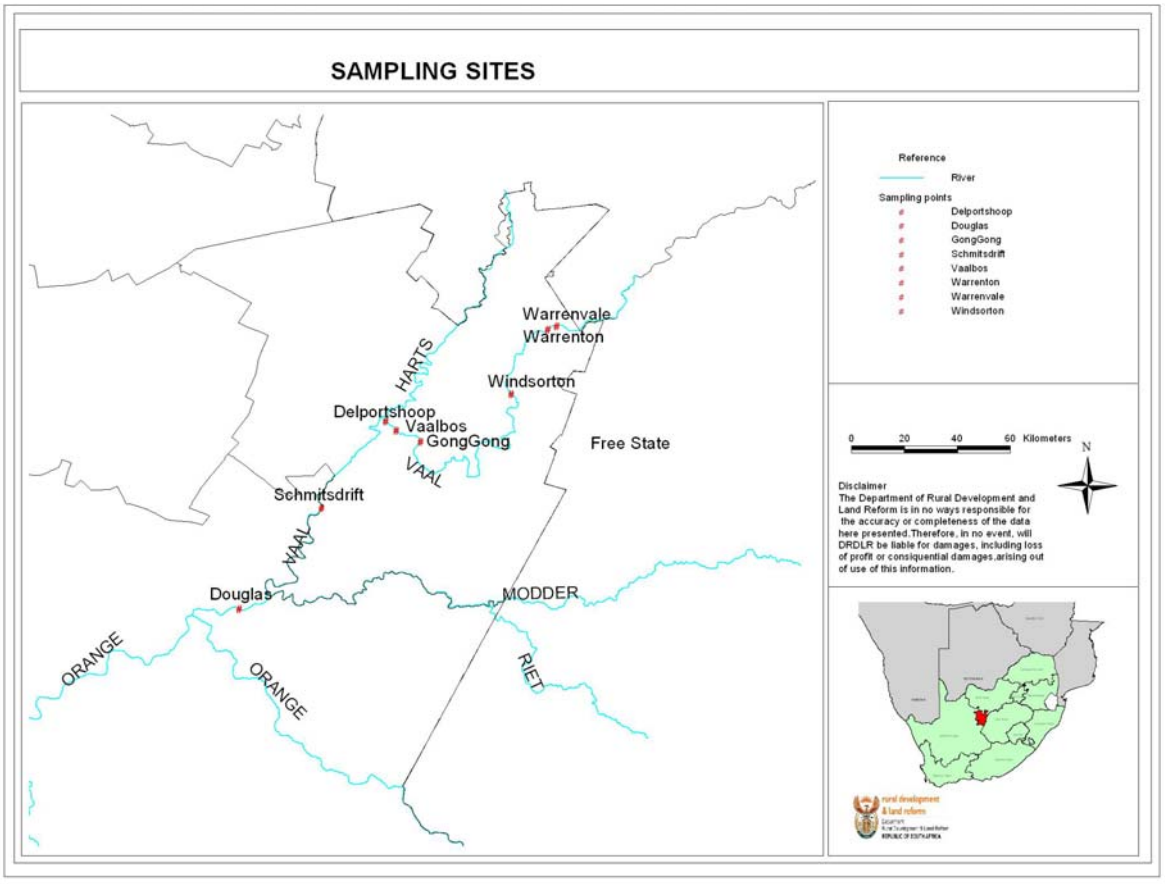

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Fig 1: The sampling sites in the Lower Vaal River

Fig 2: Warrenvale (VW1) **Coordinates** S 28º05'45.1" E 24º52'10.9"

The banks are bordered by riparian vegetation. The vegetation includes large indigenous trees, reeds (*Phragmentis australis*), alien red river gum (*Eucalyptus spp.)* and indigenous water grasses *(Potamogeton spp.)* which are submerged in the waterway. The stones in current and out of current are covered with algae. The invasive water hyacinth (*Eichhornia crassipes*) is blooming and floating.

Fig 3: Warrenton (VW2) **Coordinates** S 28° 06' 26.2" E24° 50' 23.5"

The site is braided, below the Margaretha Prinsloo Bridge in the Warrenton area. The riparian vegetation is dominated by sedges *(Cyperus papyrus),* reeds (*Phragmentis australis)*, bulrushes (*Typha capensis),* karee trees (*Rhus pendulina*) and red river gum (*Eucalyptus spp).* The invasive water hyacinth *(Eichhornia crassipes)* is submerged in the waterbody which prevents sunlight from penetrating.

Fig 4: Windsorton (VW3) **Coordinates** S 28° 19' 32.5" E 24° 43' 00.1"

The site is bordered by sedges (*Cyperus papyrus)*, karee trees (*Rhus pendulina*), a few shrubs, water hyacinth (*Eichhornia crassipes)* and alien red river gum (*Eucalyptus spp.*) The river is diverted to allow for alluvial diamond diggings. Alluvial diamond mining is rife adjacent to the river banks. The riparian vegetation is removed; stones in current and out of current are covered with algae.

Fig 5: Vaalbos (VV4) Coordinates S 28 ° 27' 00.7 E 24° 19' 34.2

The site is rocky and below the low water bridge next to Vaalbos Nature Reserve. No riparian vegetation occurs at the site except for a few patches of grass and sedges on the bank. The rocks are covered with algae which makes it difficult to sample. The vegetation is highly degraded due to alluvial diamond mining.

Fig 6: Gonggong (VG5) Coordinates S 28°29'17.4" E024°24'31.4"

The site is highly degraded by mining activities. Little vegetation is found along the river banks. The marginal vegetation out of current is dominated by sedges. There are informal settlements upstream and along the river banks.

Fig 7: Delpoortshoop (VD6) Coordinates S 28° 25' 06.5 E24° 17' 25.7"

The site is below the culverts of the road to alluvial diamond diggings which disturb the river flow. Little vegetation such as *Acacia karroo* and sedges (*Cyperus papyrus)* occur at this site. The site is highly degraded by alluvial mining activities.

Fig 8: Schmisdtdrift (VS7) Coordinates S 28° 42' 42.1" E24° 04' 21.3"

The site is below a weir. Riparian vegetation is highly degraded due to alluvial mining activities. There are only a few reeds (*Phragmentis australis*), sedges *(Cyperus papyrus)* and shrubs at the bank and the water grasses *(Potamogeton spp.)* are submerged in the waterway.

Fig 9: Douglas (VD8) S29° 03 12 5 E23° 47' 38. 1"

The site is very stony and in the current is covered with lots of algae. The vegetation occurring at this site include sedges (*Cyperus papyrus),* reeds (*Phragmentis australis)*, karee trees *(Rhus pendulina)* and red river gum (*Eucalyptus spp.)* bordering the river banks. The alien red river gum trees serve as the habitat for birds at this site.

4. METHODOLOGY

4.1 *In situ* water parameters

The pH, water temperature, total dissolved solids (TDS) and electrical conductivity (EC) were determined *in situ* by means of a hand-held multi parameter instrument (YSI) at all the sampling sites during June 2009 and November 2009.

4.2 Invertebrates

The freshwater invertebrate communities of the Lower Vaal River were assessed using the standardised method of SASS 5, which has been accredited and widely used in the River Health Programme (RHP). The system was designed for the low to moderate flow hydrology. The index is ideally suited for the assessment of flowing systems with a diversity of habitats, specifically riffles and rapids (Dickens and Graham 2002). During this study unidentified invertebrates were collected and preserved in alcohol for further identifications. The SASS 5 scores were calculated and the Ecological Categories were determined as appears in the below-mentioned Figure 10 and Table 1:

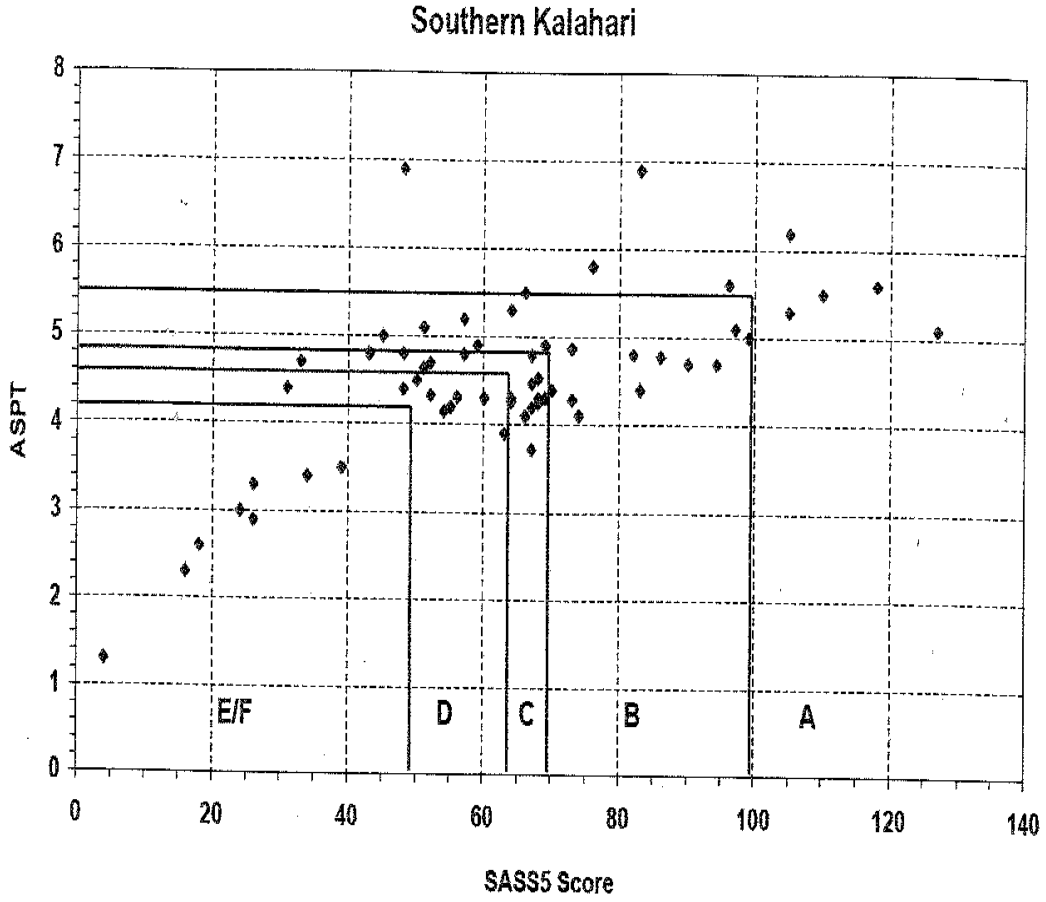

Fig 10: Reference state conditions for the Southern Kalahari Aquatic Ecoregion (Dallas 2007).

Table 1: Eco-classification model for determining the present ecological state for Southern Kalahari Aquatic Ecoregion based on SASS Score and Average Score Per Taxon (Dallas 2007).

SASS 5 Score	ASPT	Condition	Class
>100	>5.5	Natural/unmodified	A
70-100	4.8-5-5	Minimally modified	B
65-69	4.6-4.7	Moderately modified	C
50-64	4.2-4.5	Largely Modified	D
<49	0-4.1	Seriously Modified	E/F

5. Results

5.1 Water Parameters

Table 2: *In situ* water parameters for Winter (June 2009) and Spring Survey (November 2009).

	Winter Survey							
Water parameters	**VW1**	**VW2**	**VW3**	**VG4**	**VV5**	**VD6**	**VS7**	**VD8**
pH	7.8	6.7	7.4	8.4	7.7	7.4	8.4	7.8
EC (µS)	583	597	574	585	659	686	778	651
Temperature (ºC)	26.6	22.3	22	24.6	20	18.4	20	26.6
TDS (ppm)	284	292	269	308	337	345	401	331
	Spring Survey							
pH	8.4	8.7	7.7	8.4	6.9	8.5	8.8	8.7
EC (µS)	1365	1157	1361	624	621	1400	816	439
Temperature (ºC)	24.1	26.5	30	27.2	28.7	27.3	28.5	29
TDS (ppm)	680	578	685	307	319	681	417	214

5.1.1 pH

Most fresh waters are usually relatively well buffered and more or less neutral, with a pH range from 6.5 to 8.5, and most are slightly alkaline due to the presence of bicarbonates of the alkali and alkaline earth metals (Dallas and Day 2004). The pH target for fish health ranges between 6.5 and 9.0, as most species will tolerate and reproduce successfully within this pH range (Alabaster and Lloyd 1982).

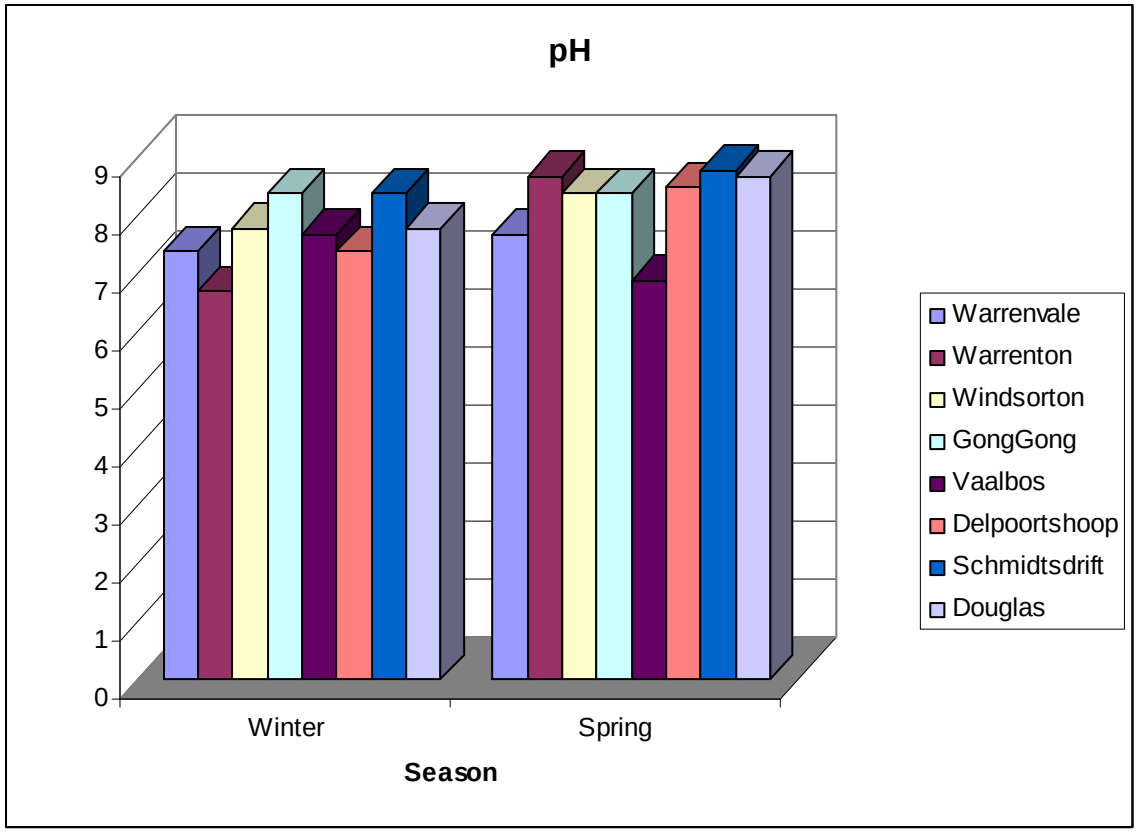

Fig 11: pH concentrations of the eight sampling sites

pH values recorded during this study were generally alkaline and ranged from 6.7- 8.8 at all sites (fig. 11). According to Hellawell (1986) an increase in pH values may be affected by an increase in the biological activity and photosynthetic activity of algae and higher plants. This may be the case for the sampled sites. According to Dallas (2004) the pH of natural waters is determined by geological influences and biotic activities. Based on the results of the two surveys the pH at all sites were within the targeted water quality guidelines and were thus not considered to have a limiting affect on aquatic biota.

5.1.2 Temperature (˚C)

Water temperature plays an important role in aquatic ecosystems by affecting the rates of chemical reactions and therefore also the metabolic rates of organisms (DWAF 1996). Temperature affects the rate of development, reproductive periods and emergence time of organisms (Davies and Day 1998). The temperatures of inland waters in South Africa generally range from 5 - 30 °C (DWAF 1996).

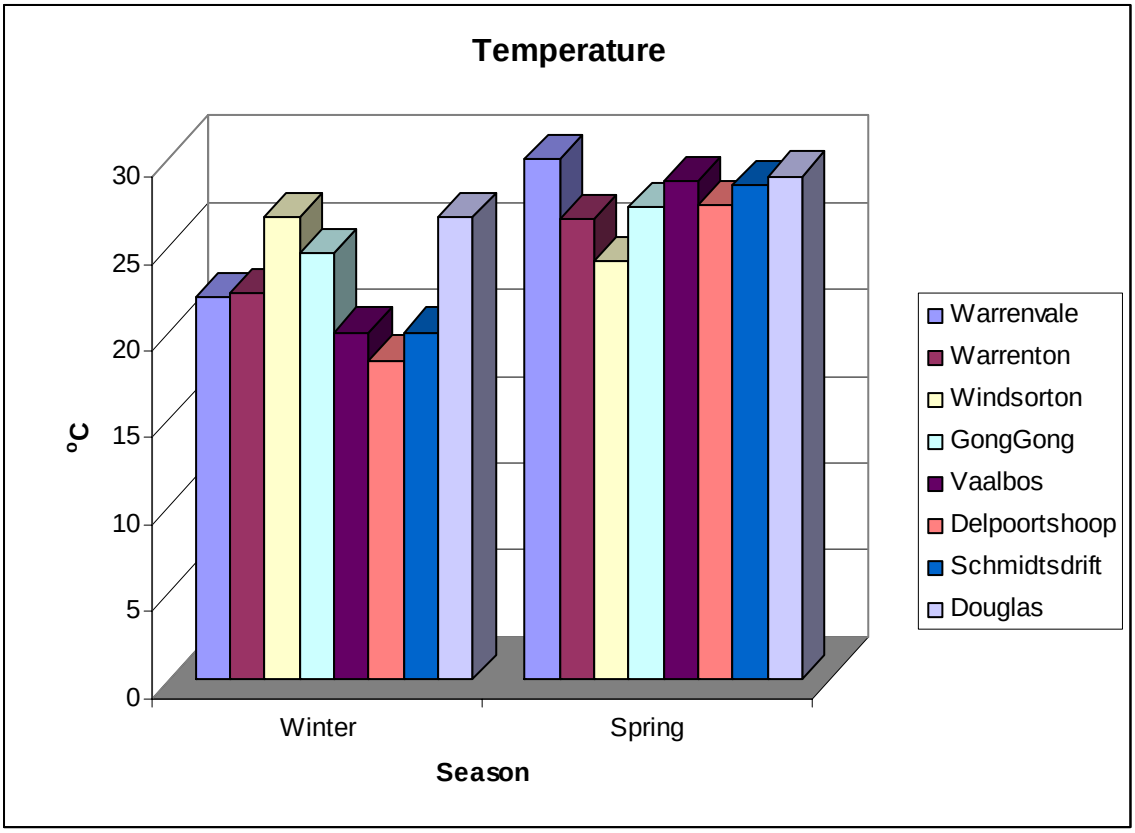

Fig 12: Water temperatures in degrees Celsius (ºC) of the eight sampling sites.

During the Spring and Winter survey the water temperatures ranged from 18.4˚C to 30˚C and were within the targeted range as described in DWAF water quality guidelines (fig.12). The water temperatures recorded were considered to be normal for the freshwater aquatic systems at that time of the sampling and would not have a limiting effect on aquatic biota.

5.1.3 Electrical Conductivity (EC)

Electrical conductivity (EC) is a measure of the ability of water to conduct an electrical current (DWAF 1996). This ability is as a result of the presence of major ions such as carbonate, bicarbonate, chloride, sulphate, nitrate, sodium, potassium, calcium and magnesium, all of which carry an electrical charge (DWAF 1996). Many organic compounds dissolved in water do not dissociate into ions (ionize), and consequently they do not affect the EC (DWAF 1996).

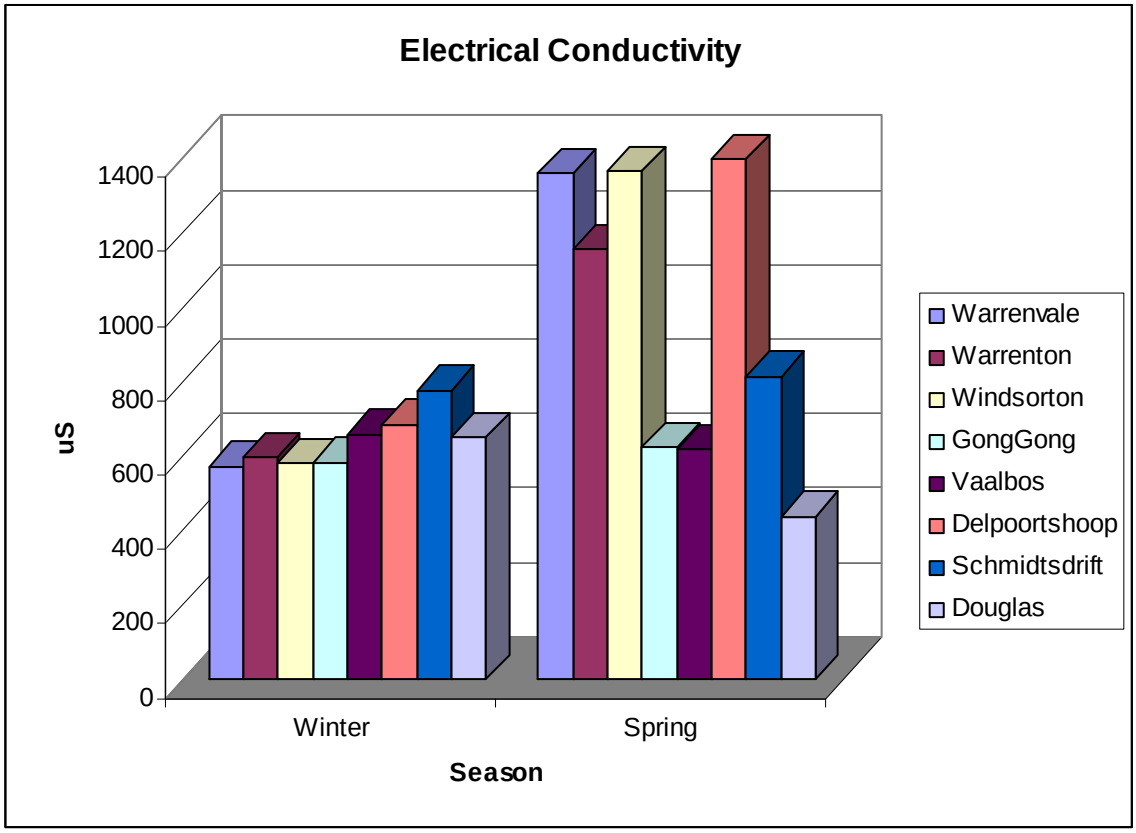

Fig 13: Electrical Conductivity of the eight sampling sites.

The electrical conductivity ranged between 574 µS -778 µS during Winter and did not exceed 1000 µS. The EC levels ranged between 439 µS -1400 µS during Spring and were thus considerably higher (fig. 13). These high concentrations can be attributed to the high dissolved salt concentrations in the water emanating from geological weathering and anthropogenic activities.

5.1.4 Total Dissolved Salts

The total dissolved solids (TDS) are a measure of the total amount of all the materials that are dissolved in water. According to Davies & Day (1998), freshwater organisms usually occur at TDS values less than 3000 mg/ ℓ . According to DWAF (1996) the rate of change of the TDS concentration and the duration of the change is more important than absolute changes in the TDS concentration. Most of the macro-invertebrate taxa that occur in streams and rivers are sensitive to salinity, with toxic effects likely to occur in sensitive species at salinities >1000mg/ℓ (DWAF 1996). TDS concentrations in South African inland waters should not be changed by > 15% (DWAF 1996).

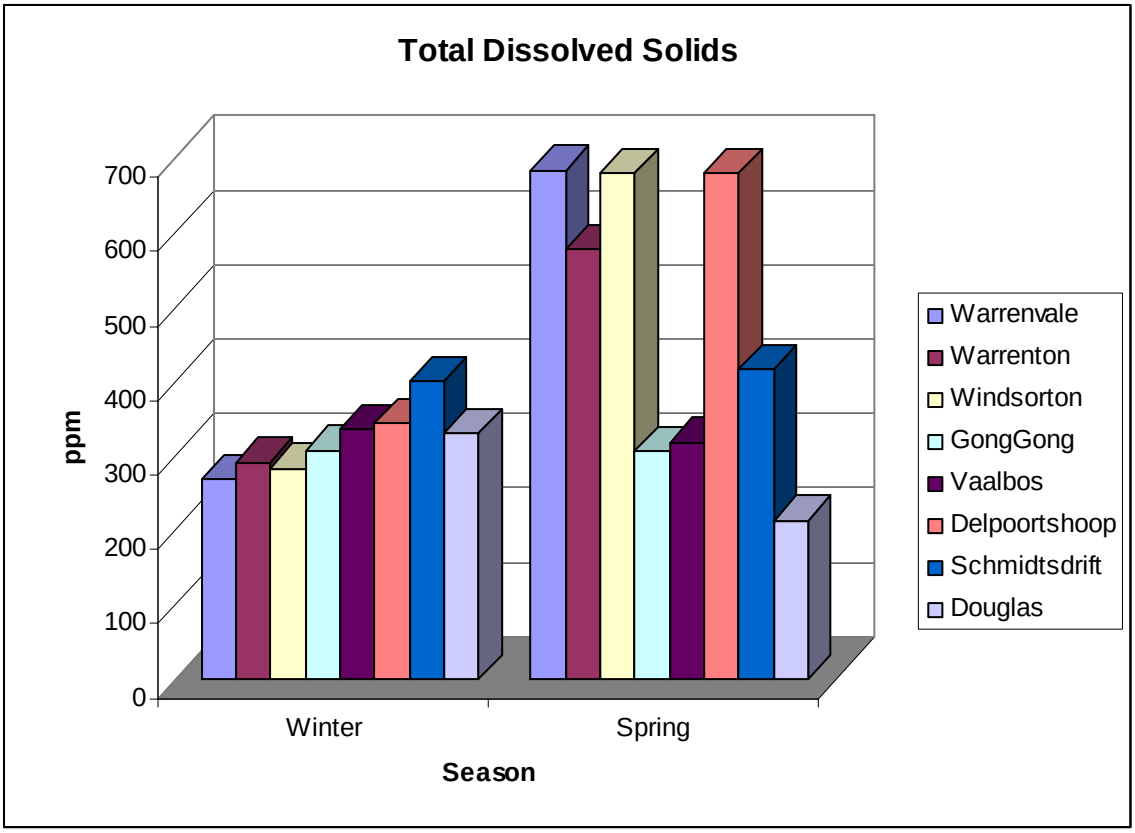

Fig 14: TDS concentrations at the eight sampling sites.

During Winter the Total Dissolved Solid (TDS) concentrations ranged from 269 ppm to 345 ppm and did not exceed 400 ppm. In Spring the concentrations were high in Windsorton, Warrenvale, Warrenton, declined dramatically at Gong-Gong and Vaalbos and increased at Delpoortshoop and declined again at Schmidtsdrift and Douglas (fig. 14). The high levels of TDS during this study can be ascribed to both natural and anthropogenic activities. Within the observed range, TDS concentrations should not have a limiting effect on aquatic biota.

5.2 Aquatic Macroinvertebrates

The SASS 5 results are presented in **Table 3** for the invertebrates sampled and were interpreted according to Figure 10 and Table 1.

Table 3: SASS 5 results in the Lower Vaal River during Winter 2009 and Spring 2009.

	Winter Survey (June 2009)		PES	Spring Survey (November 2009)		PES
Warrenvale	SASS Score	62		SASS Score	87	
	Taxa	15		Taxa	17	
	ASPT	4.1	D	ASPT	5.1	B
Warrenton	SASS Score	66		SASS Score	76	
	Taxa	15		Taxa	15	
	ASPT	4.4	C	ASPT	5.1	B
Windsorton	SASS Score	91		SASS Score	74	
	Taxa	15		Taxa	13	
	ASPT	6.1	B	ASPT	5.7	B
GongGong	SASS Score	69		SASS Score	71	
	Taxa	12		Taxa	12	
	ASPT	5.8	C	ASPT	5.9	B
Vaalbos	SASS Score	70		SASS Score	100	
	Taxa	12		Taxa	19	
	ASPT	5.8	B	ASPT	5.3	B
Delpoortshoop	SASS Score	71		SASS Score	75	
	Taxa	13		Taxa	16	
	ASPT	5.5	B	ASPT	4.7	B
Schmidtsdrift	SASS Score	76		SASS Score	65	
	Taxa	17		Taxa	12	
	ASPT	4.5	B	ASPT	5.4	C
Douglas	SASS Score	47		SASS Score	38	
	Taxa	10		Taxa	10	
	ASPT	4.7	E/F	ASPT	3.8	E/F

In Winter the present ecological category of Warrenvale was D and improved dramatically to B category in Spring. The ecological category of Warrenton was C during Winter and improved slightly to B category in Spring. In GongGong the ecological status was class C and B during Winter and Spring respectively. The most suitable biotopes for aquatic invertebrates at this site were stones-in-current and out of current mostly covered with algae. The stream had little marginal or instream vegetation and the riparian vegetation has been removed by alluvial diamond diggings. The SASS score in Windsorton was fairly high in Winter, making it to be in category B and declined slightly in Spring. The ecological category of Vaalbos was B and it improved considerably during Spring. In Delpoortshoop was B category during both seasons (Winter and Spring). In Schmidtsdrift the ecological category was B in Winter and declined to C in Spring probably due to poor water quality emanating from Vaal and Harts River. The Douglas site was very poor (Class E/F) during both seasons. These can be ascribed to unsuitability of biotopes (no gravel sand and mud, stones in current and out of current covered with algae), impacted water emanating from the main system and its tributaries (Riet and Harts River). Though there were few significantly sensitive species present, there was a good representation of taxa at all sites except in Douglas.

The low scores of integrity habitat assessment indicated that the habitat integrity at some sites was poor and was therefore regarded as the limiting factor. The results from the SASS5 survey at all the sites resulted in overall good to fair ecological integrity (Class B/C) according to the ecoregions described by (Dallas 2007). The presence of few sensitive taxa such as Heptagenidae, Tricorythidae, Atydae, Leptophilibidae indicated that water quality was good, and this was reflected in a high Average Score Per Taxon (6.1). The aforementioned families are sensitive to water quality changes, flow modification, turbidity and substrate conditions.

6. Conclusion

The aquatic macro-invertebrates at all the sampled sites were found to be in fair to good condition, but the habitat in places was poor and the water quality was sometimes poor. The high abundance of invertebrates in the soft-bottom substrates were dominated by the tolerant Chironomidae, Huridenea and Oligochaeta and were indicative of nutrient enrichment in the Lower Vaal River. It is recommended that a more intensive study be conducted in this river system, so as to accomplish better baseline information of expected conditions for rivers of the region. It is generally believed that macroinvertebrate assemblages are best characterized by combining data collected from different seasons. Combining seasonal data increases the taxa observed at a site in two ways. Firstly, as with any increased sampling effort, more habitats are sampled and therefore more taxa are collected. Secondly, because of the variability in life cycles and turnover in different macroinvertebrate groups, some taxa are collected in one season but not in another. This information would furthermore be pivotal for management purposes to prevent further degradation of this important aquatic ecosystem.

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RIVER HEALTH BIOMONITORING IN THE FREE STATE

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Abstract
Biomonitoring in the Free State is done as part of a BloemWater contract on rivers (Modder, Riet and Caledon) where the Water Board has an influence through abstraction or where the quality of water abstracted is impacted on by other entities such as the municipality or local residents. Other projects are Water Research Commission projects where the Seekoei River in the Northern Cape is being sampled twice a year and other rivers in South Africa (Mokolo, Swartdorings and Touws Rivers) are being sampled on a once-off basis.
A six weekly monitoring programme is followed in the Modder, Riet and Caledon Rivers where water chemistry, algae and macroinvertebrates are sampled. Fish, geomorphology and riparian vegetation are monitored on a year to three year basis.
Ten indigenous fish species are known to occur in the Modder River including the Vaal-Orange smallmouth and largemouth yellowfish. The fish assemblage in the Modder River is dominated by *Tilapia sparrmanii* and *Labeo capensis*.
In March 2007 the Fish Response Assessment Index (FRAI) indicated that the river was in a C/D (fair to poor) class in the Upper Modder River, and a C (fair) class in the Middle and Lower Modder River. No largemouth yellowfish (*Labeobarbus kimberleyensis*) were sampled although they were expected to be present and the smallmouth yellowfish (*Labeobarbus aeneus*) were sampled in all the reaches of the river. There does appear to be a decline in the abundance of smallmouth yellowfish from 1973 to 2007.
The condition of a river ecosystem reflects the ability of the river to function normally. In other words, the river should be able to process its ecological resources and supply its ecological products (in this case good quality water), but it cannot in the case of the Modder River. So the downstream users are at a disadvantage. This places a responsibility on the managers of water resources in the metropolitan area of Mangaung.

KWAZULU-NATAL REPORT

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Introduction

The major challenges facing yellowfish in all province, to a lesser or greater degree, is a combination of pollution, water abstraction, poaching, alien fish and land transformation. Climate change is the ultimate conundrum that affects all of our biodiversity and ultimately humanity. In a sense humanity has overstepped the threshold for a sustainable (peaceful) existence on earth as the world's population increases exponentially against a background of dwindling natural resources. Yellowfish are not exempt from these environmental pressures and now face a much greater enemy in terms of acid mine drainage. Governments need to heed the call of the environmental lobby as this problem is going to have a severe impact on future biodiversity and food security. Taking this rather bleak scenario into account, my presentation is going to focus more on the progression of land transformation currently taking place in KZN.

Land Transformation

Land transformation is a major problem and gives a rise to and momentum to a host of environmental problems, including habitat change and the spread of alien invasive organisms, which prosper in changed conditions, often ousting indigenous biota in the process. KZN has a well developed systematic conservation plan that takes into consideration broad landscape issues. The provinces support a high population of people in extensive urban, peri-urban and rural settlements. Much of the landscape is now covered in sugar cane and commercial forestry at the direct expense of wetlands, grasslands, forests and associated biota. Centre pivots have become commonplace in our commercial farmlands. The slides show the rate of transformation taking place in the province based on land use practices. KZN Wildlife has a committed team of Conservation Planners that deal with a heavy workload of development applications. This team draws heavily on our Systematic Conservation Plan for guidance, and in many instances, depend on the expert knowledge from our group of dedicated scientists based in our Biodiversity Division. Although understaffed in terms of our provincial responsibility, KZN Wildlife still boasts a core of dedicated conservation professionals and I remain proud to be associated with them.

A map derived from KZN's Systematic Aquatic Conservation Plan was presented to the audience showing KZN Wildlife's formally protected areas (Conserved Layer) together with areas outside of protected areas that are earmarked as being important in terms of the biodiversity assets, other areas of lesser conservation and finally areas that are largely excluded from the plan due to major transformation of the landscape. The aquatic map was compared to KZN Wildlife's overall conservation layer which highlights ecosystems that are considered to be irreplaceable in terms of their current biodiversity assets, shows the extant of all land under formal protection and identifies currently transformed and untransformed landscapes. Slides were then shown to the audience regarding identified altitudinal corridors that are important for the connectivity of all ecosystems. A suite of free flowing rivers was identified allowing the unhindered passage of aquatic organisms between the freshwater and estuarine biomes, that included the Mkuze, Black Imfolozi, Buffalo/Thukela, Umvoti, Mkomazi, Mzimkhulu and Mtamvuna river systems. A slide was presented on KZN's Biodiversity Plan and its influence on

Biodiversity Sector Plans, IEM Scoping, Protected Area Asset Identification, Bioregional Plans, Protected Area Land acquisition, Land Stewardship and Conservation Agreements.

Concerns were expressed about the latent threat of Inter-Basin Water Transfer Systems (IBWTS), specifically the Drakensberg Pumped Storage Scheme (DPSS) involving Sterkfontein (OFS) and Kilburn Dam (KZN). A new development is the Ingula Pumped Storage scheme (IPSS) located at Besters near Ladysmith. Both systems are capable of polluting the genetic integrity of KZN's freshwater fish lineages. Environmental officials of Eskom, in close collaboration with KZN Wildlife, have appointed private consultants to conduct further research into the distribution of Orange/Vaal and KZN freshwater species in the upper Thukela basin, pressure testing (50 bar) on indigenous species that pass through the generation shafts, thermal shock on fish and eggs, translocation and the use of piscides like rotenone.

To the best of my knowledge there are no yellowfish conservancies in KZN. KZN Wildlife supports the moratorium that yellowfish should not be trans-located within and between provinces. Emphasis should be placed on sports fisherman pursuing yellowfish within their natural habitat. No formal monitoring programmes are in place for yellowfish species in this province. At current no formal research projects are currently in place or have been proposed for the three yellowfish species in KZN.

THE KWAZULU-NATAL RIVER DISTURBANCE INDEX

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Abstract

The River Disturbance Index (RDI) surface is a first attempt in KwaZulu-Natal (KZN) to try and determine, via a desktop analytical procedure, the relative condition of our river network(s). Based in large part on a paper by Stein *et al* (2002)2, the approach takes into account both the local and cumulative effects of terrestrial surface impacts of neighbouring and upstream watersheds (via the development of the Catchment Disturbance Index – CDI), as well as the impacts of in-channel modifications (both direct via stream channel manipulation and indirect via impoundment via the Flow Regime Disturbance Index - FRDI). Each of these facets are initially addressed as independent factors, but are later combined (equal weighting) to establish an overall assessment of river (segment and system) condition.

To facilitate this analysis, watershed and river network coverage's were developed for KZN province using the 90 SRTM (version 3) data. Once identified, the Mainstem Rivers were broken up into segments at points of intersection. Watersheds for each river segment were then established, along with their inter-connectivity.

The primary data source utilised in the development of the CDI was the 2005 Modified KZN Land Cover. Other complimentary datasets were also employed, namely the roads coverage from the Department of Transport, telecommunications and electrical infrastructure from Telkom and Eskom respectively, and mining, sand-mining and point pollution data, all obtained from a variety of different sources. Whilst it is acknowledged at the onset that a number of the coverage's are incomplete, they do represent the most accurate information available at the time of the assessment.

The various land use types were combined into a number of sub-categories; namely Pollution, Settlement, Land Use and Infrastructure. The land class categories housed in each sub-category were ranked relative to one another on a scale from 0 to 1.0 as per the level of impact that each imparts onto its surrounding drainage systems. In the case where a number of categories were present, decision support software was used to establish the ranking value for each of the categories concerned.

In addition to establishing weighted rankings for each land use category, distance thresholds were also established. These thresholds, determined based on expert opinion, indicate the range (as water flows) from a river segment within which a category is expected to impart a maximum impact on that segment i.e., if a gravel road is located within 500m (as water flows) from a river segment, the full weighting ascribed to this category is used. However, should the category fall outside of the threshold boundary, the weight is reduced as a function of increasing distance for the river segment. The weightings, and resultant influences, of all categories were modified in this manner.

2 Stein, J. L., Stein, J. A. and Nix, H. A. (2002**) Spatial analysis of anthropogenic river disturbance at regional and continental scales: identifying the wild rivers of Australia.** *Landscape and Urban Planning* **60**: 1 – 25.

The final category employed was that of impoundment. Unfortunately, no information regarding levies or canals was available at the time of the assessment and has thus not been considered. Instead, the impoundment impacts were realised using the Ezemvelo KZN Wildlife dam coverage, with increasing impact weightings being assigned to impoundments of increasing size (~ surface area). In the case of both the CDI and FRDI, the cumulative effects of each of the indices components were calculated for each watershed on a cumulative basis. The RDI was then calculated by combining the CDI and FRDI indices (assigned an equal weighting).

It is recognised that this is a desktop study, and field work to either support or contradict the findings has yet to be initiated. It is also recognised that improved data sources would greatly improve the accuracy of the study, particularly the data defining point pollution and mining activities. In future, it is envisaged that other influencing factors will also be considered, though their inclusion will be governed largely by data availability. Some examples include a) the influence of ground water on river flow, b) extraction influences (both from the rivers and via boreholes), c) inter-basin transfer scheme influences, and d) additional artificial inputs (e.g. storm water outflows into rivers that would not normally receive this flow originally). In the short term, however, the index will be re-run using the new 2008 KZN Land Cover (expected to become available by the end of 2010)

WESTERN CAPE REGIONAL REPORT

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1. General introduction and aims of the Western Cape Yellowfish Working Group

The Western Cape Province is home to three indigenous yellowfish species. These are the Clanwilliam yellowfish (*L. capensis*), the Clanwilliam sawfin (*B. serra*) and the Berg-Breede River whitefish (*B. andrewi*). The first two species occur in the Olifants river system while the whitefish presently only occurs in the Breede River system, having gone extinct from the Berg River. In addition to these three species, the Smallmouth yellowfish (*L. aeneus*) is known to occur in the Gouritz river system where it is listed as an invasive alien species. The conservation status of *L. capensis* is Vulnerable, according to the most recent IUCN criteria, while *B. serra* and *B. andrewi* are listed as Endangered.

In an attempt to ensure conservation of the species and encourage joint conservation efforts between the private and public sectors, the Western Cape Yellowfish Working Group (WCYWG) was formed and has identified the following aims: (1) to protect healthy populations of yellowfishes presently found; (2) to restore depleted populations in appropriate sections of the Doring, Olifants, Berg and Breede systems; (3) to maintain and improve habitat and riparian zones in river systems where yellowfish are found, (4) to stimulate research and improve awareness of the species.

In a recent joint project between the WCYWG and CapeNature, dams in the upper Ratels River catchment were stocked with yellowfish and sawfin in March 2010. Fish were sourced from the Beaverlac dam and the lower Ratels River and stocked into two dams in the upper catchment. With the development of the Indigenous Fish Utilization policy and the associated species management plans, clear communication is needed between WCYWG and CapeNature for achieving conservation objectives identified in these documents.

2. CapeNature policies, permits and species management plans

CapeNature in the process of finalizing an Indigenous Freshwater Fish Utilization policy. The aim of this policy is to contribute to the conservation of indigenous fish species by guiding research and stocking applications. This policy is relevant to yellowfish as it will determine where and when restocking will be allowed, and will therefore have implications for recreational angling. The above-mentioned policy will be used concurrently with species-specific management plans which are in the process of being developed. Dean Impson is responsible for developing a large cyprinid management plan for the Western Cape, while Martine Jordaan will focus on the smaller species, mainly redfins and Cape galaxias. The short term goal is to develop action plans where the main threats to the species are identified and management actions are formulated and implemented, while the long-term plan is to develop species management and recovery plans according to the formal Norms and Standards for Biodiversity Management Plans for species (BMP-S) as specified in the National Environmental Management: Biodiversity Act (NEMBA) regulations. The first BMP-S will be developed for the Tradouw River redfin in a joint project between SAIAB and CapeNature.

The CapeNature permit system is in the process of being updated in order to ensure consistency in the permitting process and implement the NEMBA alien species regulations and associated national zoning scheme. CapeNature is also in the process of developing an alien fish utilization

policy which will be used in conjunction with the NEMBA zoning maps and will serve to guide, amongst others, aquaculture and fish harvesting projects.

3. River Health Program (RHP)

The River Health team at CapeNature has successfully conducted a survey of the greater Breede River water management area in 2008/2009 and has completed the technical report for the survey. The contract with CapeNature as implementing agent for the RHP was, however, not renewed by the Department of Water Affairs (DWA) at the end of March 2010 and the future of the RHP in the Western Cape has not been decided. It is likely that the RHP will in future be implemented by the Resource Protection section of DWA.

4. Collaboration with Northern Cape Nature Conservation - Oorlogskloof fish survey

A five-day survey of the Oorlogskloof River was conducted to determine the health and conservation status of the indigenous fish species occurring in the Oorlogskloof Nature Reserve. The results indicated that all the indigenous species (Clanwilliam yellowfish, Clanwilliam sandfish (*L. seeberi*), Chubbyhead barb (*B. anoplus*) and Clanwilliam Sawfin) were present in the expected numbers, with the exception of the yellowfish that were caught in lower numbers than expected. The reason for this is likely the method of sampling as only a seine net was used and the sample of fish that were caught were likely not completely representative of the resident fish community. The sandfish and sawfin were in good health but most of the yellowfish and barbs were infested with various ectoparasites. All species caught, with the exception of the yellowfish, showed a good size range distribution which is an indication of successful recruitment in these species.
The lower reaches of the Oorlogskloof River are invaded by bluegill (*L. macrochirus*) and smallmouth bass (*M. dolomieu*) up to a waterfall barrier, while a new invasion of banded tilapia (*T. sparrmanii*) was observed at the upper end of the reserve. The source of introduction is strongly believed to be the Nieuwoudtville town dam that had overflowed during a recent very severe winter flood. This example illustrates clearly the dangers of stocking alien species into sensitive catchments as these dams often serve as sources of new introductions.

5. Rondegat River Rehabilitation Project

The proposed date for implementation is February 2011 and the major constraint that prevented implementation in 2010 is the construction of a barrier weir at the lower end of the Rondegat River to prevent re-introduction of alien species from Clanwilliam Dam. A stakeholder meeting involving officials from DWA, CapeNature and Cape Action for People and the Environment (CAPE), as well as local landowners, was held in March 2010 to determine the way forward.
Actions that are required prior to implementation of the alien fish removal include the following:

- Improvement of existing weir & subsequent construction of new barrier weir in the lower Rondegat River. The construction of the new weir will likely form part of a bigger DWA project for raising the Clanwilliam Dam wall.
- Finalization and implementation of monitoring protocols and identification and finalization of treatment sites and protocols.
- Finalization of the way forward for alien vegetation clearing in catchment – landowner engagement critical

6. GCBC Aquatic Stewardship Project

This is a two-year contract position with the aim of creating awareness of aquatic conservation priorities in the Greater Cederberg area with the focus being on fish conservation initiatives.

The rivers included in the project are the Noordhoeks, Thee, Ratels, Oudste and the Twee River, as well as the upper Olifants River Gorge.
The project aims to ensure effective communication and collaboration between riparian landowners, CapeNature, DWA, Department of Agriculture, WWF, and Water Users Associations. The following are the priorities for the project for 2010/2011

- Securing adequate funding for alien vegetation clearing in priority areas
- Initiating a Water Neutral project for wine industries and developing Citrus Best Practice Guidelines for the citrus industry in the area
- Signing up stewardship contracts with riparian landowners in priority areas
- Producing status reports on each of the priority tributaries in the area
- Hosting awareness days for landowners and farm workers regarding sound land use practices and the need for the conservation of riverine ecosystems

7. The Way Forward

1. Finalization of the Freshwater Fish Utilization Policy and Large Cyprinid Management Plan – clear communication is needed with stakeholders to ensure successful implementation of conservation objectives set out in these documents.
2. Ensure objectives are met for successful implementation of the Rondegat project in 2011
3. Initiation of BMP-S for Tradouw River redfin and other species
4. Initiation of a catchment management plan for Oorlogskloof in a joint project with Northern Cape Conservation Department
5. Maintaining the good momentum with GCBC Aquatic Corridor project

DEVELOPMENT OF A LARGE INDIGENOUS CYPRINID MANAGEMENT PLAN FOR THE WESTERN CAPE PROVINCE

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Introduction

CapeNature and interested stakeholders are in the process of preparing a management plan for the large indigenous cyprinids of the Western Cape. This is because the province has South Africa's largest concentrations of threatened large and small cyprinid species. The small species are mostly redfins (*Pseudobarbus*), whereas the large indigenous cyprinids (LIC) comprise five species belonging to three genera; *Barbus, Labeo* and *Labeobarbus* (Table 1). This Management Plan will focus on the latter group. All five species were widespread and abundant in their natural distribution range prior to the introduction of predatory alien fishes into these rivers in the 1900s. The species with the most severe impact have been the North American basses, especially the smallmouth bass *Micropterus dolomieu*, which is now widespread in the river systems where the indigenous large cyprinids occur.

Table 1: Large indigenous cyprinids of the Western Cape

Species	Common name	Distribution	Conservation status
Barbus andrewi	Berg-Breede whitefish	Berg and Breede River systems	Endangered
B. serra	Clanwilliam sawfin	Olifants-Doring River System	Endangered
Labeo seeberi	Clanwilliam sandfish	Olifants-Doring River System	Critically Endangered
Labeo umbratus	moggel	Gourits River System	Least Concern
Labeobarbus capensis	Clanwilliam yellowfish	Olifants-Doring River System	Vulnerable

Aims of the Management Plan

One of the key aims will be to down-list the conservation status of all species within a specified period through appropriate management actions by conservation authorities and interested stakeholders. This will require restoring self sustaining populations in priority rivers by controlling the population of predatory non-native species in the native range of the LIC species, eradicating alien fish species in selected areas and improving habitat quality through implementation of Environmental Flows, alien plant control projects and Aquatic Stewardship programmes.

Key principles of the Plan

- Prevention of the extinction of any key populations of the LIC species
- Protection of critical habitat required for the LIC species
- Conservation of the LIC species within their natural distribution ranges
- Prevent further translocations of the LIC species
- Promote an interest and appreciation in the LIC species through more effective education and awareness programmes for riparian land-owners and anglers
- Downlist the conservation status of all LIC species within 20 years through the implementation of appropriate habitat rehabilitation, non-native species control, stakeholder involvement and other management actions
- Limit the stocking of LIC species through the implementation of a rigorous permit system

The Year Ahead

A final version of this management plan will be presented at the next yellowfish conference in 2011 in Mpumalanga.

Acknowledgement

Sean Marr, Ernst Swartz and Martine Jordaan are thanked for guidance and comments in the current early stages of preparing this management plan.

ADOPT-A-RIVER PROGRAMME PROGRESS REPORT

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The Department of Water Affairs (DWA) has initiated an "Adopt-a-River" programme as a means of creating awareness among South Africans of the need to care for our scarce water resources and to actively participate in the protection and management of our water resources.

This programme was initiated when a question was asked in Parliament whether South Africa's rivers were healthy and fit for use. Some Members of Parliament volunteered to adopt a river and serve as patron for those rivers, as a sign of their own commitment in protecting the health of our rivers.

Implementation of the Programme is following a phase approach with the Phase I & II completed in 2007 and 2009 respectively. Products of the Programme thus far are available at: http://www.dwaf.gov.za/iwqs/rhp/naehmp.asp, follow the Reports & Manuals link. At the end of Phase II the Programme was nationally launched in Eerste River in the Western Cape Province on the 17th of March 2010. The Launch was well attended and the Deputy Minister of Water & Environmental Affairs, Honourable Rejoice Mabudafhasi addressed all present including learners and encouraged them to take care of environment for their wellbeing and to conserve the natural resources. The Stellenbosch Local Municipality signed a pledge to adopt the Eerste River. The next immediate phase of the Programme is Pilot Testing. The programme design and the implementation plan will be tested in selected rivers and the development of tools, techniques and training material will take place on an ongoing basis, as well as information and task sharing with interested parties.

For more information about the Programme, please contact Nadene or Ramogale at +27(0)12 808 9500 or Helen Moremong at +27(0)12 336 7349.

WHERE ANGLING AND CONSERVATION MEET - WITH SPECIAL REFERENCE TO ARTLURE[1] ANGLING[2]

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INTRODUCTION

For most people a dam or river is just another piece of water - needed for drinking water, agricultural purposes or recreational uses - boating canoeing, fishing, etc. Many people do not realise that water actually hosts ecosystems. It is the habitat of thousands of species that live in the water. Big ones like fish, or small ones like invertebrates. Water in dams and rivers are game reserves under the surface of the water.

ANGLING

Angling is a way to pierce that curtain
To unveil the mystery…
A way to see what is under the surface.

Because of this mystery anglers keep on coming back - to catch that bigger one, or to catch that missing fish species.
The passion of anglers enjoying their sport.

Some angling facets, concentrating on certain species, e.g. going for the big carp, with boilies.

Bass anglers searching for the bucket-mouth big bass.

Others, like fly fishermen are targeting that big trout or yellow.

Artlure anglers are aiming for the most possible fish species to catch.

In order to succeed, whether you are fishing with bait, fly or lure - requires a lot of skill and endurance. You must get to know as much as possible about the fish species you are hunting. The conditions, the seasons, the water temperatures, the species, the ecosystem, the habits, angling techniques, angling equipment, etc.

I believe every angling facet has its own joys, catching fish.

However, without being biased, there is no other angling facet that requires more skill than artlure angling - catching all the possible fish species available in a piece of water. Because artlure angling is species angling, it teaches you what is really going on under the water surface. You need to know the species, the ecosystem and apply your knowledge to catch these species. Therefore, artlure anglers are expert specie anglers.

1 Artificial lure angling
2 Report prepared by Bernard Venter, trustee Eco-Care Trust, National Conservation Officer SASACC and dedicated artlure angler.

CONSERVATION

But what has angling to do with conservation?

If you don't know the behaviour patterns of fish species, you won't catch them.

Catch and release has become a major concern for many anglers.

Because of the passion for their sport, anglers are a huge source of valuable information on fish species.

Eco-Care Trust[1] used this opportunity, the knowledge of especially artlure anglers to compile a list of fish species in certain bodies of water.

We are the first to admit that this is most probably not reckoned as pure scientific research. We don't use nets, or electric shocking methods to find the species.

However, with the assistance of volunteer artlure anglers with well equipped boats, we often have the numbers participating in an event and because of the eagerness to find all possible fish species, and knowledge of ecosystems, etc the information that we receive is valuable. This data often includes more detail than just the presence of fish species. Information on water quality, fish kills, unlawful netting, mammals, birds, reptiles, etc, is gathered by artlure anglers in an aquatic conservation project under the auspices of Eco-Care Trust.

State departments in many instances don't have the human resources to patrol and gather necessary information of what is happening at our dams and rivers.

Anglers and NGO's can do much to fill this gap.

Eco-Care Trust[2] compiled aquatic monitoring reports[3] on certain dams and has forwarded it to DWAF, DEAT, universities, conservation authorities, media, etc. to use.

Here is a synopsis of some of the information gathered in some of the dams:

- Vaalkop Dam (NW) - all the tilapia species are abundant. Yellowfish - no smallscale or largescale yellowfish caught and no papermouth yellowfish either. Previously good numbers of papermouth yellowfish occurred in the dam. A number of years ago largemouth bass occurred in the dam, currently no bass found in the dam. Very large silver catfish of 1 kg were caught, but in limited numbers. Crocodiles have disappeared and the number of hippos dwindled.
- Klipvoor Dam (NW) – Carp, barbel and silver catfish are abundant in the dam. No bass or canary kurper and limited numbers of vlei kurper. The dam is in the same river system as Roodeplaat Dam which has good numbers of largemouth bass and canary kurpers. No smallscale or largescale yellowfish caught and no papermouth yellowfish either. Good number of hippos but no crocodiles observed.

- Arabi Dam[4] (Mpumalanga) - very good species diversity. The numbers of largemouth bass exploded in the dam and might have a negative influence on small species. Still good numbers of small papermouth yellowfish. No canary kurper. Silwer carp abundant.

Worrying factor that papermouth yellowfish are becoming a scarce yellowfish species in many dams like Vaalkop, Klipvoor, Roodeplaat, Rustderwinter, Hartbeespoort and even Loskop.

- Vaal Barrage (Gauteng) - Alien species like largemouth bass and carp (including grass carp) abundant in the area, with no largemouth and smallmouth yellowfish being caught. Small species like ghielemeintjies, vlei kurper and dwarf kurper in limited numbers and found in difficult structures, eg small cracks and holes in between rocks.
- Albert Falls (KZN) - The influence of largemouth bass on certain species is notable. Almost no ghielemeintjies and dwarf kurpers are found in the dam.
- Misverstand Dam (WC) - The interesting effect of barbel, which is also not an indigenous species in the Misverstand Dam, on all bass species[5] is remarkable. Bass numbers declined and more difficult to catch in the dam due to the competition for food against barbel. No witvis has been caught during the Artlure National Championships in 2007.

However, in order to succeed we need information on a much broader scale. Funds are the main problem to expand the aquatic monitoring projects.

On a broader scale, Eco-Care Trust has used the eyes, ears and feet of anglers to monitor many of our dams and give reports of fish kills, water pollution, and unlawful gillnetting and alien invasive fish species to relevant State Departments.

Very interesting statistics can be gathered from open angling competitions[6] regarding fish stocks and weights of different fish species in different dams[7].

Organised angling[8] aims to make it compulsory that weigh-in results are kept and forwarded to SANBI.
Organised angling has played an active role assisting SANBI in the mapping of fish for purposes of the Alien and Invasive Species Regulations.

CONCLUSION

Anglers are a tank full of knowledge. Together with the knowledge of scientists we can make a difference in aquatic conservation.

It is time to take hands to conserve our angling waters!

3 Eco-Care Trust is an environmental NGO working in the field of water and aquatic conservation.
4 In consultation with Envass, an environmental monitoring company.
5 See eg Vaal Barrage Report 2008; Vaalkop Dam Report; Klipvoor Dam Report.
6 Also known as Flag Boshielo Dam
7 Largemouth, smallmouth and spotted bass occur in the dam.
8 E.g Bloemhof Dam Bonanza.

GUIDELINES FOR THE DEVELOPMENT OF CONSERVATION MANAGEMENT PLANS FOR FRESHWATER FISH

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Water Research Commission funding was granted to develop a conservation framework applicable to threatened fish species of southern Africa's highly diverse and important freshwater ecosystems. A suitable species was chosen that could serve as a candidate species for developing the methodology. The selection criteria included that the species should be listed as threatened, sensitive to environmental variables and that its perceived population size should be large enough to accommodate research and sampling. Opsaridium peringueyi proved to be suitable and was subsequently selected as the test species for the study. An attempt was made to use the widest possible range of methodology and procedures. This allowed the team to produce a practical conservation framework with different options, i.e. comprehensive versus rapid planning methodology. The conservation framework describes a comprehensive process that could be followed to develop a conservation plan for a threatened fish species

INTRODUCTION

The conservation of biodiversity in southern Africa's highly diverse and important freshwater ecosystems is an important but often neglected conservation management priority. Dudgeon *et al.* (2006) grouped the main threats to freshwater biodiversity under five categories; these are over-exploitation, water pollution, flow modification, destruction or degradation of habitat, and invasion by exotic species. A substantial number of fresh water fish species from southern Africa are listed in the IUCN Red Data List (Darwall *et al.* 2009). Skelton, (2001) indicated that apart from the species in the IUCN Red List many other fish species in Southern Africa may be threatened.

It is thus important that sufficient tools are available to conservation organizations which should ensure that effective conservation management towards the survival of threatened fish species is achieved.

Water Research Commission (WRC) Project funding was granted to a group of researchers, with the University of Limpopo as lead organization, to develop a conservation framework for threatened fish species. It was envisaged that this framework should be applicable to southern African conditions and should lead to effective conservation management. The conservation framework developed for *Opsaridium peringueyi* during the project could serve as one of the tools for effective conservation management of threatened fish species. In the project a suitable species was chosen that could serve as a candidate species for developing the needed methodology. The selection criteria included that the species should be listed as threatened, sensitive to environmental variables and that its perceived population size should be large enough to accommodate research and sampling. *O. peringueyi* proved to be suitable and was subsequently selected as the test species for the study. An attempt was made to use the widest possible range of methodology and procedures. This allowed the team to produce a practical conservation framework with different options, i.e. comprehensive versus rapid planning methodology. The conservation framework describes a comprehensive process that could be followed to develop a conservation plan for a threatened fish species.

IDENTIFICATION OF THREATENED SPECIES

The need to develop and implement conservation measures to save a species from possible extinction is usually the outcome of observations of a medium to long term decline in population size of a species. This decline can be the result of cumulative factors (i.e. degradation of habitat by development), or a single disastrous event (i.e. pollutant spill). For cumulative factors the IUCN Red data list is normally a good indication that a species might need special intervention (IUCN, 2009). In the case where a single event causes population decline it might be that the species is not listed as threatened but needs protection measures to be saved from extinction in a certain geographical area (i.e. river system).

Although the need for a conservation plan is initiated when a certain species is threatened by extinction, the plan normally addresses the whole array of threats causing the decline and the protection of one aquatic species could thus be beneficial for a whole aquatic system with associated species.

The IUCN Red Data List is a list providing species risk of extinction (IUCN, 2009; Skelton, 1993 and 2001). Each listed species would have been assessed against the IUCN Red List Criteria as the standard for assessing a species risk of going extinct within a specific time frame. A substantial number of fresh water fish species from South Africa are listed in the IUCN Red List (IUCN, 2009). Skelton (1993) indicated that apart from the species in the IUCN Red List many other fish species in southern Africa. The South African Institute of Aquatic Biodiversity (SAIAB) has recently reviewed the IUCN Red Data List for southern African Fish (IUCN. 2009). Vié *et al.* (2009) regards the Red Data Lists as a "key conservation tool" and stresses the importance of its use as a conservation tool.

The documents produced by Darwall *et al.* (2009), Kotze *et al.* (2006), Roux *et al.* (2008) and Vié *et al.* (2009) are excellent reading material that will assist the team to a great extent and is regarded as essential.

The conservation status and therefore the risk of extinction of the species are obtained from the IUCN Red Data List for Southern African Fish (IUCN, 2009). The process and use of Red Data lists is well described in Vié *et al.* (2009) and it is suggested that the publication should be utilized. Information regarding the sensitivity and specifically sensitivity rating as well as the frequency of occurrence of the species can be obtained from Kleynhans *et al.* (2007).

The next step is to assemble a planning team. Before this is done it should be born in mind that in addition to the development of the plan certain aspects of the selected species and the area should be researched. Based on this it is suggested that the team consist of a conservation planner, a GIS specialist and specialist scientists that can deal with the biology and ecology of the fish species as well as with the limnology, geomorphology and physical and chemical instream aspects of the identified river reaches or water bodies. It is also important that one or more of the specialist scientists have working knowledge of a) the currently employed freshwater monitoring, and specifically biomonitoring, techniques and indices and b) a rating of the impacts, both at an instream and river reach level.

TECHNICAL ADVISORY COMMITTEE

The function of this committee is to get a wide representation of specialists to assist the research project members with the project. The complexity of the water sector and the management of a river system or fish species necessitate a "broad" reference group. It should be noted that the main function of the committee is to guide and assist the researchers and not to manage the project. As the title indicates it should give sound technical advice to guide and ensure that the final product on the table is what was intended at the onset of the project. The advisory committee must share their expertise, experiences and lessons learned with the members of the project team.

LITERATURE SURVEY

Once the candidate species has been selected a literature survey has to be carried out. This literature survey should cover the historic occurrence data, species ecology and biology as well as information on aquatic systems in the known distribution range. This component of the exercise is invaluable and extremely important as it will not only supply the available knowledge but it will also highlight the "gaps" in the knowledge base. This latter aspect then becomes the basis for the in-depth studies on the biology of the species.

The main sources of historic distribution data is the data that are housed within the provincial environmental conservation agencies, the national department of environmental affairs (DWEA), universities, museums and in particular in the data records of the South African Institute of Aquatic Biodiversity (SAIAB). Care should be taken to access the data of historic environmental agencies such as for example the Transvaal Provincial Administration (TPA) or the Cape Provincial Administration (CPA). At the same time the personal data of the regional experts should not be forgotten and it is advised that a list of possible contributors be drawn up by the team and that a specific team member be tasked to access this data. At the same time the large number of published books and guides as well as theses should also be consulted. The following is an example of authors of these books, guides and theses that could be included:
Bell-Cross and Minshull, 1988; Crass, 1964; Gaigher, 1969; Jubb 1967; Le Roux and Steyn, 1978; Russell 1997 and Scott *et a*l. 2004.

With regard to the literature survey of the ecology and biology of the species the focus should be on published scientific articles and theses. However the list of authors mentioned above can again contribute greatly to the necessary data.

CURRENT SPECIES STATUS: SPECIALIST INPUT

This part of the project is a crucial component and is linked to other components within the overall process. Once the literature survey is completed it will be time for the project team to reflect on the extent of the problem and they must identify the way forward.

The best approach would be to have workshops with various regional role players to determine the current status of the species under consideration. The number of workshops to be held will mainly depend on the distribution of the species and can ranges for a single workshop that bring all identified experts where the species distribution rage is limited to the table or regional workshops if the distribution range is extended. If possible, a single workshop is regarded as the best option as it brings all the experts together and allows the discussion of possible problems that might occur further down the line. A typical problem that can occur will be the issue of rivers traversing more than one province or country. This latter situation will not only imply that different provincial legislations apply but also raises the question on who will be responsible for

implementation of the strategy once it is completed and what the issues will be with regard to sampling and transport of material.

The main aim of the workshop is to discuss the current distribution of the species and to gather and collate anecdotal information with regard to aspects such as: the best possible sampling sites, who to contact to get access to certain restricted areas, when to sample and any other relevant information. The workshops also offer an opportunity for expert inputs with regard to observed and perceived threats to the species, the habitat and other general aspects regarding the rivers, fish habitat and water quality. The information gathered will guide the research team to ensure that all possible avenues with regard to historic information, and in particular grey data" is exploited. To date access to grey data is one of the most difficult issues and should receive a great deal of attention.

The information gathered during the workshop forms the basis for further research strategies and surveys. The information will also feed into the "species distribution" component which is aimed at surveying historical sites and distribution ranges. The continued links with the experts is vital as the majority of them can also serve on the reference or technical advisory committee.

The data collected also forms a major component of the "Background report" which will serve as the starter document for the "Background report review workshop". While this process is ongoing, the research team can start with the specialist studies regarding *inter alia* the distribution, ecology, biology, breeding and population genetics of the species as well as the aquatic ecosystem.

RESEARCH AND FIELDWORK

Species distribution

Distribution from historic data

An attempt should be made to survey each of the historic sites to determine if the candidate species is still present. In cases where a number of sites are in close proximity in the same river stretch a representative site should be selected and then surveyed as the representative site. Where difficulties are encountered in locating the historic site, such as where the original coordinates in the historic data are not accurate, the site name can be linked with names on topographical maps. If this is not possible a representative site in the general area of the given coordinates can be identified and surveyed.

Surveys at the historic sites also provide the opportunity to collect additional data (See paragraph 6.2)

Over and above the aspects mentioned the data recorded should include the number and fork lengths of the candidate species collected at each site. This will be used to establish the population size. In addition all the species collected should be recorded in order to establish the fish assemblage composition and diversity at the site.

At each site the physico-chemical aspects such as electrical conductivity, total dissolved solids, temperature and dissolved oxygen should be determined and recorded.

The macro-invertebrates at each site are to be collected, using SASS5 protocol (Dickens and Graham, 2002) and identified on site. A sample can be preserved for a later, more intensive, identification.

Distribution through niche modelling.

GIS based systems like Biomapper and Maxent that uses locality data to predict habitat suitability as well as species distribution can be useful tools. These software packages use only presence data which is useful if no reliable absence data is available. Biomapper uses ecological niche factor analysis to compute habitat suitability maps and define the niche of a species according to a few important habitat variables (Hirzel *et al.* 2002). Maxent, on the other hand, estimates a target probability distribution of maximum entropy (i.e. that is most spread out or closest to uniform), subject to a set of constraints that represent the incomplete information about the target distribution (Phillips *et al.* 2006). The information about the target distribution presents itself as a set of real variables called "features". When Maxent is applied to presence only species distribution modelling, the pixels of the study area make up the space on which the Maxent probability distribution is defined (Phillips *et al.* 2006). Pixels with known species occurrence data constitute sample points and the features are different variables like vegetation types, slope, aspect, rainfall etc. The result for both the Biomapper as well as Maxent is a raster map indicating potential suitable habitat for a species.

These models can be useful when some historical locations are known and the possibility exist that the species might occur in other areas where little sampling has been done. The distribution maps generated can then be used to guide sampling/searching effort to find the species in unsampled areas.

Species biology

In any conservation planning exercise knowledge of the reproductive biology, feeding biology, migratory patterns, and habitat selection of the proposed indicator species is imperative.

It should be noted that the aspects listed below are only done if the literature survey shows that data with regard to these aspects is limited or does not exist.

It is also important that a team of experts be put together to do the in-depth studies. This team should consist of accredited specialist scientist in the relevant fields indicated below.

Habitat selection.

During the survey at each of the selected sites the following procedure should followed:

- The general data e.g. coordinates and macro dimensions of the site must be determined and recorded.
- The site must be investigated and the different velocity- depth classes (biotopes) identified (Kleynhans, 2007).
- A sketch map must be drawn on which these biotopes are indicated
- The fish are then collected in each biotope using collection methods described in Kleynhans (2007).
- The fish must be identified and recorded as the fish data per biotope. Where in the past voucher samples of the species collected had to be submitted to SAIAB the current trend is to rather supply SAIB with a good digital photograph that displays the distinguishing characters described in Skelton (2001). The site data should be submitted on the forms available on the SAIAB website
- In each biotope the following should be determined: substrate composition (Rowntree and Wadeson, 2000), cover (Kleynhans, 2007), depth, velocity.

Breeding ecology and biology

As part of the research on the reproductive biology the habitat preference of the various life stages, the gonadal development as well as the preparatory physiology prior to breeding of the species must be included. To obtain these results it is imperative that specimens be collected

monthly at a selected site. This should be a site where sufficient numbers of the species occur and care should be taken that only single specimens of adult fish are collected. The following are regarded as important aspects and should be included in the research:
a) A visual observation, and classification, of the condition or classes of fat deposition (Nikolsky, 1963) and gonadal development De Villiers (1991)
b) The condition factor that can be calculated as proposed by Nikolsky (1963) and Hamman (1974).
c) Seasonal reproductive trends that are determined by calculating the monthly Gonadosomatic Index (GSI) values (Glazier and Taber, 1980) and the Maturity Coefficient (MC) (Gaigher: 1969 and 1976). This is to be combined with the size frequency distribution method used by Gaigher (1976) to determine whether the species is a total or multiple spawner. Ova counts and size distribution of the ova will assist to establish the fecundity of the species, while the length at sexual maturity (Gaigher, 1969) supplies the necessary information on the size at which the species starts reproducing . The spawning chronology is determined by a combination of the GSI values and the ova diameters as suggested by Settles and Hoyt (1978).

Feeding biology
The basic functions of an organism, namely growth, development and reproduction, all take place at the expense of energy which enters the body in the form of food. Feeding is therefore one of the most important functions of an organism. The same specimens used in the reproductive study can be utilized for this component.
The specimens should be dissected and the stomachs removed and preserved. The stomach contents are routinely examined and the contents identified (Marriott *et al.*, 1997). The frequency of occurrence of the different prey items and index of dominance is determined and goes a long way to establish the preferred food of the species.

Migration patterns
Studies concerning the migratory patterns are time-consuming and the majority of information is based on expert knowledge and anecdotal information. It is therefore imperative that contact should be made with experienced local experts. However a large amount of this data has been compiled through workshops on the migratory behaviour of fish and is collated into a report (Bok *et al.* 2007).

Population genetics
This section of the study is specifically designed to determine the current genetic status of the species.
The objectives for a detailed genetic analysis of the species under investigation should be:
• To screen for the possible genetic structure within the species i.e. to investigate whether different genetic variants exist in geographically isolated populations. This is in line with the Evolutionary Significant Unit (ESU) concept, a concept now widely recognized in international and South African conservation programmes for all taxa.

• To determine the levels of genetic diversity in isolated populations. This data will serve to:

i. Identify the best possible source populations for any future breeding and augmentation programmes, since populations with the best levels of genetic diversity can then be selected for breeding.
ii. Assist in identifying populations, through establishing reduced levels of genetic diversity, that have experienced genetic bottlenecks as a result of human influences.

• To elucidate overall systematic relationships within the genus, if more than one species occur in the genus, to which the species belong.

• To use trends and patterns observed in the different populations, if applicable to the specific species, to formulate wider strategies for conservation of southern African freshwater fish species.

Aquatic system information

When the background information regarding the species, based on a literature survey and the research results, have been gathered it is advisable to compile a document that capture all information collected. Apart from serving as a reference document, it can form part of the documents for the review reports and later workshops. It can also form the basis of documents that can be prepared for other stakeholder groups.

Apart from feeding off the literature survey for information, this part will also gain from the "Technical advisory workshop" and the information gathered from the expert panel. This component will supply information to the sub project on "artificial breeding", as this information will assist with regard to water quality needs for breeding, temperature regimes during breeding and the juvenile stages and habitat requirements to a lesser extent.

This section of the project must gather critical data on the current status of the water quality in the total distribution range of the species and this must include aspects causing pollution and habitat modification. The information gathered must give direction to future monitoring needs for species conservation/protection and must guide the relevant authorities to put measures in place that will improve the water quality in general, but specifically to protect the endangered species under investigation.

It is important to look at current data bases to see what historic information is available, but it is also very important to include additional parameters. The fact that certain parameters are excluded doesn't mean it is not important. With new technologies and knowledge available, one can improve the understanding of the species, its needs and the impacts from the environment.

Data generated will feed information on a regular basis to the "background reports". The interpretation must be done on a regular basis, as this will assist all the other components dependent on the water quality information (listed above). It will also provide the research team with enough material to present to stakeholder and managing authorities. This could in turn initiate strategies to improve the water quality at an early stage.

Artificial breeding

Captive breeding is a conservation strategy that is widely used for the recovery and reintroduction of endangered fish species.

As little is known about the reproduction of many threatened species, research is needed to develop and standardize techniques for captive breeding. This expertise can then be used to help conserve threatened species. A captive breeding program can provide a further measure of protection against extinction and conservation of the gene pool of the species. Captive breeding is becoming accepted as one component of species improvement making the conservation effort more effective (Gipps, 1991).

Captive breeding has been used to help conserve populations of nearly 30% of the North American fish species listed as endangered. Indeed, captive breeding may provide a means to prevent extinction of threatened populations, especially during the early implementation of an environmental recovery and rehabilitation program (Arkush and Siri, 2001) providing a responsive, research-based mechanism for adaptive management.

BACKGROUND REPORT

Report

From the collected data a background report must be compiled. Over and above serving as a record of the work done the report is intended as reading material for the participants in the: a) the stakeholder workshop where the conservation plan is to be discussed and b) the red listing re-evaluation process, if deemed necessary.

It is suggested that the following aspects form part of the report:

- A summary of the literature survey regarding the selected species. Care should be taken to indicate the gaps in the existing knowledge and in particular its IUCN rating.
- The historic distribution of the species.
- The current distribution of the species based on the results of survey carried out by the team.
- A summary of the status of the rivers within the distribution range. Care should be taken to report on the geomorphology, available fish habitat, impacts and threats as well as outstanding features such as associated wetlands. In each of the rivers the probable/possible conservation areas should be identified and listed.
- Specialist scientific reports on various aspects regarding the selected species.

It is suggested that habitat selection, breeding biology and ecology, feeding biology, genetics as well as migration patterns are included. Although the "knowledge gaps" identified in the literature survey form the major gist of these reports, it is important that the reports should include summaries of the existing and available knowledge on each of the topics.

Background report review workshops

When the first draft of the background report is available the technical advisory committee and project team needs to review the report. This workshop is an important step in the process and its main aim is to evaluate progress during the preceding period and to determine if the set objectives have been achieved.

The review will determine if there are any gaps in information assembled, that needs to be addressed, or if the background report is ready for distribution to stakeholders.

Population viability assessment

Population habitat viability assessment (PHVA) is a procedure that allows managers to simulate extinction processes that act on small populations and therefore assess their long-term viability through the use of computer models (Clark *et al.* 1990). In both real and simulated populations, a number of interacting demographic, genetic, environmental, and catastrophic processes determine the vulnerability of a population to extinction (Clark *et al.* 1990). These four types of extinction processes are simulated in computer models and the effects of both deterministic and stochastic forces can be explored (Clark *et al.* 1990). In turn, the outcome of various management options, such as reducing mortality, supplementing the population, and increasing carrying capacity can also be simulated. The purpose of the Population and Habitat Viability Analyses

(PHVAs) is to help managers understand the risks facing small populations, to identify the relative importance of the factors that put a small population at risk, and to evaluate the effectiveness of various management strategies (Lacy *et al.* 1992). PHVA also offers managers a powerful strategic planning and policy tool when faced with limited financial resources. The PHVA modelling procedure does require certain types of data which in some cases is difficult to acquire or not available.

STAKEHOLDER WORKSHOP

Workshop

Once the background report is complete it must be distributed to all identified stakeholders. The intent is that all stakeholders are informed about the species and its status prior to stakeholder workshop. Stakeholders include interested and effected parties within the species important distribution areas. This would generally include implementing agents, government departments, water use associations, land owners, NGO's, local government and local communities.
The objective of the stakeholder workshop is to develop a vision, key result areas and goals for the conservation plan (BMP-S). During the workshop, actions as well as responsibilities are determined to reach the set goals.

IUCN Red-list

Since the IUCN Red Listing procedure makes provision for the re-assessment of species when new information becomes available, the status of the selected candidate species could re-evaluated if new information indicates a need for it. This decision is based on the findings of the specialists that are collated in the background report. If a re-evaluation is deemed necessary the items described below should be followed.

As part of the BMP-S development the re-evaluation should consist of a stakeholder workshop during which the conservation status of species is re-assessed as a population within the borders where the species occurs. It is also important to include the specialists in the process. These specialists should include local, regional and national freshwater specialists and particularly specialists in freshwater fish. The involvement of person/s with experience in the IUCN Red data listing process is imperative. If possible, the experts who did the most recent IUCN evaluation should be involved. Other stakeholders attending the workshop must include future role players in the conservation exercise such as aquatic experts from the involved provincial conservation agencies and regional representatives of the Department of Water Affairs. The specialist scientist and the other members of the research team should form the other participants attending the workshop.

Prior to the workshop all the identified participants should be supplied with a copy of the "background report.

The findings of the workshop should be collated in report format if the re-assessment shows a change in the current IUCN listing of the species. The findings should be incorporated in the current IUCN red list for fish species. Official procedures should then be followed to change the listing in the IUCN Red list.

BMP-S DEVELOPMENT AND IMPLEMENTATION

South African legislation (National Environmental Management: Biodiversity Act (Act 10 of 2004)) provides the opportunity and legislative support for the development biodiversity management plans for indigenous species (BMP-S). It has been shown that a conservation plan

for a fish species has the potential, not only to ensure the long term survival of the species, but several other aquatic species as well as ecological processes, river types and goods and services (Venter *et al.* 2009). Aquatic species conservation poses unique challenges mainly because of the uni-directional environment (rivers) they occupy. In most cases a threatened and sensitive fish species is widely distributed (in several river systems) but conversely localized in a few river reaches with suitable habitat quality.

Because of the large distribution range of the some species a BMP-S can make provision for planning and stakeholder involvement processes on evolutionary significant unit (ESU) or regional level. Management goals and associated key result areas (KRA) with specified actions to achieve these KRA's should be developed with associated timeframes. Provision could be made for developing focused subsidiary conservation plans for each ESU where geographical distance and area uniqueness warrants it.

In South Africa a set of norms and standards were developed which were adopted and approved by the Minister of Environmental Affairs and Tourism in 2008. The norms and standards set clear guidelines to the process and content of a BMP-S (Department of Environmental Affairs and Tourism, 2008). The BMP-S process makes provision for the conservation plan to be endorsed by the Minister and thus formally incorporated into legislation. This gives the conservation plan a more formal status which could prove beneficial for the successful implementation of the plan.

The purpose of the BMP-S is to ensure that the implementing agent has clearly defined objectives and activities to direct the protection of the species over a five year time horizon. The BMP-S indicates where the implementing agent and partners should focus its efforts in the five year project period. The BMP-S thus provides the medium-term operational framework for the prioritized allocation of resources and capacity in the implementation of the plan. It must be noted that the BMP-S focuses on strategic priorities rather than detailing all operational and potential reactive courses of action. While planning for some emergencies is part of the BMP-S, it remains possible that unforeseen circumstances could disrupt the prioritization established in a BMP-S. These could be addressed in the annual review and update of the BMP-S.

IMPLEMENTATION MODELS

Species in general and fish in particular tend to have distributional ranges that transcend National and Provincial boundaries. National and Provincial Government Authorities have specific management mandates within their areas of due restriction. This in association with poor communication between National and Provincial Government Authorities often results in the mismanagement of species through inconsistent conservation policies and changing conservation priorities depending on the density of the species, available habitat and existing land use practices. Three examples of how species or sector coordinators/managers can assist in the integrated implementation of management plans that transverse provincial and National boundaries will be cited in an attempt to provide the reader with enough information to be able to decide on the way forward for the implementation of species management plans.

Orange Vaal River Yellowfish conservation and management association

In an attempt to ensure a more integrated approach the Orange Vaal River Yellowfish Conservation and Management Association was set up in 1996 at the small farming town of Bothaville in the Free State. A coordinator was elected to drive this Association. The aim was to develop a Yellowfish Conservation Area in both the Orange and Vaal Rivers. The initial site was in the Vaal River between the Vaal Dam and Bloemhof Dam. It was immediately understood by

all concerned that the Association had to develop conservation principles that needed to be applied in almost all the Provinces in South Africa. This was done and an inter-Provincial steering committee was set up and managed. The aim was to integrate the management capacity of all the associated Government Departments with the entrepreneurial and technical skills in the private sector. The Association (OVRYCMA) has been in operation since 1996. The same principles are still being applied today. There are over 700 members and in excess of 700 kilometres of riparian zone and its associated river reaches are being managed as part of this Association. Quarterly steering committee meetings take place in order to drive the process.

A critical aspect of this success is the existence of an inter-Provincial Programme manager/coordinator. The existence of the inter-Provincial steering committee has facilitated good communication between the different Provincial Departments, funders and the private sector. This type of management scenario would be the ideal option to test when implementing the Biodiversity Management Plans for threatened fish species.

C.A.P.E. Estuaries program

The World Bank funded Cape Action for People and the Environment (C.A.P.E.) Estuaries Programme was initiated in 2005 with a regional stakeholder workshop aimed at developing priorities for the overall programme. It was once again understood by all concerned that this programme would encompass an area that was being managed by two Provinces as well as several District and Local Authorities. Based on lessons learned in the overall C.A.P.E. Programme the position of a coordinator/programme manager was identified as being essential to the success of the overall programme. Without this focus a new concept or programme will not be developed. In other words the principle of a programme coordinator is accepted at International Best Practice (World Bank funding standards).

A programme coordinator was employed in April 2006. The first task of this coordinator was to set up the C.A.P.E. Estuaries Programme Intergovernmental Task Team. This immediately facilitated good communication between the different Government Departments and Provinces. The co-coordinator was then able to focus on developing a Generic Estuary Management Plan Framework (=Protected Species Management Plan) and a Regional Estuary Conservation Planning Document (= Background report on species) to provide managers with a regional perspective on the value (biodiversity, social and economic) of each estuary. Once these guiding documents were produced and reviewed the first six estuary management plans were developed. The coordinator followed all the necessary procurement processes for both the Local Departments and the World Bank. No Departmental officials have time to do this extra work. It is important that the coordinator is an experienced conservation manager. In addition to this the coordinator was in a position to focus all the attention on the consulting teams developing the plans. Facilitating and the recording the interactions between stakeholders is also a crucial role that is played by the co-coordinator. A co-coordinator does not represent any one Department so can remain unbiased in the evaluation of problems/processes.

In essence the focused implementation process has resulted in 25 estuary management plans at various stages of development. The area being covered is from the Olifants estuary on the West Coast to the Mtentu Estuary on the East Coast. The concept of an inter-Governmental Task Team driving or steering the process is a sound one. The coordinator can always rely on the Government officials for support and the Government officials can achieve a great deal more by working through this co-ordinated process. International funders support this type of co-operative process as there is a stable track record that they can follow and audit.

This type of integrated co-operative approach driven by an experienced programme manager is supported by Government Departments who understand that this process facilitates the implementation of different Government management mandates within a programme that has been prioritized by all participating Government Departments. It is important that the management interventions carried out by different Government Departments in the same ecosystem is co-ordinated.

Endangered Wildlife Trust – Working Groups

The Endangered Wildlife Trust (EWT) is a non-governmental conservation organization which focuses on conservation action through the use of specialist Working groups. These working groups include the Bat Conservation Group, Ground Hornbill Working Group, Riverine Rabbit Working Group and the Crane Working Group. Most of the working groups operate with the use of dedicated field workers. The field workers cover areas which broadly correspond with the focus species distribution range and not necessarily political boundaries. The field workers are able to engage with a broad spectrum of stakeholders which include government, land owner communities and communities. They are not bound by overly burdensome bureaucratic structures, political boundaries and are able to focus on species or habitat specific issues. The EWT has over the years been able to build a solid conservation track record and are thus recognized and respected in the conservation arena of South Africa.

CONCLUSION

The process described in this document is a guideline and could be adapted where necessary. Some cases might exist where an urgent need for a plan or financial constraints will necessitate a simpler or less involved process of developing a conservation plan. There are also several other tools available that might prove effective under certain conditions and it is not the intent of the authors to set rigid rules for conservation planning processes. It is however important that any conservation plan should be adaptive, practical and cost efficient. In addition possible planning and implementation should be backed up by good background data. It is also imperative that an effective monitoring system should form part of the conservation plan in order to measure effectiveness of conservation actions implemented.

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FURTHER EXPLORATION OF OUR LIVING GOLD: POPULATION STRUCTURE OF *LABEOBARBUS POLYLEPIS* FROM SOUTH AFRICA

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Introduction

The main focus of the presentation was diversity in the Bushveld smallscale yellowfish, *Labeobarbus polylepis*, by using a molecular genetic and morphological approach. The use of a genetic marker approach using 147 sequences from the mitochondrial DNA control region was adopted to assess the genetic diversity within the populations. Thereafter the morphometric assessment involved the use of multivariate statistical methods to assess the potential differences of 159 morphological measurements taken.

Study focus area

The *L. polylepis* populations used in this study included individuals from two catchments of South Africa, namely the Komati River and the Phongolo River. Within the Komati River catchment three isolated populations including the Elands River, Ngodwana Dam and Komati River populations were used. In the Phongolo River Catchment the Assegaai River and the Phongolo River populations were used.

Results

From the morphological and genetic assessment it is clear that consistent morphological and genetic differences do exist between the five populations of Bushveld smallscale yellowfish. Based on the genetic assessment of these five populations, findings indicate that three groups, consisting of the Phongolo/Assegaai populations (group 1), individuals from the Komati and selected individuals from the Elands and Ngodwana populations (group 2) and most of the individuals from the Elands and Ngodwana populations (group 3), should be considered as separate conservation units. An extreme case of genetic variation was obtained in this study in the discovery of a group of individuals from the Elands River and Assegaai River that shows a clear unique genetic divergence not only from the remaining populations of Bushveld smallscale yellowfish but also from all of the other small-scaled yellowfishes considered in South Africa to date.

In conclusion, the use of a genetic marker such as the mitochondrial DNA (mtDNA) control region, is extremely useful in identifying populations of yellowfish that are sufficiently different from other populations to warrant specific conservation and management. Although the morphological and genetic assessment identified the uniqueness of the Elands River and the Ngodwana Dam populations of *L. polylepis,* without the genetic assessment the uniqueness of the isolated Assegaai and Phongolo river Bushveld smallscale yellowfish in comparison to the northern populations considered in this study would not have been established.

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THE GENETIC INTEGRITY OF LABEO SPECIES (CYPRINIDAE) IN SOUTH AFRICA IN RELATION TO INTER-BASIN WATER TRANSFER SCHEMES

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Abstract
The distribution of fish and other freshwater organisms has been affected by inter-basin water transfer schemes (IBTs). Water is translocated from a donor river system across a certain distance via tunnels to a recipient river system. They were mainly built for irrigation purposes in semi-arid places and for the generation of electricity. The focus in building these schemes was mainly on economic development and not on ecological and social considerations. Aquatic ecosystems are negatively affected, because of the introduction of fishes (genetic contamination, predation and competition), invertebrates, algae, pests, disease vectors or hosts of parasites. It also causes changes in flow and water chemistry and soil erosion in the recipient system. There were about 22 IBTs in Southern Africa in 1999.

The Orange-Fish and Cookhouse tunnels act as pathways for invasion by several fish species from the Orange River system to the Great Fish and Sundays River systems. This includes *Labeo umbratus* and *Labeo capensis*. *Labeo umbratus* was found naturally in the Great Fish and Sundays River systems before the inter-basin water transfer scheme (IBTs) was built. *Labeo capensis* on the other hand used to be found only in the Orange River system. The two species are reported to hybridize in Hardap Dam (Namibia). There are also anecdotal reports of hybridization between these two species in Darlington dam (Sundays River system).

The overall aim of the research was to assess whether introgression of *L. umbratus* lineages and hybridization between *L. capensis* and *L. umbratus* has occurred in Darlington and in Hardap dams. The objective was to differentiate between the two species using mitochondrial (mtDNA) cytochrome *b* and nuclear (nDNA) S7 introns and to use these markers to assess hybridization.

A total of 275 individuals were analysed from the Orange (Hardap Dam, Onseepkans, Kanoneiland, Gariep Dam, Vaal River and Brak River) Great Fish (Kat River Dam) Sundays (Darlington and Slagboom dams) Bushmans, Nahoon, Gamtoos and Gouritz River systems. The analysis of mtDNA and nDNA revealed that Orange River and the Eastern Cape populations of *Labeo umbratus* populations and *Labeo capensis* could be distinguished from each other. It also showed that there is mixing of all three lineages from these three river systems in Darlington Dam. From preliminary results, it appears as if only *L. capensis* mtDNA alleles persisted. This is despite field identifications suggesting that both morphs and hybrids of the two species occur and despite the persistence of nDNA alleles of both species.

The genetic integrity of these *Labeo* species has therefore been compromised in at least Hardap and Darlington dams. The Eastern Cape stock is considered to be under threat of complete introgression. The hybridization might be caused by habitat modification or a lack of historical contact between the Eastern Cape populations of *L. umbratus* with *L. capensis*. Some pure stocks of the Eastern Cape populations remain that requires protection from hybridization. This can be achieved by not allowing further translocations, particularly in the tributaries of the Great Fish and Sunday River systems that are protected by dams that were constructed before the IBTs were built.

MAPPING AREAS FOR THE NATIONAL ENVIRONMENTAL MANAGEMENT: BIODIVERSITY ACT - IMPLICATIONS FOR RECREATIONAL ANGLING AND CONSERVATION OF YELLOWFISH

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Introduction

Swartz (2001) cautioned that the promotion of public interest in flyfishing for yellowfishes has many positive aspects for conservation management, but that it may lead to increased pressure on fishery managers to stock yellowfishes in dams and streams that are accessible to clubs, syndicates and the general public. Alien fishes are internationally recognised as the number one threat to the survival of many indigenous fish populations (Cowx, 2002). In South Africa, alien fishes are the main threat to over 95% of the endemic or near endemic fishes in the Cape Floristic Region (Tweddle *et al.*, 2009). The most effective way to control the spread of alien fishes is to prevent their movement by humans, because once they have established in an environment, it is very difficult and expensive to completely remove them. South African freshwater angling and aquaculture is largely dependent on alien species such as carp (since 1859), trout (since 1892) and bass (since 1928). Complete eradication of these alien fish species is therefore neither feasible nor economically desirable. The question is, therefore, how to facilitate a continued role of alien fishes in the economy whilst managing their threat to the environment?

The South African Institute for Aquatic Biodiversity (SAIAB) was recently tasked with providing maps that will regulate the use of alien fish species in South Africa as part of the new National Biodiversity Management: Biodiversity Act (http://www.environment.gov.za/HotIssues/2009/invsvSpecies/alienInvsvSpecs.html). Alien animals, including fishes, have been categorised to several different categories ranging from *"prohibited in the country"* to *"regulated by activity"*, but most popular angling species (e.g. carp, trout and bass species) have been listed in category two. Species in this category will be *"managed by area"* (Table 1). This category includes most of the important angling, aquaculture and fisheries species, some of which are listed amongst the 100 most invasive species on earth (Lowe *et al.*, 2000).

During the recent mapping, these fish were broadly allocated to areas where:

- Several activities (e.g. stocking of dams, use for fish farming) will be allowed;
- A risk assessment will have to be done before the use of the species will be allowed;
- Only low escape risk aquaculture facilities will be allowed;
- The species will be prohibited
- A potential indigenous area (risk assessment required to check if the species historically occurred there).

Two true yellowfish species, the smallmouth yellowfish (*Labeobarbus aeneus*) and the Clanwilliam yellowfish (*Labeobarbus capensis*) and one large barb the Clanwilliam sawfin (*Barbus serra*) are of interest to the Yellowfish Working Group and had to be included in category two, because these species pose a risk of establishing extralimital populations in rivers where they do not occur naturally and where they would be alien. This has already happened for smallmouth yellowfish in

the Gouritz, Great Fish and Great Kei Rivers. Their presence in these areas is now seen as economically important, despite the risk to the environment due to their invasive potential.

Table 1. Species currently listed in list 3 category 2 to be *"managed by area"* of the National Environmental Management: Biodiversity Act (NEM:BA) regulations.

Common Name	Scientific Name	Main uses
Rainbow Trout	*Oncorhynchus mykiss*	Angling and aquaculture
Brown Trout	*Salmo trutta*	Angling
Atlantic Salmon	*Salmo salar*	Aquaculture
Largemouth Bass	*Micropterus salmoides*	Angling
Florida Bass	*Micropterus floridanus*	Angling
Smallmouth Bass	*Micropterus dolomieu*	Angling
Common Carp	*Cyprinus carpio*	Angling
Sterile Grass Carp	Triploid *Ctenopharyngodon idella*	Biological control
Mozambique Tilapia	*Oreochromis mossambicus*	Angling and aquaculture
Nile Tilapia & hybrids	*Oreochromis niloticus & hybrids*	Aquaculture
Sharptooth Catfish	*Clarias gariepinus*	Angling and aquaculture
Smallmouth Yellowfish	*Labeobarbus aeneus*	Angling
Clanwillilam Yellowfish	*Labeobarbus capensis*	Angling
Clanwilliam Sawfin	*Barbus serra*	Angling

NEM:BA alien yellowfish areas and their future management

There may be alien populations for all six yellowfish and all three large barbs in South Africa (Swartz, 2008), but the alien ranges of only three species were considered for the new NEM:BA regulations. There are three main alien areas that have been mapped for Clanwilliam sawfin and Clanwilliam yellowfish in the Olifants River system. These are the Koue Bokkeveld, the upper Ratels and the Bushmanskloof Nature Reserve. Stocking in all three areas could have been avoided had it not been for the pressure to establish alien fish areas for yellowfish. Smallmouth yellowfish (indigenous to the Orange River system) has been widely introduced as an alien species, including the Gourits River system (Western Cape Province), several river systems in the Eastern Cape, in the Olifants branch of the Limpopo River system and they may also occur in the Thukela (KwaZulu-Natal) due to inter-basin water transfer schemes (Swartz, 2008). Of these areas, only some catchments in the Eastern Cape and Western Cape were considered suitable for use of smallmouth yellowfish, mainly because there are no other yellowfish species that they could hybridize with. An inter-basin water transfer scheme also allows fish from the Orange to continually invade the Great Fish and Sundays River systems. There is therefore not much that can be done about the Orange-Fish-Sundays inter-basin water transfer schemes and the distribution of smallmouth yellowfish at this stage, but we would personally like to see a return to natural distribution ranges for the Clanwilliam yellowfish and Clanwilliam sawfin in the Olifants River system in future re-evaluations of NEM:BA, because these fishes pose a risk to aquatic invertebrates in upper catchments.

Artificial breeding

The problems associated with artificial breeding of our indigenous species was previously discussed in the Yellowfish Working Group proceedings (Swartz, 2001) but despite several subsequent calls for this practice to end there is continued interest in the culture of indigenous

sport fishes. It is therefore worth highlighting the potential consequences of captive breeding again:

- Adaptive gene complexes can be eliminated due to artificial selection in hatchery environments (Garcia de Leániz *et al.*, 1989; Waples and Teel, 1990) and invariably leads to loss of genetic diversity (Quattro and Vrijenhoek, 1989; Briscoe *et al.*, 1992; Leary *et al.*, 1993).
- Hatcheries spread aquatic parasites during stocking, because of the high density of fish, contact between different species and movement of fish between different facilities.
- Different species, unique lineages or populations from different river systems or regions can be mistakenly mixed.
- There are invariably escapes of fish or parasites or both into the local river system.
- Lack of knowledge of the genetic structure of the species prior to stocking can lead to the loss of unique evolutionary lineages through hybridization or complete introgression (Dowling and Childs, 1992; Leary *et al.*, 1993; Quattro *et al.*, 1996; Avise *et al.*, 1997)

Problems associated with stocking farm dams and private waters

Farm dams and private waters offer little conservation value in species recovery programmes, especially since none of the yellowfish or large barb species is currently considered Critically Endangered or Endangered (see latest IUCN assessments, Darwall *et al.*, 2009). Stocking of small private waters could result in all of the problems associated with artificial breeding and in addition:

- Farm dams often dry up.
- Landowners, their children or farm workers often move fish between farm dams with unexpected consequences and alien introductions.
- Illegal further stocking from farm dams is easier under private ownership.
- Many farm dams are linked through canals or pipes leading to undesired introductions.
- Conservation authorities lose control over the distribution and management of threatened fishes.
- Genetic diversity of the founder population is often low.
- In conservation assessments, farm dams artificially increase the range of species, leading to a downgrading of conservation status.
- It complicates conservation policies and regulations.
- It is not a high conservation priority.
- It sends the wrong education message.

The situation is, however, more serious for whitefish (*Barbus andrewi*), because this species can no longer survive in any of its native rivers due alien fishes. We still feel that farm dams and artificial breeding is not a good conservation strategy for this species. Larger public waters within the natural range of the species where conservation authorities have control over access, could however provide valuable sanctuary areas, especially if alien fishes can be eradicated. A detailed conservation genetic management plan needs to be in place to ensure long-term viability of such populations.

A proposed Yellowfish Working Group policy statement

Given the above arguments and unpublished genetic evidence that shows hybridisation in mudfish (*Labeo*) species (SAIAB) and mixing of lineages in smallscale yellowfish (*Labeobarbus polylepis*) (University of Pretoria), we feel that there is enough evidence that the ongoing artificial

breeding and/stocking of yellowfishes and large barb species is not justifiable as a conservation strategy. In many cases, it can even be more environmentally friendly to stock an alien species that is already in the catchment than moving an indigenous species, due to the many threats outlined above. In terms of fisheries management, we feel that only environmentally friendly angling in natural rivers should be promoted. In the case of the Western Cape where the populations are too threatened to support flyfishing, we should work with CapeNature to support their river rehabilitation efforts. Two of the proposed rivers, the Rondegat and Krom in the Cederberg, could, after rehabilitation, result in new yellowfish angling waters for Clanwilliam yellowfish and Clanwilliam sawfin within their natural range. These rehabilitated streams could then support a small number of anglers, whilst the remaining natural populations are kept for the conservation of genetic diversity for future rehabilitation efforts.

The following statement on stocking is therefore proposed to influence government, conservation authorities, researchers, landowners and the angling public to support environmentally friendly use of our indigenous fishes:

"The Yellowfish Working Group does not encourage the stocking of farm dams and small private waters with indigenous species, because of the many threats to our environment associated with the movement and release of indigenous fishes. There are many unintended consequences of stocking and we encourage landowners to carefully consider whether they really need to stock their private waters and to work closely with conservation authorities and the new National Environmental Management: Biodiversity Act. The Yellowfish Working Group is strongly against the stocking of any indigenous species outside its natural range unless such stocking is undertaken after an Environmental Impact Assessment. We are also strongly opposed to the artificial breeding and subsequent stocking of indigenous species, because of several well-documented threats to the genetic integrity of species and biodiversity in general. We will continue to work for healthy rivers with natural populations of indigenous species that can support environmentally friendly and sustainable angling."

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"WHY SHOULD THE DEPARTMENT OF AGRICULTURE, FORESTRY AND FISHERIES CONSIDER RECREATIONAL ANGLING IN ITS LONG-TERM PLANS FOR INLAND FISHERIES?"

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Introduction – Inland Fisheries

Inland fisheries are of considerable importance to local food security and national economies in several African countries (Marshall & Maes, 1994; Weyl *et al*, 2007) where the fisheries resources have traditionally been harvested by indigenous peoples. As a result, in these countries the inland fisheries sector is well established at both rural and national levels (Kapetsky and Petr, 1984; Marshall and Maes, 1994; Ribbink, 1994). The situation in South Africa is very different. There are over 4 000 dams that range in size from small reservoirs <1km^2 to very large impoundments >300km^2 (DWA, 2009). While the primary motivation behind the construction of these dams was for water storage and subsequent utilisation in agriculture and industry (Andrew, 2001), the fish resource in these waters represent a considerable opportunity for the development of inland fisheries (Andrew, 2001; Weyl *et al*, 2007). Due to a number of factors including a limited historical participation in fishing, cultural resistances and limited access to adequate fishing gears, the fisheries in most dams remain undeveloped (Andrew, 2001; Weyl *et al*, 2007) . The fact that South Africa lacks an inland fisheries policy – or any form of institutional framework managing inland water resources and its users – has been a significant contributor to this state of affairs (Weyl *et al*, 2007).

Despite an emerging sector (Ellender *et al*, 2009), inland fishery resources in South Africa are currently utilised largely by recreational anglers (Andrew, 2001). At present the freshwater recreational angling fraternity comprises several angling disciplines e.g. bank angling, bass angling, artificial lure angling, flyfishing and numbers approximately 1.8 million formal and informal anglers - a historically significant, multi-billion rand industry (Leibold & van Zyl, 2008). The activities of subsistence fishermen have only recently been documented (Ellender *et al*, 2009) and subsistence fishing has been reported from some localities including the Gariep Dam in the Eastern Cape/Free State (Ellender *et al*. 2009), the Phongola River floodplain in Kwazulu-Natal (Merron & Weldrick, 1995), the Mutshindudi River in the Limpopo Province (van der Waal, 2000) and the Orange River in the Richtersveldt area of the Northern Cape (Andrew, 2001). Commercial fishery operations have been developed, with varying degrees of success, on a limited number of impoundments including the Gariep-, Bloemhof-, and Molatedi Dams (Weyl *et al*, 2007). Clearly inland fisheries remain largely the "domain" of recreational angling activities.

Recent Structural Change

Prior to 2009 there had been no national lead agent in South African inland fisheries. In May 2009, however, the inland fisheries function became the mandate of the Department of Agriculture which subsequently became the Department of Agriculture, Forestry and Fisheries (DAFF). Inland fisheries insofar as the national policy objectives of food security, economic empowerment and poverty alleviation contained within the DAFF mandate apply to the development of South Africa's inland fishery resources. There are several implications that may result from this. First, there will be increasing pressure to develop fisheries in ways that move toward achieving the goals of national policy promoted by the DAFF. This process will however be complicated given the limited published information available to decision-makers regarding the value of extant fisheries. Some inland waters, for example, already have multiple users (e.g. anglers, subsistence fishers, and boaters) but current knowledge of these sectors is scarce and

little is known about potential conflict areas between them and a potential new fishery. This may lead to complications when allocating access to resources for different user groups.

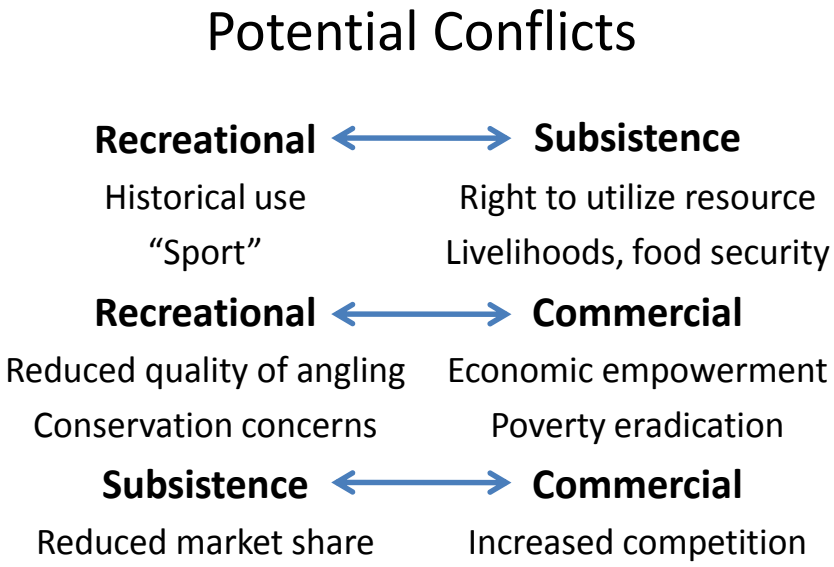

Figure 1: Potential conflicts due to resource allocation

Potential conflict areas are summarised in figure 1. Recreational anglers with historical interests in a particular waterbody may clash with subsistence anglers who feel they have a right to utilise that resource given its potential to contribute towards livelihoods and food security. Such opportunities, in the minds of the largely poor subsistence fishermen, outweigh the recreational or "sport" benefits provided by the resource. A commercial sector may clash with recreational anglers over a resource that has the potential to provide economic empowerment and poverty alleviation but which may, from a recreational perspective, result in poorer angling and conservation issues. Finally, subsistence and commercial fishermen may clash over issues related to market share and competition for the resource.

The following two case studies illustrate how recreational angling, with or without other resource users, can play a key role in the decisions that are taken in the development of management recommendations for inland fisheries.

Case Studies

Gariep Dam

A study conducted by Ellender *et al* (2009) showed that the Gariep Dam fishery was utilised exclusively by subsistence and recreational anglers. Subsistence anglers numbered 450 participants that harvested approximately 45 tonnes of fish per year with carp *Cyprinus carpio* comprising over 80% of this harvest (Ellender *et al*, 2010). These subsistence anglers either consumed or sold their catch at ZAR5/kg, their activities consequently yielding low revenues but contributing significantly to livelihoods. The recreational fishermen – who were either casual anglers or took part in organised angling competitions - also largely targeted carp. These fish were mostly consumed (60%) but also released (20%) or given away (10%). Casual recreational anglers harvested approximately 20 tonnes/year while recreational competition anglers accounted for 7.5/tonnes during the course of the competitions. It was estimated that recreational competition anglers spent an average of ZAR70/kg of fish caught including

transport and accommodation but excluding expenses on fishing tackle (Ellender *et al*, 2009). This highlights the contrast between the subsistence and recreational sectors with recreational angling constituting a high revenue activity and providing potential for benefits such as job creation through related service industries (e.g. accommodation).

The potential for a commercial gillnet fishery operation was investigated during the course of the study. Unlike subsistence or recreational fishing activities which targeted the alien carp, gillnets were found to target indigenous cyprinids (e.g. moggel *Labeo umbratus* and smallmouth yellowfish *Labeobarbus aeneus*. With the market price for freshwater fish being a low ZAR5/kg, a fishery harvesting 200 tonnes/year would yield approximately ZAR1 million in gross income and, given the start-up and running costs of such an operation, profit margins and job creation are limited. The potential for conflict of such a commercial fishery with existing recreational and subsistence fishermen is also a significant factor. Finally, unlike the recreational and subsistence sectors which utilise the alien carp, a gillnet operation would target indigenous cyprinid species such as smallmouth yellowfish *Labeobarbus aeneus* and Orange River mudfish *Labeo capensis*, a practice that may not be in line with conservation objectives.

Objective	Recreational	Subsistence	Commercial
Food Security	No	Yes	No
Economic empowerment	No	No	Maybe
Tourism Development	Yes	No	No
Poverty Alleviation	Yes	Yes	Maybe
Conservation	Yes	Yes	No
DAFF	Yes	Yes	No

Table 1: Potential contribution of recreational, subsistence and commercial fishery sectors to sustainable management objectives for the Gariep Dam fishery resource.

Table 1 indicates that the existing subsistence and recreational fishery groups on Gariep Dam contribute sustainably to different objectives outlined in the DAFF development while also utilising alien species –an important consideration from a conservation perspective. In conclusion, the Gariep Dam case study illustrates that knowledge of the multi-sectoral nature of inland fisheries and the relationship between different user groups is important in developing inland fisheries in a way that promotes different national policy objectives while also accounting for conservation principles.

Darlington Dam

Darlington Dam is located in the Addo Elephant National Park, Eastern Cape. This is an important recreational angling venue catering for approximately 2 000 anglers comprising three sectors: the Eastern Cape Light Tackle Boat Angling Association; the Eastern Cape Bank Anglers Association; and a casual angling fraternity. The potential for a commercial fishery on Darlington Dam was investigated and it was found that, from a fish availability perspective, there were opportunities for the development of a gillnet fishery (targeting moggel *Labeo umbratus*) and a longline fishery (targeting sharptooth catfish *Clarias gariepinus*) which are alien in this water body. However, several potential conflicts with the existing recreational sector could arise if the development of such a fishery were to take place. These include negative public

perception of gillnets/longlines, reduced quality of angling as a result of commercial harvesting, interference with boating activity, conservation issues with harvesting of non-target species, as well as ethical considerations associated with harvesting practices in a South African national park. Management recommendations for Darlington Dam therefore have to consider the trade-offs between the existing benefits derived from the recreational fishery and those accrued if a commercial fishery were to be developed. Given the fact that Darlington Dam supports an important recreational sector catering for a large angling fraternity (generating high revenues) coupled with the minimal conservation impacts this fishery sustains, it was recommended that recreational angling tourism be promoted. This case study illustrates the importance of recreational angling in fisheries development – an existing high revenue activity which contributes further to the goals outlined in the DAFF mandate than a commercial fishery would while also ensuring conservation principles are not compromised.

How can recreational angling form part of fisheries development?

Recreational anglers have a history of participation and comprise the major resource users in inland fisheries. In many cases recreational anglers are highly organised in associations such as FOSAF, SABAA, SASACC and SAALAAE, making them ideal former partners to DAFF in developing inland fisheries policy. In addition such formal bodies can also be engaged in co-management agreements, whereby an arrangement between recreational anglers and other resource users, such as subsistence or commercial fishermen, can contribute to the sustainable utilisation of the water body. Recreational angling is also multi-faceted with several organised angling bodies forming part of a billion rand industry – an industry which can contribute to national policy objectives such as economic empowerment and poverty alleviation while upholding existing conservation principles. This can be achieved through promoting angling activities which lead to benefits in related service industries such as tourism, resulting in job creation and community upliftment. It is therefore the role of recreational anglers to sensitise decision-makers to the importance of their sport and illustrate how important recreational angling activities are to local and national economies compared to subsistence or commercial fishing activities. Recreational anglers need to highlight the impacts subsistence or commercial activities would have on the sport and decide if there is potential for common ground in the management of inland fishery resources. In addition, they need to indicate what waters and what species are important to their activities. Such information would allow resolutions to the conflicts which have been highlighted in the case studies.

The importance of catch data

It is the aim of this study to investigate the potential of dams in South Africa for various levels of development. We hope to determine the different resource users and make distinctions between areas/dams suitable for different sectors such that conflict is avoided and conservation goals are not compromised. In order to do this, competition catch data are required, either from local, regional, or national tournaments. With catch data we intend to:

- Demonstrate historical participation/ involvement in the fishery by recreational anglers
- determine how important different species are to the sport
- predict species specific distribution and abundance based on dam size and productivity/fertility indices
- draw a base map of current distribution of important recreational angling species.
- Assess potential fish yield from different dams i.e. predict productivity in dams not utilized by recreational angling.

The outcomes of the study are to provide research that will lead to recommendations for the development of an inland fisheries policy which recognises the multi-user nature of inland fishery resources and the need to formalise and manage fishing rights for different sectors while ensuring historical utilisation practices are not ignored. In this way, the national policy objectives outlined in the DAFF mandate are considered in conjunction with policies emphasising sound conservation objectives.

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SUMMARY OF COMMENT AND DISCUSSION FOLLOWING EACH PRESENTATION

The Orange/Vaal River Yellowfish Conservation & Management Association Report – *Dirk Human* (Paper not submitted)

Peter Mills commented that conservation departments needed to think creatively so as to fit in with the objectives and avoid conflict with organisations like the OVRYCMA.

Peter Arderne asked whether Pierre de Villiers was still able to lead the OVRYMCA as he now resided in the Western Cape and was extremely busy. Dirk replied that Pierre was still committed to the cause.

Limpopo Province Report – *Paul Fouche & Stan Rodgers*

Dean asked why the catch results in the Nandoni Dam were heavily skewed to 3 species and whether this was the result of illegal netting or sampling method. Paul replied that they only used gillnetting and that in Tzaneen Dam this was also done overnight which resulted in a high number of butter-barbel. He said that it was also surprising that so few Clarias had been captured. He also mentioned that other sampling methods would be used in future.

Jim McCafferty asked whether there was conflict between recreational fishers and netters and Paul stated that the subsistence fishers were well controlled by the tribal leaders.

Wayne asked whether rising temperatures increased the prevalence of anchor worm and Paul said he had not observed this. Wayne said they had experienced major problems in the Magalies area with low flow and high temperature

Paul mentioned that the stratification in the Nandoni Dam was interesting as he always thought that there was little stratification in warmer areas.

Aspects of the reproductive biology and ecology of *Labeobarbus marequensis* in the Luvuhu River catchment – *Paul Fouche, Wynand Vlok & Antionette Jooste.*

Martine asked about profiles and Paul agreed that this was a good route to take and they would look into it in future.

In answer to Wayne about what happened if there was no cobble spawning areas Paul said this resulted in migration to suitable areas and that he had not seen them using other substrates. Wynand felt that in the absence cobbles they might use other substrates with a subsequent heavy loss in recruitment. Wayne said that they had lost suitable breeding areas in the lower Magalies due to siltation.

Dean asked whether the reduced size at spawning was due to pressures such as illegal netting but Paul suggested that the smaller size was probably due to loss of good pool habitat.

Physiological response of Vaal-Orange smallmouth yellowfish (*L.aeneus*) to catch & release angling induced stress in the Vaal River – *Ruan Gerber,Nico Smit* & Glyn Howatson.*

Dean pointed out that the 320 000 fish returned will include repeat catches. In addition we should ensure that released fish are healthy and have recovered so they can avoid predators. We should also publicise the facts about good C & R practice.

Magalies River Conservancy – *Wayne Sinclair* (Paper not submitted)
Peter Mills said that the YWG could always be used as a lobbying agent particularly when opposing inappropriate developments.

Sya Buthelezi asked about the progress made with fencing the erosion dongas and Wayne said that there had been little progress to date.

North West Province Report – *Hermien Roux & Daan Buijs*
Wayne Sinclair asked whether illegal netting was on the increase and Hermien stated that it had been a problem in Marico Dam but possibly the bad pollution of certain waterways meant that the scope was limited. It was also fortunate that a number of fairly pristine areas like the Upper Marico were protected as they were on game farms.

Dean Impson stated that in the Western Cape they were determined to implement the ecological reserves and then monitor these. He also felt that there had to be a simpler version of the indices which amateurs could use.

Rob Karssing enquired about the flow from the dolomitic eyes and Hermien said these were quite constant but when centre pivots were installed there was a lag between the installation and the drop in flow.

KZN Report – *Rob Karssing*
Ernst asked about KZN species being transferred into the Orange/Vaal and Rob said the unconfirmed reports of scalys in Sterkfontein were very few. Dean mentioned that he attended the Eskom meeting on behalf of CapeNature. Furthermore he said that Eskom claimed they could implement systems which would prevent further inter-basin transfer of fishes.

KZN River Condition Index based on land cover – *Boyd Escott presented by Rob Karssing*.
Dean pointed out that it was vital that the weighting of scores be done correctly although Rob felt that Boyd Escott's weighting was pretty accurate. However there was agreement with Paul's contention that a higher weighting could be given to weirs in upper catchments.

Western Cape Province Report- *Martine Jordaan*
Dean mentioned that they had also observed bluegills in the Lower Oorlogskloof. With regard to the delay until 2011 in the commencement of the rehabilitation programme for the 4 streams Peter Arderne asked whether this was primarily because the Rondegat which is to be used as the pilot needed a heightening of the weir because the Clanwilliam Dam was to be raised. Dean confirmed this and said it would also allow the team to assess the inverts in autumn.

Wayne asked about the stewardship programmes and Rob Karssing said they had launched 5 in KZN while there were also programmes in other provinces such as SE Mpumalanga (Phongola).

With regard to Ernst Swartz's question as to how aquatic corridors were delimited Dean said this tied up with Roger Bills' WRC programme but it would be advantageous if SAIAB participated also.

Bernard Venter asked how stocking of yellows fitted in with the moratorium and Martine said that this was limited to dams and the fish had to be sourced from the same system. Moreover there had to be a conservation plan. Bernard then pointed out that if we declined permission to stock yellows land owners would stock bass or other aliens. However, Ernst stated that it would

be extremely dangerous if the incorrect yellows were stocked and Dean agreed saying that in certain instances it might be safer to grant permission to stock with largemouth bass.
Dean stated that permission had been given to stock dams in the upper Ratels catchment with Clanwilliams and sawfin from the same system and this catchment had been zoned as extra-limital in the NEMBA mapping to allow for stocking.

Peter Mills said that the people in the various provinces rather than the YWG would have to take these decisions but that the YWG would have to review the moratorium.

The development of the large indigenous cyprinid programme of the Western Cape – *Dean Impson.*
Ernst said that there was no problem developing yellowfish fisheries like the Rondegat River, but handing over control of dams on private properties meant one lost control. Dean replied that it was very important to provide appreciation of yellowfish by developing flyfishing destinations. Rob Karssing mentioned that he was feeling similar pressure to stock dams in KZN and he was very worried by this trend. Ernst added that there was no need to source from hatchery bred populations as there were plenty of healthy wild-bred populations and there was general agreement on this point.

Martine said we first had to address the problem of having to re-stock before addressing the reason for extinctions. Peter Mills stated that we had to define these problems through the use of a matrix scoring system.

Where angling and conservation meet – how angling can play a role in conservation with special reference to artificial lure angling. – *Bernard Venter.*
Ernst said that in future anglers could send images to SAIAB in addition to specimens and Jim McCafferty agreed that data collected by anglers was hugely important to SAIAB and Ernst endorsed the excellent contribution made by organised angling. Moreover everyone agreed that information should not be limited to indigenous species in future but should include all species.

Peter Mills asked whether Artlure anglers were moving species, but Bernard said that this was strictly in contravention to Artlure policy and Dean proposed that any species which appeared to have been illegally stocked should be excluded from the scoring in Artlure competitions.

Guidelines for the development of conservation management plans for threatened fish species – *Wynand Vlok*, Jan Venter & Paul Fouche*
Dean asked whether the Minister would appoint a person to take overall responsibility for the plans, but Wynand said this responsibility should be handled at provincial level. He also asked about the genetic analysis and Wynand said they were still struggling to find the correct primus.

Peter Mills queried whether there was a plan on the table and what does it mean and Wynand stated that they looked at specific problems per catchment and being WRC funded they did not look outside SA.

.Further exploration of our living gold: Population structure of *Labeobarbus polylepis* from South Africa -*Carel Oosthuizen*, Gordon O'Brien, Amanda Austin & Paullette Bloomer*
Ernst queried the presence of two lineages in one system and Carel said this appeared to be the stocking of the Elands system with Komati fish.

Dean asked about sampling from the Komati system and Carel said this had been done and the results will be in future reports. Likewise the compromised species in the Spekboom could also be sampled in future.

The genetic integrity of labeo species in SA in relation to IBT schemes.- *Mpho Ramoejane *& Ernst Swartz & Olaf Weyl*
Dean asked whether *L.umbratus* samples had been collected from the Orange system and Mpho answered that they had collected at Brak, Gariep Dam and Vaal Dam. He had struggled to find them in Gariep and could not find them in the Barrage or the main Vaal but there were plenty in Vaal Dam.

With regard to a question on hybridization asked by Nico Smit, Mpho said that the 2 species in Gariep used different bays to spawn, but that the Hardap, which is in an arid area, had a rocky bottom that favoured *L.capensis*.

In answer to a question from Jim, Mpho said they would be doing sequences on hybrids in future.

Dean asked whether there was not a flaw of Mitochrondrial DNA (mtDNA) testing to assume that only *L.capensis* females were participating in mating and Mpho said this was not correct as these females are mating with its males, *L.umbratus* males and hybrids as well, and that is the reason we find only *L.capensis* mtDNA as this is only maternally inherited.

Mapping areas for NEM:BA – implications for recreational angling and conservation of yellowfish. – *Ernst Swartz & Olaf Weyl*
Dean complimented Ernst on his comprehensive mapping which made it much easier for provincial departments to take decisions.

Bernard asked which smallmouth dams had been mapped and Ernst said most were in the Western Cape with one each in Mpumalanga, KZN and Eastern Cape respectively. Martine added that the bass anglers were very happy with the impoundments that had been included in the maps.

Why should the Dept. of Agriculture, Fisheries & Forestry consider recreational angling in its long term plans for inland fisheries – *Jim McCafferty & Ernst Swartz & Olaf Weyl*
Dean pointed out that we needed to find out what capacity the new DAFF would have and Rob said that the lack of an inland fishery policy was causing major problems and KZN were trying to develop their own provincial policy.

There was general agreement on the urgent need for a policy. Peter Mills was concerned that agriculture usually had objectives which were the opposite of conservation.

Rob said that gill netting could never be sustainable anywhere and Daan Buijs mentioned that the commercial fishery operation at Bloemhof which was based on seine netting was sustainable and that the dam continued to provide good recreational fishing.

Wayne enquired whether the plans for commercial fisheries included rivers and Jim said that at this stage only dams were included.

Foodweb restructuring towards diversity – *Petrus Venter* (Paper not submitted)

Elize Tempelhoff asked about Bruma Lake and Petrus said that sediment was pumped out and sent to them. In answer to a question from Jim he said that they had not yet reached their target and there had been a shift in populations

SUMMARY OF THE CONFERENCE PROCEEDINGS

Peter Mills
Chairman of the Yellowfish Working Group

Papers presented at the conference ranged widely from genetic studies, the conservation status of rivers and species to angling best practice guidelines. An important component of the conference was the regional reports from representatives of the Provincial Conservation Departments.

The following are the main points to emerge from this year's proceedings.

- Just about all the papers reflected on the declining condition of all rivers in the country and the subsequent loss of habitat for all our yellowfish species.
- Not surprisingly development, whether it be mining, urban encroachment or illegal settlements were a growing concern and an ongoing threat to healthy rivers systems. Poor town planning and local authority administration was seen as a major contribution to the destruction of riparian and river habitat and the declining state of river condition in the country.
- In turn, conservation planning, does not take into account broader issues of ecosystems services. The main focus of conservation strategies and activities remain with PA (Protected Area) management and on single species management. Even though this ideology is changing with many conservation departments now having semi-functional C-Plans (Conservation Plans) but there are not enough skills or manpower to role this programme out effectively. The idea that communities and society in general should pay for ecosystem services is receiving little attention and undermining the long term importance of good ecosystem planning. This can happen in a number of ways but really implies that people living downstream of catchment and who use the water should pay upstream communities for that service (constant flow and clean water – in theory).
- There is a surprising dearth of information about species behaviour. Very little is known about fish behaviour, let alone yellowfish. More research is required so that we can understand the impact of various environmental factors on our yellowfish species. Not only is more research needed but anglers can be an important source of data.
- Angling is not necessarily a conservation activity but depending how anglers behave can be an important management tool to achieve specific aquatic conservation targets. It became apparent during the conference that catch - and - release is an important management activity but it if not properly implemented can have negative impacts on river ecology. For example, releasing fish caught out of natural distribution ranges cannot be considered as sound conservation practice. However, angling can generate funds through proper licensing that should be ploughed back into river management.
- Conservation must happen outside protected areas to achieve biodiversity targets. The idea is not new that conservation practice should be focussing outside of existing protected areas and to ignore this will leave protected areas as islands with limited long-term sustainability for their biodiversity.

Main issues raised

- There was general consensus that South African rivers are in a rapidly declining state of health.
- The River Health Programme, although a good programme, was in a declining state of management with few provincial programmes now being actively managed.
- Government Departments are not fulfilling their legal mandate, especially Departments like Water, Minerals and Energy and Environmental Affairs.
- In addition to the above government environmental polices are inconsistent and not applied by officials.
- Conservation Departments do not have the staff with enough knowledge or skills to apply their legal mandate, in terms of their Ordinances or Act, effectively and in many cases Conservation Departments are reluctant to apply the law because the law might not be politically popular.
- Conservation Departments lack legal capacity and relevant legislation that is applied judiciously over the public. Very little law enforcement is taking place to prevent things like poaching, illegal fishing and the issuing of permits.
- Poaching in the form of unsustainable subsistence and commercial harvesting was placing undue stress on the fish resources of the country. The Provincial Conservation Departments whose job it is to manage aquatic biodiversity have either abandoned permitting altogether or are not policing their Ordinance effectively. The result is that there is no conservation management or control over the country's rivers systems and subsistence fishing is often used as an excuse for indiscriminate harvesting (netting with shade cloth was posing a real threat to fish species).
- Hybridisation of species through inter basin transfers (IBT's) is mixing the genetic make-up of some of the yellowfishes thus exposing fish to new diseases and making whole populations of these animals vulnerable. The prevention of hybridisation of species is at the heart of any conservation strategy which aims to keep the genetics of each species pure.
- There is a smattering of aquatic scientists left in Conservation Departments leaving departments with little capacity to develop appropriate policies and the implementation of adequate conservation measures.
- Angler behaviour could be having a negative impact on fisheries. Wading on yellowfish spawning beds has previously been raised by the working group and the concept of catch-and-release has now come into question. In this regard the YWG will soon publish a policy statement and guidelines on best practice guidelines for catch-and-release.
- The idea of conservation management zones was mentioned by more than one speaker and all presenters identified that the application of management interventions to manage each zone is not possible because of the lack of knowledge and skills mentioned above.
- The problem of hatcheries and the stocking of rivers is an issue that has been raised at previous conferences and remains an issue. The main issue is that hatcheries are employing poor stocking policies which mean that fish are being stocked outside of their natural distribution ranges.

Immediate actions that are to be taken by the Yellowfish Working Group.

- A statement on catch-and-release will be published shortly.
- Similarly the YWG will be reissuing a statement on the stocking of dams from hatcheries and the risks associated with this.
- A strategy will be put in place that highlights existing river conservation initiatives.
- The establishment of a fresh water angling forum will be investigated.
- The YWG will lobby, where possible, for the sustainable use and management of SA Rivers by registering as an interested and affected party for development and mining activities that are seen to be threatening aquatic resources.
- The 2011 conference will be held at Badplaas in February.

FOSAF FLYFISHING MILESTONES

Since its inception FOSAF (Federation of Southern African Flyfishers) has led and continues to lead a series of initiatives of benefit to fly fishing in particular and to the aquatic environment as a whole. Including:

- Negotiating with Government and Provincial Authorities on the situation in the Cape where angling for trout was deregulated. As a result of these negotiations and discussions, suitable arrangements have been worked out between the Cape Department of Nature Conservation and the Cape Piscatorial Society who now control these waters.
- Publishing an official journal which has grown into the popular bi-monthly magazine Fly Fishing. A magazine that, although we no longer have a financial interest in, continues to play a role in disseminating FOSAF communications to our members and the fly fishing public in general.
- Making donations to various organisations for research projects of benefit to flyfishing. These include cost effective breeding of trout, genetic selection and breeding tigerfish, and research on population genetics of yellowfish.
- Holding discussions with timber companies to promote flyfishing as a sport and to obtain concessions for fly fishers on their land or waters.
- Organising flyfishing expositions which have been held in Grahamstown, Barkly East, Stutterheim, King William's Town and Somerset East.
- Liaising with Provincial trout hatcheries and authorities regarding the breeding and stocking of trout.
- Organising a tour of prominent international flyfishers to South Africa to promote the sport of flyfishing and local flyfishing opportunities as a tourist attraction.
- Rendering advice and guidance to authorities and anglers concerning the ethics and discipline of trout fishing.
- Supporting the efforts of the Eastern Cape Chapter which has facilitated cost effective methods for rearing trout as well as researching and recommending the merits and value of stocking remote areas with trout fry.
- Assisting in funding and obtaining displays for the flyfishing section of the Knysna Angling Museum.
- Making important submissions to government on white papers on Forestry, Water Affairs and Environmental Affairs.
- Hosting a watershed workshop entitled "TROUT '94" where 33 presenters from government departments, researchers and other interested parties produced papers from which 61 issues emerged which were handled at a further workshop in August '95 and resulted in the formulation of FOSAF Policy Guidelines in 1996.
- Negotiating with the Mpumalanga Parks Board to prevent the de-regulation of the protection of trout waters which now have protection as flyfishing waters. Providing advice and guidance on the debate which resulted in permission being granted for the stocking of trout in Wakkerstroom.
- Producing and publishing the first comprehensive guide on flyfishing venues in Southern Africa, The Nedbank Guide to Flyfishing Venues in Southern Africa in 1996 with four subsequent editions published with sponsorship from Nedbank. This was a milestone in the promotion of and association with fly fishing by major sponsors.
- Obtaining a sponsored vehicle from Samcor for the Dept. of Ichthyology and Fisheries Science at Rhodes University in Grahamstown, for work on behalf of the Eastern Cape Chapter of FOSAF.
- Holding Trout '97 Workshop and developing proceedings on small scale breeding of trout, weed control, stocking strategies, managing high and low intensity fisheries and improving the productivity of man-made impoundments in Mpumalanga.
- Commissioning, also in 1997, a study on the economic benefits on flyfishing in South Africa by a researcher at Stellenbosch University, and a major market research project by Markinor in 2001.
- Founding the Yellowfish Working Group (YWG) to uplift the status of this magnificent indigenous freshwater game fish as an angling species and to promote its conservation,

protection and re-habilitation. The first National YWG Conference was held in 1997 and subsequently conferences are held on an annual basis.

- Producing the highly acclaimed report State of the Yellowfish in South Africa - 2007 with sponsorship from the Water Research Commission, the Department of Environmental Affairs and Tourism and the River Health Programme. This was followed by the Technical Report of 2008.
- Providing guidance and encouragement for the development of flyfishing facilities in all provinces of which the very successful Wild Trout Association of the Eastern Cape is a good example.
- Making financial contributions to conservation departments such as the CapeNature to help fund the attendance of scientific officers at international conferences important to flyfishers.
- Liaising and co-operating with other NGO's with similar interests such as the Endangered Wild Life Trust, Eco Care Trust and Save the Vaal Environment.
- Instituting FOSAF Exemplary Service Awards. These have been awarded to Prof Kadar Asmal for his Working for Water Project, to Dr Louis Wolhuter and Garth Brook for their contribution in the production of the Nedbank Guide to Flyfishing Venues in Southern Africa, to Dr Douglas Hey of CapeNature for his massive contribution to conservation and to Andy Lawlor for pioneering work on introducing paraplegics to fly fishing. Other notable recipients are Fred Croney, Ed Herbst, Bill Barnes, Pierre de Villiers, Dave Rorke, Brian von Holdt, Bill Bainbridge, Dean Impson, Harvey Venter, Jake Alletson, Theo van Niekerk, Mark Yelland, Thomas du Toit and Trevor and Sue Babich.
- Co-operating with the Endangered Wildlife Trust and the Highland Crane Group by funding and advising on workshops on the situating of eco friendly dams and assisting with the pioneering Mpumalanga Highlands Wetland Study with a project cost of R100 000.
- Assisting the Free State Chapter with the stocking of the Swartwater impoundment that produced the incredible 18lb. 2½oz. Rainbow trout caught by Mike Posthumous.
- Assisting a faculty member of Stellenbosch University to attend a conference in Australia to present a paper on small development programmes for aquaculture in South Africa.
- Providing funding to the Wild Trout Association and Rhodes University for their Geographical Information System project to help to manage fly fishing waters and provide useful information to anglers.
- Providing funding to the KwaZulu-Natal Chapter of FOSAF and the School of Environment and Development to assess and develop the potential of fly fishing in the Underberg district with community-based resource management strategies.
- Sponsoring renowned international anglers and authors Darrel Martin (USA) and Taff Price (UK) to fish for our indigenous yellowfish and saltwater species and promote South African flyfishing in the international press.
- Developing a FOSAF Website that providing up-to-date reports on angling conditions throughout the country.
- Initiating in 2001, through the Yellowfish Working Group, a major study on the population genetics of the two Orange-Vaal yellowfish species. This study was undertaken mainly with funding by AngloGold-Ashanti and Lesotho Highlands Authority while much of the initial sampling was undertaken by YWG volunteers. The study was finalized in 2007 and these findings have led to other organizations carrying out similar studies on other yellowfish species.
- Helping job creation by supporting the Highlands Academy, set up to train previous disadvantaged youngsters as fly fishing guides.
- Publishing various papers and bulletins including The Yellowfish Working Group Newsletter and The Tippet (a general newsletter to FOSAF members) as well as various pamphlets of interest to fly fishermen in general.
- Publishing a popular series of books titled Favoured Flies & Select Techniques of the Experts, Volumes 1 to 5. Currently preparing the FOSAF Guide to Flyfishing which will replace the very successful Nedbank Guide in October 2010.
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