Orange-Senqu River Basin

Orange-Senqu River Commission Secretariat
Governments of Botswana, Lesotho, Namibia and South Africa

UNDP-GEF
Orange-Senqu Strategic Action Programme
(Atlas Project ID 71598)

River EFR assessment, Volume 2: Fish River EFR, supporting information

Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth

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UNDP-GEF
Orange-Senqu Strategic Action Programme

River EFR assessment, Volume 2: Determination of Fish River EFR, supporting information

Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth

This report was compiled by Rivers for Africa, e-Flows Consulting (PTY) LTD (iwre@icon.co.za), Pretoria, South Africa with assistance from Ministry of Environment and Tourism, Directorate of Parks and Wildlife Management during surveys and hydrological observed/real time data obtained from Ministry of Agriculture, Water and Forestry, Department of Water Affairs and Forestry, Namibia.

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Revision	Description	Date	Signed
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1	Initial draft (one document) for internal review by Dr B Rydgren and Mr W Hendley	02 Feb 2013	DL
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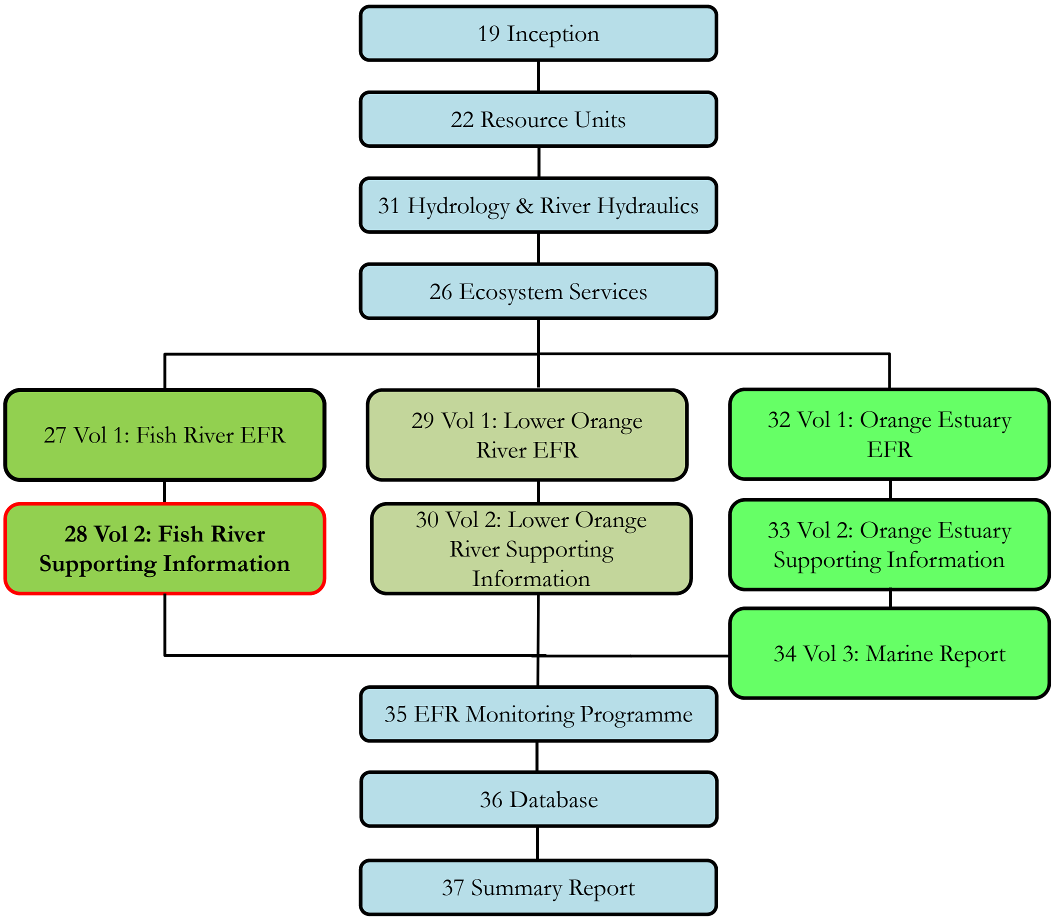
Report list

A list of the Technical Reports that form of this study is provided below. A diagram illustrating the linkages between the reports is also provided.

Technical Report No	Report
19	Inception Report, Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
22	Delineation of the Study Area – Resource Unit Report, Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
26	Consequences of Scenarios on Ecosystem Services, Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
27	River EFR assessment, Volume 1: Determination of Fish River EFR Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
28	**River EFR assessment, Volume 2: Fish River EFR, supporting information** **Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth**
29	River EFR assessment, Volume 1: Determination of the lower Orange River EFR Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
30	River EFR assessment, Volume 2: Lower Orange River EFR, supporting information Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
31	River and Estuary EFR assessment, Hydrology and River Hydraulics Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
32	Estuary and Marine EFR assessment, Volume 1: Determination of Orange Estuary EFR Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
33	Estuary and Marine EFR assessment, Volume 2: Orange Estuary EFR: Supporting Information Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
34	Estuary and Marine EFR assessment, Volume 3: Assessment of the Role of Freshwater Inflows in the Coastal Marine Ecosystem Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
35	EFR monitoring programme, Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
36	Database, Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth

Technical Report No	Report
37	Summary Report, Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth

Bold indicates current report.



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Abbreviations

ASPT	*Average score per taxon*
DO	*Dissolved oxygen*
EC	*Ecological category*
EFR	*Environmental Flow Requirement*
ESIA	*Environmental and social impact assessment*
FRAI	*Fish Response Assessment Index*
FROC	*Frequency of occurrence*
GAI	*Geomorphological Driver Assessment Index*
IHI	*Index of Habitat Integrity*
IUCN	*International Union for Conservation of Nature*
IWRM	*Integrated water resources management*
MAWF	*Ministry of Agriculture, Water and Forestry*
MCB	*Macro channel bank*
MIRAI	*Macro Invertebrate Response Assessment Index*
MRU	*Management resource unit*
NASS2	*Namibian Scoring System version 2*
NEMBA	*National Environmental Management: Biodiversity Act*
ORASECOM	*Orange-Senqu River Commission*
PAI	*Physico-chemical Driver Assessment Index*
PES	*Present ecological state*
PTV	*Pollution tolerant valve*
RC	*Reference Condition*
RO	*Release option*
SANS	*South African National Standard*
SASS5	*South African Scoring System version 5*
SPI	*Specific Pollution sensitivity Index*
TDI	*Trophic Diatom Index*
TIN	*Total inorganic nitrogen*
TWQR	*Target water quality range*
VEGRAI	*Vegetation Response Assessment Index*
WHO	*World Health Organization*

Fish species abbreviations

ASCL	*Austroglanis sclateri*
B. cf. KIM	*Labeobarbus cf. kimberleyensis*
BAEN	*Labeobarbus aeneus*
BHOS	*Barbus hospes*
BKIM	*Labeobarbus kimberleyensis*
BKIM X BAEN	*Labeobarbus hybrid*
BPAU	*Barbus paludinosus*
BTRI	*Barbus trimaculatus*
CCAR	*Cyprinus carpio*
CGAR	*Clarias gariepinus*
LCAP	*Labeo capensis*
LCAP X LUMB	*Labeo hybrid*
LUMB	*Labeo umbratus*
MBRE	*Mesobola brevianalis*
MSAL	*Micropterus salmoides*
OMOS	*Oreochromis mossambicus*
PPHI	*Pseudocrenilabrus philander*
TREN	*Tilapia rendalii*
TSPA	*Tilapia sparrmanii*

Velocity Depth Classes: Fish

FD	*Fast deep fish habitat*
FI	*Fast intermediate fish habitat*
FS	*Fast shallow fish habitat*
SD	*Slow deep fish habitat*
SS	*Slow shallow fish habitat*

1. Introduction

1.1 Background

The Orange-Senqu River riparian States (Botswana, Lesotho, Namibia and South Africa) are committed to jointly addressing threats to the shared water resources of the Basin. This is reflected in bilateral and basin-wide agreements between the riparian states and led to the formation of the Orange-Senqu River Commission (ORASECOM) in 2000. The 'Orange-Senqu Strategic Action Programme' Project supports ORASECOM in developing a basin-wide plan for the management and development of water resources, based on integrated water resources management (IWRM) principles (ORASECOM, 2011a).

The water resources of the Orange-Senqu River are heavily utilised and the system is highly regulated with 23 major dams within its Basin. It is also connected to other river systems for water import and export via six inter-basin water transfer schemes (Technical Report 22).

Environmental flow requirements (EFR) of the ephemeral but nevertheless significant Fish River, and the Orange River, from its confluence with the Fish River downstream to the Orange River mouth were not covered in any detail by the completed GIZ study, during 2009-2010 (Louw and Koekemoer (Eds), 2010). This area is to be the subject of this Research Project (ORASECOM, 2011a).

1.2 Objectives of the study

The objectives of the Fish River component of the study were to:

- develop Environmental flow requirement (EFR) methodologies with specific emphasis on the ephemeral nature of the Fish River;
- determine the present ecological state (PES), importance and future recommended ecological category (REC);
- set the EFR using the approach developed within this study;
- address scenarios in terms of the existing and new dams in the Fish River.

1.3 Study area

The study area (Figure 1) includes the following areas (Technical Report 22):

- Orange-Senqu River from the Fish River confluence downstream to the Orange-Senqu River estuary including the estuary and the immediate marine environment; and the
- Fish River in Namibia.

1.4 Delineation and study sites

Information per EFR site in the study area is shown in Table 1 below, and is taken from Technical Report 22.

Table 1. Details of EFR sites

EFR site	***River***	***Management resource unit***	***Land cover***
EFR Fish 1	Fish	MRU[1] Fish A: Hardap to Neckartal Dam	Irrigation (1%) and livestock farming (99%)
EFR Fish 2	Fish	MRU Fish B.1: Neckartal Dam to Löwen/Fish River confluence	Nature reserves (90%) and other (10%) (e.g. Seeheim: livestock farming)
EFR Fish Ai-Ais	Fish	Löwen/Fish River confluence to Orange River confluence	
EFR O5	Orange	MRU Orange G: Fish River confluence to start of estuary	National Parks, mining, irrigation

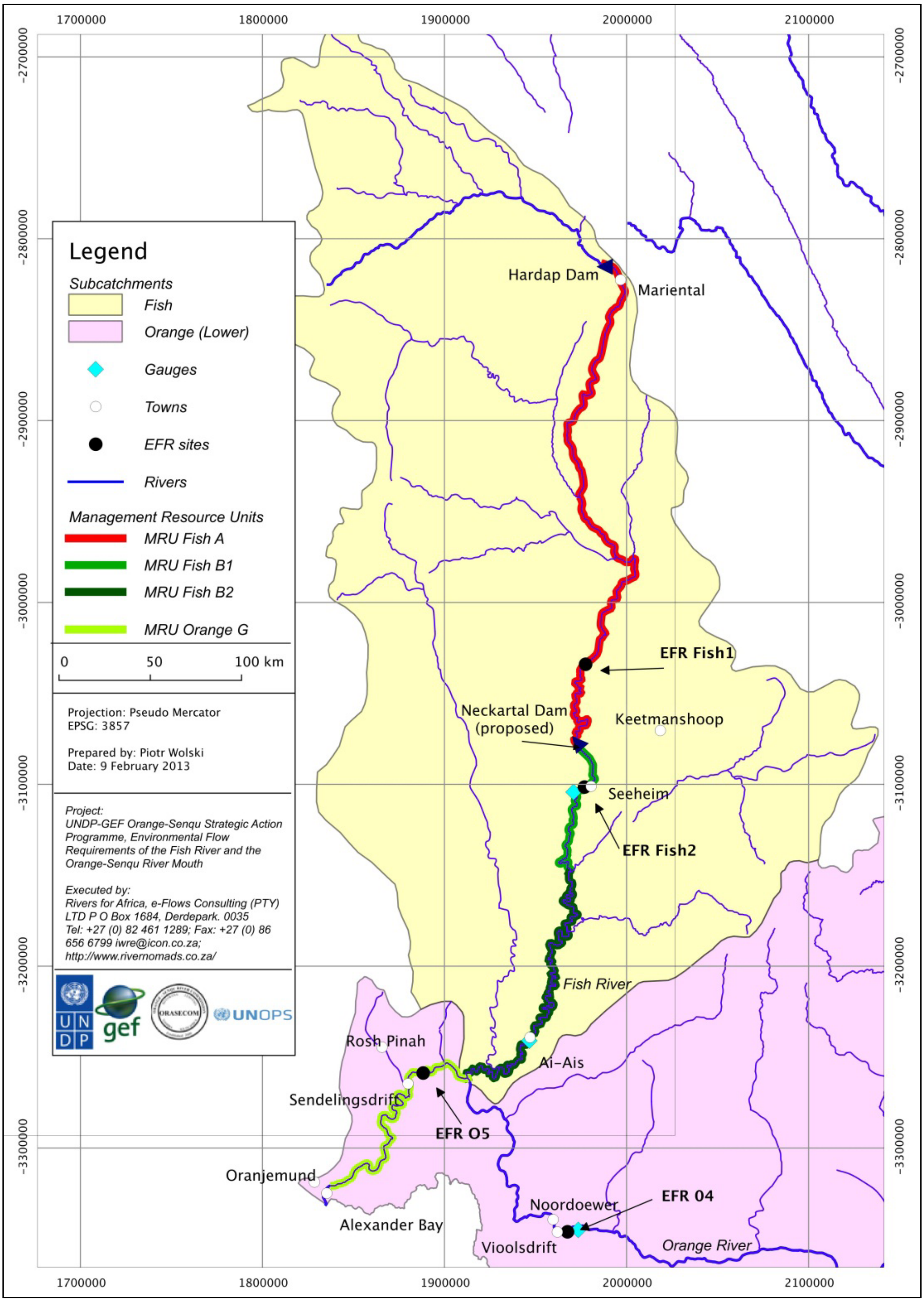

Figure 1. Study area

1.5 Report structure

The EcoClassification and EFR determination of the Fish and Orange rivers are documented in five reports:

- Technical Report 27: River EFR assessment, Volume 1: Determination of Fish River EFR Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth.
- **Technical Report 28: River EFR assessment, Volume 2: Fish River EFR, supporting information Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth.**
- Technical Report 29: River EFR assessment, Volume 1: Determination of the lower Orange River EFR Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth.
- Technical Report 30: River EFR assessment, Volume 2: Lower Orange River EFR, supporting information Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth.
- Technical Report 31: River and Estuary EFR assessment, Hydrology and River Hydraulics Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth.

Technical Report 28 is a collection of supplementary technical information which includes data collected from a site visit undertaken during 13-22 June 2012 and literature surveys. This volume provides supporting information and background to Technical Report 27. Each specialist contribution forms a chapter of this volume. This document should not be seen as a stand-alone volume but should be read in conjunction with Technical Report 27. All component assessment indices and raw data are provided on the ORASECOM website (www.orasecom.org).

The report structure is outlined below.

Chapter 1: Preface
This chapter provides an overview of the study area and objectives of the study.

The individual specialist reports are provided as the following chapters:

Chapter 2: Water quality

Chapter 3: Diatoms

Chapter 4: Geomorphology

Chapter 5: Riparian vegetation

Chapter 6: Riverine fauna

Chapter 7: Macro-invertebrates

Chapter 8: Fish

Chapter 9: Habitat Integrity of the Fish River

Chapter 10: References

Appendix A: Species lists

This Appendix lists the riparian vegetation species observed at the EFR sites of the Fish River as well as the riverine fauna species occurring in the Fish River and Orange River.

Appendix B: Riverine fauna habitat plan views
The plan views linked to habitats showing the differences in height above water level experienced during the site visit are provided.

Appendix C: Issues regarding reference fish species and fish identification in the Fish River
There is uncertainty regarding the identification of fish species in the Fish River due to introduction of alien fish species in the river, possible interbreeding etc.

Appendix D: Fish information used during the Ecological classification process
A summary of available data and survey results are provided. The preference of fish for different velocity-depth categories and cover features and different tolerance levels to changes in their environment is provided.

2. Water quality

2.1 Methods and approach

The methods and approach are described in DWAF (2008) and not provided in detail in this document. The following parameters were evaluated:

- pH: 5th and 95th percentiles.
- Electrical Conductivity, ions, metals: 95th percentiles.
- Nutrients, i.e. Total inorganic nitrogen (TIN) and ortho-phosphate: 50th percentile.
- Chlorophyll-a (phytoplankton): Average or mean of values.
- Diatoms: Average or mean of values.
- Turbidity, dissolved oxygen (DO), temperature: Narrative descriptions as no data are available.

Water quality data were utilised in the following way: Nutrients, pH, chlorophyll-a, turbidity, DO, temperature and electrical conductivity data were compared to benchmark tables in DWAF (2008). All ionic data (i.e. macro-ions and salt ions) were compared to benchmark tables in DWAF (2008) or the target water quality range (TWQR) guidelines of the South African aquatic ecosystem guidelines (DWAF, 1996a). Standards available from the Neckartal Dam development environmental and social impact assessment (ESIA) monitoring database, i.e. World Health Organization (WHO) standards, South African National Standard (SANS) for irrigation and drinking water, and Namibian determinants for class A drinking water, were also utilised for comparative purposes for the Fish River. Diatom data were utilised as provided by the diatomologist for the study.

2.2 Reference conditions

The most critical part of a water quality assessment is setting reference condition (RC) which represents the natural state. The change or deviation from RC defines the water quality present state. As early water quality data were not available for the Fish River, benchmark tables for an A category or natural/least impacted state were used as a proxy for RC. This information was modified using available information where possible (see below for salts). The lowest confidence for the RC was for nutrients, as phosphate, macro- and benthic algae levels are elevated throughout the catchment although causes are not always evident. Detection levels for phosphate were also relatively high, i.e. 0.6 mg/ℓ, making accurate assessments of the present state problematic.

The RC for Electrical Conductivity was set at 42.02 mS/m, using the mean of the following data:

- 95th percentile of Electrical Conductivity data from SW2 on the Löwen River downstream Naute Dam (n=13): EC was 43.54 mS/m;

- mean of the records for the Löwen River (Naute Dam and directly downstream the dam) for August 2009 and February 2010, i.e. the Aquatic Ecosystem specialist study of the ESIA (Nepid Consultants, 2010): Electrical Conductivity was 40.5 mS/m.

The benchmark for the A category of DWAF (2008) was therefore re-rated as follows:

- EC A (0 rating): Estimated Fish River RC was 42.02. The DWAF 2008 RC was ≤30. The RC was reset to ≤ 42.

Based on the above, the new A reference condition was used to adjust the B to D values using the re-rated calculation (30/42 = 0.714) (Table 2).

- EC B (1 rating): DWAF values are 30.1 - ≤55 and using the calculation (55/0.714 = 77) it was adjusted to 42.1 – 77.
- EC C (2 rating): DWAF values are 55.1 - ≤85 and using the calculation (85/0.714 = 119) it was adjusted to 77.1 – 119.
- EC D (3 rating: DWAF value are >85 and the re-rated benchmark is >119.

Table 2. Re-rated benchmarks for the different Ecological Categories

Category	***Rating***	***DWAF (2008)***	***Estimated Fish River RC***	***Re-rate calculations***	***Re-rated categories***
A	0	≤ 30	42.02	30 /42 = 0.714	≤ 42
B	1	30.1 - ≤55		55/0.714 = 77	42.1 – 77
C	2	55.1 - ≤85		85/0.714 = 119	77.1 – 119
D	3	>85			> 119

As the regional geology and high evaporation rates would lead to naturally elevated salinities, re-rating of the A category is of low confidence, as natural levels in the Fish River may be higher than 42.02 mS/m.

2.3 Available information and confidence

An assessment of the geology of the region, needed for the interpretation of metals data, was extracted from Swart (2008) by Frank Bockmühl, the geohydrologist for the study. The Namaqua Metamorphic Complex, Orange River Group, Elim formation and Rehoboth Sequence as well as the Pan-African Damara Belt geological formations all have moderate to high mineral content containing lead, gold, copper and uranium which may appear in the groundwater and surface water. However, it is not possible to consider the geological background as a source of metal elevations unless these elevations can be traced to the surface water via a groundwater route.

Data used for the water quality assessment was collected as part of the Knight Piesold study for the Neckartal Dam development ESIA, as no information was available to characterise the baseline. Monitoring has continued as part of baseline characterisation, although it is assumed that the monitoring network will be expanded once construction of the dam starts. Surface water monitoring points are shown in Figure 2. Note that pools are also monitored, but never under shallow or stagnant water conditions. Water samples are collected by officials of the Ministry of Agriculture, Water and Forestry (MAWF), which is the client for the Neckartal Dam project (Briel, Knight Piesold, pers. comm., January 2012; October 2012). The data record is short (February 2010 to April 2012). Data from SW4 (upstream Neckartal Dam) were used to assess the water quality present state for EFR Fish 1, with the average of results for SW1 (downstream Seeheim), SW2 (downstream Naute Dam on the Löwen River) and SW3 (downstream Neckartal) used for EFR Fish 2.

Table 3 shows the location of additional water quality sites sampled during the field survey at the end of June 2012 and site locations are included in Figure 3. Table 4 indicates electrical conductivity and pH that were measured at these sites during the June 2012 survey.

Table 3. Location of additional water quality survey sites

Site	***River***	***Location***	***Latitude***	***Longitude***
WQ1	Fish River	Bridge upstream (US) of confluence	28°5'36.1"	17°10'23.2"
WQ5	Konkiep River	D43 to Witputs	27°24'15.4"	17°11'30.4"
WQ2	Fish River	D531 to Berseba	26°14'58.2"	17°48'9.2"
WQ3	Fish River	Road from Berseba to Tses	25°55'8.2"	17°56'24.3"
WQ4	Fish River	Road between Kalkrand to Mariental	24°35'32.2"	17°56'22.0"

Table 4. Water quality measurements taken during the field survey of June 2012

Site	***Date sampled***	***pH***	***Electrical conductivity (mS/m)***
WQ1	19 June 2012	8.38	92.9
WQ5	19 June 2012	7.74	102.5
WQ2	21 June 2012	8.92	148.7
WQ3	21 June 2012	8.96	160.9
WQ4	22 June 2012	9.06	54.3

The availability of diatom data and confidence is provided in Chapter 3.

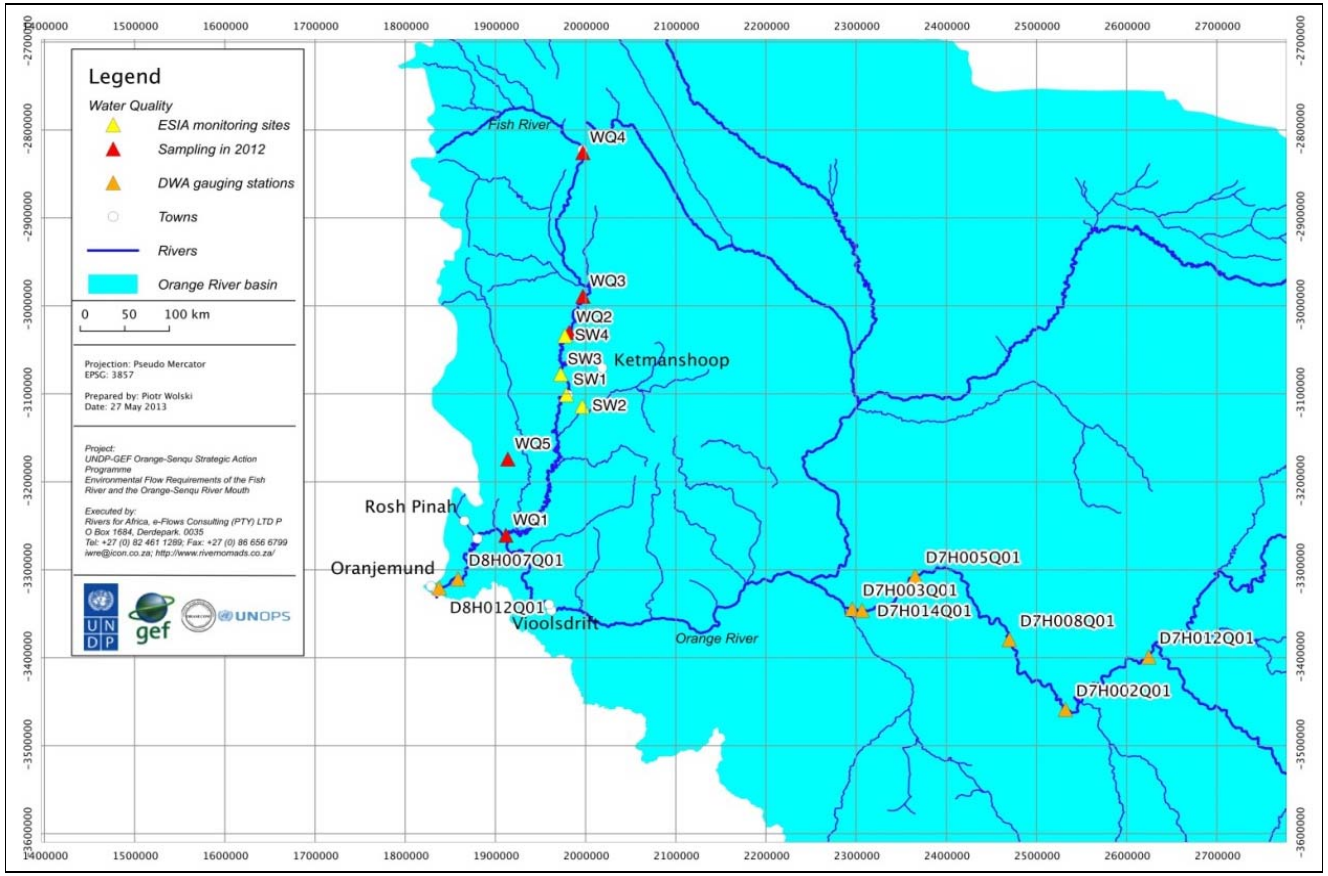

Figure 2. Water quality monitoring points from the Knight Piesold study, as at September 2010.

2.4 Data assessment

2.4.1 EFR Fish 1

Table 5 shows the water quality present state assessment for EFR Fish 1, i.e. the stretch of the Fish River between Hardap and Neckartal dams. The water quality site used for this assessment is SW4 (see Figure 2) based on data collected from February 2010 to April 2012 (n = 6–12 for physical parameters and ions; 3–5 for metals and 1 for diatoms). Reference conditions were derived from modified benchmark tables (DWAF, 2008). The water quality category is shown on the Physico-chemical Driver Assessment Index (PAI) table (Table 6).

Table 5. Water quality present state assessment for EFR Fish 1

Parameter/units	***PES value***	***Ecological Category/Comment***
Inorganic salt ions (mg/ℓ)		
Sulphate as SO_4	1,189.30	Exceeds all guidelines. No SA ecosystem guideline
Sodium as Na	1,171.60	Exceeds all guidelines. No SA ecosystem guideline
Magnesium as Mg	59.4	A (no SA ecosystem guideline)
Calcium as Ca	44	A (no SA ecosystem guideline)
Chloride as Cl	842.2	Exceeds all guidelines. No SA ecosystem guideline
Potassium as K	16.2	A (no SA ecosystem guideline)
Electrical Conductivity (mS/m)	**528**	**E/F**
Nutrients (mg/ℓ)		
SRP	0.3 (n=3)	E/F[1]
TIN	0.3	B
Physical variables		
pH (5 th and 95th % tiles)	7.6 and 9.1	C
Temperature (ºC)	No data	Diatom samples indicated high oxygen saturation levels. However, fluctuations in oxygen and temperature levels are expected due to constantly fluctuating flows, exacerbated by upstream abstractions from Hardap and farm dams, which further reduce instream flows.
Dissolved oxygen (mg/ℓ)	No data-	
Turbidity (NTU)	No data	The system appears stable with gentle slopes and little sediment movement.
Response variables		
Chl-a: phytoplankton (ug/ℓ)	4 (n=6)	A
Macro-invertebrate score (MIRAI)[2]	74% (n=1)	C
Diatoms	SPI[3]=17.1	A/B
Fish score (FRAI)[4]	83%	B
Toxics (mg/ℓ)[5]		

Parameter/units	***PES value***	***Ecological Category/Comment***
Fluoride as F	1.24	A
Manganese as Mn	0.103	Exceeds all excl. SANS drinking water
Iron as Fe	0.63	Exceeds all excl. SANS irrigation
Copper as Cu	0.009	A to B[6]
Zinc as Zn	0.009	Exceeds SA aquatic ecosystem guideline
Boron as B	1.725	Exceeds all guidelines (no SA ecosystem guideline)
Molybdenum as Mo	0.01	A (no SA ecosystem guideline)
Lead as Pb	<0.01	Below detection
Cadmium as Cd	<0.01	Below detection
Mercury as Hg	<0.01	Below detection
Arsenic as As	0.01	A
Selenium as Se	0.027	Exceeds SA aquatic ecosystem guideline
Chromium as Cr	<0.01	Below detection (no SA ecosystem guideline)
Nickel as Ni	<0.01	Below detection (no SA ecosystem guideline)
Cobalt as Co	<0.01	Below detection (no SA ecosystem guideline)
Vanadium as V	0.01	A (no SA ecosystem guideline)
Uranium as U	0.0093	A (no SA ecosystem guideline)
Lithium as Li	0.0093	A (no SA ecosystem guideline)
Aluminium as Al	1.065	E/F
Overall site classification (from PAI table)	**C (66.2%)**	

1 Confidence in the phosphate category is low as few samples and unknown RC levels.
2 Macroinvertebrate Response Assessment Index 3 Specific Pollution Index score.
4 Fish Response Assessment Index 5 Low confidence in data.
6 Adjusted from an E category (according to guidelines) due to evidence of Cu associated with natural geology, although RC unknown.

Table 6. PAI table for EFR Fish

Metric	***Rating***	***Confidence***
pH	1	3
Salts	3	4
Nutrients	3	4
Water temperature	1	2
Water Clarity	0.5	3.5
Oxygen	1	2
Toxics	2	2
PC modification rating	1.69	
PC Category (%)	**C (66.2%)**	

The present state category for water quality is a C category, with a low confidence. Few data were available for the assessment, with no information available on the expected natural state of the system.

2.4.2 EFR Fish 2

Table 7 shows the water quality present state assessment for EFR Fish 2, i.e. the stretch of Fish River between Neckartal dam and the confluence with the Löwen River. The water quality sites used for this assessment were SW1 (downstream Seeheim), SW2 (downstream Naute Dam), and SW3 (downstream Neckartal Dam) (see Figure 2) based on data collected from February 2010 to April 2012 (n = 37 for physical parameters and ions; 9–13 for metals and 1 for diatoms). Reference conditions were derived from modified benchmark tables (DWAF, 2008). Note that SW2 was excluded where large deviations were evident as compared to the other two sites, i.e. EC and salt ions. The water quality category is shown on the PAI table (Table 8).

Table 7. Water quality present state assessment for EFR Fish 2

Parameter/units	***PES value***	***Ecological Category/Comment***
Inorganic salt ions (mg/ℓ)		
Sulphate as SO_4	951.1 (excl. SW2)	Exceeds all guidelines (no SA ecosystem guideline)
Sodium as Na	967.2 (excl. SW2)	Exceeds all guidelines (no SA ecosystem guideline)
Magnesium as Mg	40.6 (excl. SW2)	A (no SA ecosystem guideline)
Calcium as Ca	42.8 (excl. SW2)	A (no SA ecosystem guideline)
Chloride as Cl	676.5 (excl. SW2)	Exceeds all guidelines (no SA ecosystem guideline)
Potassium as K	17.0 (excl. SW2)	A (no SA ecosystem guideline)
Electrical conductivity (mS/m)	212.5 (excl. SW2)	E/F
Nutrients (mg/ℓ)		
SRP	0.03	E/F[1]
TIN	0.47	B
Physical variables		
pH (5^{th} and 95^{th} % tiles)	7.36 and 8.95	C
Temperature (ºC)	No data	Diatom samples indicated high oxygen saturation levels.
Dissolved oxygen (mg/ℓ)	No data	
Turbidity (NTU)	No data	
Response variables		
Chl-a: phytoplankton (ug/ℓ)	30.92	D/E
Macro-invertebrate score (MIRAI)	86%	B
Diatoms	SPI[2]=17.8	A/B
Fish score (FRAI)	86%	C
Toxics (mg/ℓ)[3]		
Fluoride as F	0.88	A
Manganese as Mn	0.14	Exceeds all guidelines
Iron as Fe	0.417	Exceeds all excl. SANS irrigation

Parameter/units	*PES value*	*Ecological Category/Comment*
Copper as Cu	0.01	A to B[4]
Zinc as Zn	0.008	Exceeds SA aquatic ecosystem guideline
Boron as B	0.875	Exceeds all guidelines (no SA ecosystem guideline)
Molybdenum as Mo	0.269	Exceeds all guidelines (no SA ecosystem guideline)
Lead as Pb	<0.01	Below detection
Cadmium as Cd	<0.01	Below detection
Mercury as Hg	<0.01	Below detection
Arsenic as As	0.021	Exceeds WHO, SANS drinking water and SA ecosystem guideline
Selenium as Se	0.013	Exceeds WHO guideline and SA ecosystem guideline
Chromium as Cr	<0.01	Below detection (no SA ecosystem guideline)
Nickel as Ni	<0.01	Below detection (no SA ecosystem guideline)
Cobalt as Co	<0.01	Below detection (no SA ecosystem guideline)
Vanadium as V	0.008	A (no SA ecosystem guideline)
Uranium as U	0.0063	A (no SA ecosystem guideline)
Lithium as Li	0.0067	A (no SA ecosystem guideline)
Aluminium as Al	0.37	E/F
Overall site classification (from PAI table)		**C (70.2%)**

1 Confidence in the phosphate category is low as few samples and unknown RC levels.
2 Specific Pollution Index score
3 Low confidence in data.
4 Adjusted from an E category (according to guidelines) due to evidence of Cu associated with natural geology, although RC unknown.

Table 8. PAI table for EFR Fish 2

Metric	*Rating*	*Confidence*
pH	1	3
Salts	3	4
Nutrients	3	3
Water temperature	0.5	2
Water Clarity	0	3.5
Oxygen	0.5	2
Toxics	2	2
PC modification rating	1.49	
PC Category (%)	**C (70.2%)**	

The present state category for water quality is a C category, with a low confidence. Conditions are slightly improved as compared to EFR Fish 1, but water quality appears to be driven by similar variables, i.e. elevated salt and nutrient levels from the upstream area being exacerbated at times of low flow. No information was available on the expected natural state of the system. It is recommended that monitoring be intensified for a number of variables, e.g. metal ions.

2.4.3 EFR Fish Ai-Ais

This stretch of river is downstream of the Löwen River confluence to that of the Fish and Orange rivers (MRU Fish B.2). Although nutrient levels are expected to be elevated due to the sewage discharges at Ai-Ais and the water quality category is expected to drop, it should stay within a C category, largely due to the position of Ai-Ais in the lower section of the reach.

2.5 Conclusions

The flow regime of the Fish River and its tributaries is characterised by highly variable flow (Technical Report 31), which impacts on the water quality of the surface waters. Note that few releases are made from Hardap Dam – only nine releases have been made between 1963 and 2006, although some releases are made from Naute Dam on the Löwen River. Zero flows are experienced 70% of the time at Seeheim, and 78% of the time at Ai-Ais (Technical Report 31), although very wet years are also experienced. The pattern of daily flows at Seeheim seem to largely represent natural state, while magnitude might be lowered by storage and use from Hardap Dam (Technical Report 31).

There appears to be a general dependence on river flows and limited dam releases to sustain fresh water in the system, e.g. water sourced for the /Ai-/Ais Hot Springs Resort are from shallow boreholes drilled to approximately 14 m on the river bank. Boreholes are pumped from 5 m to ensure fresh water for domestic use (Electrical Conductivity values were determined as approximately 175 mS/m). (Thomas Skrywer, Namibia Wildlife Resorts, pers. comm., 20 June 2012).

Extensive fish kills have been reported in the Fish River Canyon, e.g. December 2008 as well as 2012. An investigation was conducted by Lesley Kukerri of the Ministry of Fisheries and Marine Resources, but results were not available at the time of drafting this report. Fish kills (i.e. yellow fish and modderbek) appear to be linked to fluctuations in oxygen levels, with the presence of blue-green algae reported (le Roux, pers. comm.). Spraying of reeds has also taken place below Hardap Dam, although it is unlikely this is related to fish kills.

The area is also experiencing extensive issues with malfunctioning sewage treatment systems. At the /Ai-/Ais Hot Springs Resort untreated sewage has been pumped directly into the Fish River below the resort for at least a year. Sewage is pumped as a constant flow through a 50 mm pipe. Resort capacity is 700 persons per night, with 100% occupancy in July and approximately 50% in May and June. (Francois Snyders, Namibia Wildlife Resorts, pers. comm., 20 June 2012). Sewage treatment systems at Hobas (start of the Fish Canyon Hiking Trail) were also non-functional during the survey of June 2012 (Max Witbooi, Ministry of Environment and Tourism, pers. comm., 20 June 2012). Non-functional and overflowing STW are also evident at Tses (north of Mariental), where overflows are into a tributary of the Fish River. Extensive eutrophication can be seen in the Gibeon area (Roberts; personal observation, June 2012). Gibeon is at the confluence of the Khom!garib and Fish rivers. The spring close to the confluence first attracted people to settle in Gibeon, but now the spring water seems to be of questionable quality due to contamination from, amongst other things, overflows from the vacuum sewerage system in the village (Technical Report 26).

High eutrophication levels are evident in the Hardap area. There is a centre pivot upstream Hardap, but approximately 10 km from the river (Bockmühl, pers. comm., June 2012) and unlikely to cause the eutrophication evident in the channel.

Note that the information below was collected on site by the author and Ms Roberts during a field survey in June 2012. Information regarding community water use was therefore collected during one-on-one interviews with said communities or representatives of relevant organizations (see text below) by Scherman and Roberts during the June field survey.

Communities appear to collect good quality water in many areas around Neckartal Dam from groundwater and springs (e.g. in the Kameel River at Snyfontein (Mrs April; Headmistress, SC Vries Pre-primary School, Snyfontien, pers. comm., 21 June 2012)). The Gaab and Holoogberg rivers, tributaries of the Fish River, also have natural springs and good quality groundwater (Roberts, 2012). Biota of the Fish River seems to be sustained by perennial pools in many areas. Pools appear to be perennial, although not connected during the dry season (e.g. June to November at Fish River Lodge, approximately 90 km downstream of Seeheim, which is south of Neckartal Dam; (Ralph Dantu, Fish River Lodge, pers. comm., 19 June 2012)). These pools are important refuges for fish, and other aquatic species, as well as water sources for various wildlife species (Technical Report 26). According to Technical Report 31, it appears that annual and seasonal replenishment through channel flow is the main driver of maintaining pools, with some contribution by groundwater seepage into the channel zone.

A number of metal ions were elevated above available guidelines in the samples collected by MAWF for the ESIA, suggesting toxics may be present in the water column. According to the South African aquatic ecosystem guidelines (DWAF, 1996a) elevations above detection limits were seen in February 2012 but it should be noted that the detection limits provided in the guidelines are extremely sensitive. Monitoring should therefore be intensified for these variables so as to check the validity of the values, instream toxicity testing should be included on a quarterly basis as part of the baseline monitoring programme and, data, units and guidelines should be checked. The source of elevated metals being the geology of the region should also be investigated, particularly the elevated copper levels.

3. Diatoms

3.1 Background

Algal-based bio-assessments in streams have been extensively researched worldwide and applied in regular riverine- and lake-monitoring programmes with great success. Diatoms are commonly employed in monitoring efforts as sensitive biological indicators to determine the anthropogenic impact on aquatic ecosystems, and have for a long time been used in bio-assessments (Kasperovičienė and Vaikutienė, 2007). As benthic diatom assemblages are sessile they are exposed to water quality at a site over a period antecedent to sampling. They therefore indicate recent as well as current water quality (Philibert et al., 2006).

The aim of the diatom sampling and analysis within the context of this study was to provide biological water quality information for conditions on the day of biological-component sampling regarding the aquatic health and functioning of the aquatic system, and providing additional input to the physico-chemical component of the study as a response variable. The overall objective of this report was to assess the impacts of anthropogenic activities on the Present Ecological State of the receiving aquatic ecosystem.

3.2 Terminology

Terminology used in this chapter is outlined in Taylor et al. (2007a) and summarised below.

Variable	*Description*
Trophy	
Dystrophic	Rich in organic matter, usually in the form of suspended plant colloids, but of a low nutrient content.
Oligotrophic	Low levels or primary productivity, containing low levels of mineral nutrients required by plants.
Mesotrophic	Intermediate levels of primary productivity, with intermediate levels of mineral nutrients required by plants.
Eutrophic	High primary productivity, rich in mineral nutrients required by plants.
Hypereutrophic	Very high primary productivity, constantly elevated supply of mineral nutrients required by plants.
Mineral content	
Very electrolyte poor	< 50 µS/cm
Electrolyte-poor (low electrolyte content)	50 - 100 µS/cm
Moderate electrolyte content	100 - 500 µS/cm
Electrolyte-rich (high electrolyte content)	> 500 µS/cm

Variable	***Description***
Brackish (very high electrolyte content)	> 1000 µS/cm
Saline	6000 µS/cm
Pollution (Saprobity)	
Unpolluted to slightly polluted	BOD <2, O_2 deficit <15% (oligosaprobic)
Moderately polluted	BOD <4, O_2 deficit <30% (β-mesosaprobic)
Critical level of pollution	BOD <7 (10), O_2 deficit <50% (β-α-mesosaprobic)
Strongly polluted	BOD <13, O_2 deficit <75% (α-mesosaprobic)
Very heavily polluted	BOD <22, O_2 deficit <90% (α-meso-polysaprobic)
Extremely polluted	BOD >22, O_2 deficit >90% (polysaprobic)

3.3 Available data

Diatom samples were collected during August 2009 and February 2010, as part of the aquatic ecosystems specialist study undertaken by Nepid Consultants (Nepid Consultants, 2010). Diatom samples were also collected at the EFR sites as part of this study.

Data availability and the confidence for each EFR site are provided in Table 9. Historic and present sampling locations are provided in Figure 3.

Table 9. Data availability and confidence

Site	***Data availability***	***Confidence***
EFR Fish 1	No historic site-specific diatom data was available for this site or MRU Fish A. Due to the ephemeral nature of the Fish River the confidence in the assessment is low.	1.5
EFR Fish 2	Site-specific diatom data were available (2009–2010) as well as data from sample collected during EFR site visit. Diatom samples were collected during 2008–2009 across the reach MRU Fish B2.1, along with measured in situ water quality measurements.	2.5
EFR Fish Ai-Ais	No historic site-specific diatom data was available for this site or MRU Fish B2. Due to the ephemeral nature of the Fish River the confidence in the assessment is Low.	1.5

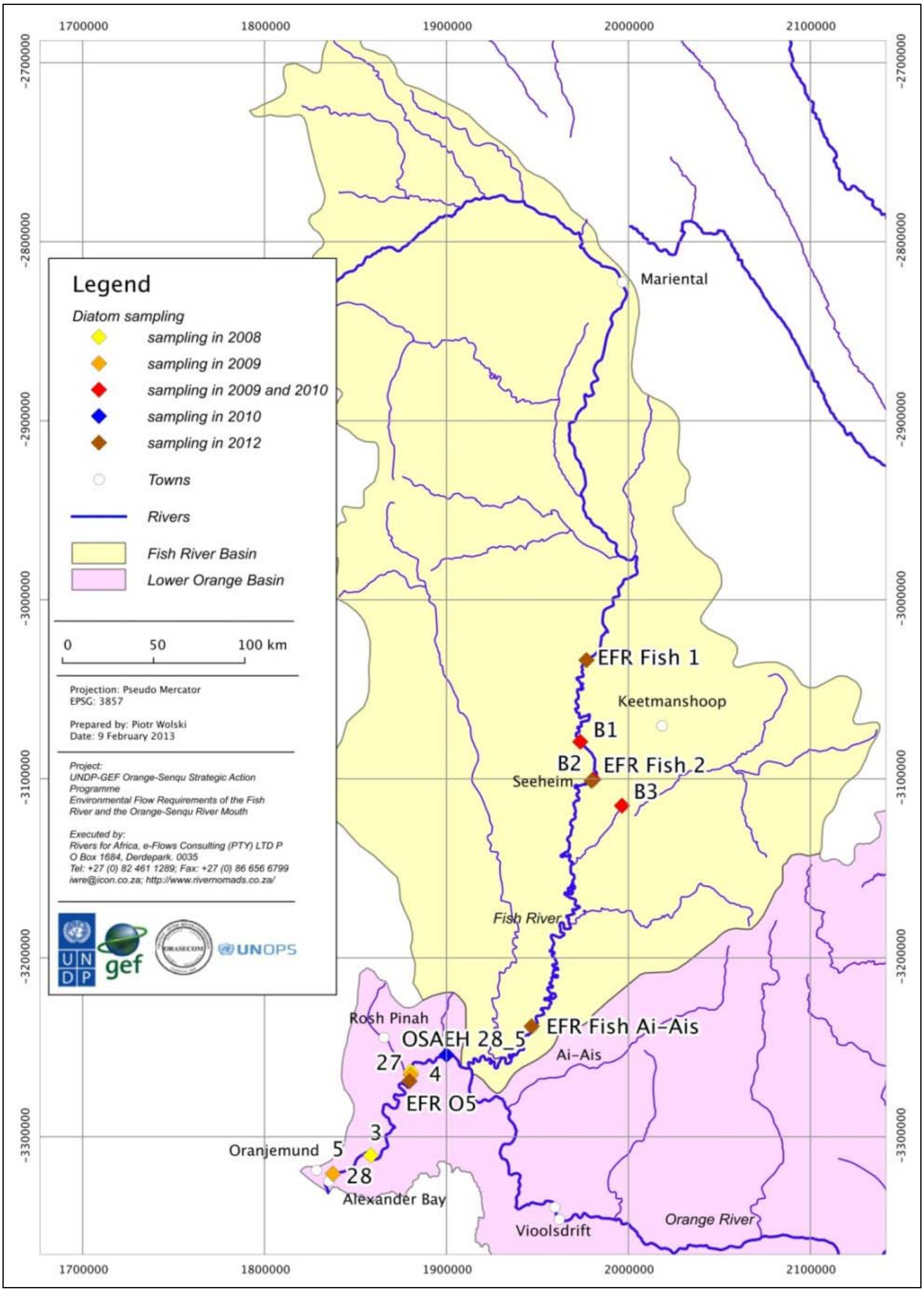

Figure 3. Location of diatom sampling sites, 2008-2012

3.4 Methods

3.4.1 Sampling

Sampling methods were followed as outlined in Taylor et al. (2007a) which were designed and refined as part of the Diatom Assessment Protocol, a Water Research Commission initiative.

3.4.2 Slide preparation and diatom enumeration

Preparation of diatom slide followed the Hot HCl and $KMnO_4$ method as outlined in Taylor et al. (2007a). A Nikon Eclipse E100 microscope with phase contrast optics (1000x) was used to identify diatom valves on slides. A count of 400 valves per sample or more was enumerated for all the sites based on the findings of Schoeman (1973) and Battarbee (1986) in order to produce semi-quantitative data from which ecological conclusions can be drawn (Taylor et al., 2007a). Nomenclature followed Krammer and Lange-Bertalot (1986-91) and diatom index values were calculated with the database programme OMNIDIA (Lecointe et al., 1993).

3.4.3 Diatom-based water quality indices

The specific water quality tolerances of diatoms have been resolved into different diatom-based water quality indices, used around the world. Most indices are based on a weighted average equation (Zelinka and Marvan, 1961). In general, each diatom species used in the calculation of the index is assigned two values; the first value (s value) reflects the tolerance or affinity of the particular diatom species to a certain water quality (good or bad) while the second value (v value) indicates how strong (or weak) the relationship is (Taylor, 2004). These values are then weighted by the abundance of the particular diatom species in the sample (Lavoie et al., 2006; Taylor, 2004; Besse, 2007). The main difference between indices is in the indicator sets (number of indicators and list of taxa) used in calculations (Eloranta and Soininen, 2002).

These indices form the foundation for developing computer software to estimate biological water quality. OMNIDIA (Lecointe et al., 1993) is one such software package; it has been approved by the European Union and is used with increasing frequency in Europe and has been used for this study. The program is a taxonomic and ecological database of 7500 diatom species, and it contains indicator values and degrees of sensitivity for given species. It permits the user to perform rapid calculations of indices of general pollution, saprobity and trophic state, indices of species diversity, as well as of ecological systems (Szczepocka, 2007).

3.4.4 Data analysis

Diatom-based water quality score

The European numerical diatom index, the Specific Pollution sensitivity Index (SPI) was used to interpret results. De la Rey et al. (2004) concluded that the SPI reflects certain elements of water quality with a high degree of accuracy due to the broad species base of the SPI. The interpretation of the SPI scores was adjusted during 2011 (Taylor and Koekemoer, in press) and the new adjusted class limits are provided in Table 10. The new adjustments will affect diatom-derived Ecological Categories from previous studies and therefore all previous results have been adjusted accordingly.

Table 10. Adjusted class limit boundaries for the SPI index applied in this study

Interpretation of index scores		
Ecological category	***Class***	***Index score (SPI score)***
A	High quality	18 - 20
A/B	High quality	17 - 18
B	Good quality	15 - 17
B/C	Good quality	14 - 15
C	Moderate quality	12 - 14
C/D	Moderate quality	10 - 12
D	Poor quality	8 - 10
D/E	Poort quality	6 - 8
E	Bad quality	5 - 6
E/F	Bad quality	4 - 5
F	Bad quality	<4

Diatom based ecological classification

Ecological characterisation of the samples was based on Van Dam et al. (1994). This work includes the preferences of 948 freshwater and brackish water diatom species in terms of pH, nitrogen, oxygen, salinity, humidity, saprobity and trophic state as provided by OMNIDIA (Le Cointe et al., 1993). The results from the Trophic Diatom Index (TDI) (Kelly and Whitton, 1995) were also taken into account as this index provides the percentage pollution tolerant diatom valves (PTVs) in a sample and was developed for monitoring sewage outfall (orthophosphate-phosphorus concentrations), and not general stream quality. The presence of more than 20% PTVs shows significant organic impact.

3.5 Diatom results

3.5.1 Management resource unit Fish A: Hardap Dam to Neckartal Dam

No historic diatom data was available for this reach. A diatom sample was collected at EFR Fish 1 during June 2012 which is approximately 65 km upstream of the Neckartal Dam site. Flow was present at the time of sampling and the dominant hydraulic biotope was Fast Shallow. The water was clear with some sedimentation present and algal growth on rocks was visible.

The SPI score and ecological classification, according to Van Dam et al. (1994), is provided in Table 11 for EFR Fish 1.

Table 11. Summary of diatom results at EFR Fish 1

Variable	***Description***
pH	Circumneutral
Trophy	Indifferent
Salinity	Fresh brackish
Oxygen	Continuously high
Nitrogen metabolism	Elevated
SPI	17.1
EC[1]	A/B

1 Electrical conductivity

The diatom-based water quality was high with a SPI score of 17.1. The diatom community was dominated by *Achnanthidium* species which has a preference for well oxygenated clean waters. *Encyonema. microcephala* was dominant indicating that oxygen saturation was high. This species is also aerophilic in nature, occurring mainly on wet and moist places and indicated that water levels were low and fluctuated. Salinity and nutrient levels are elevated although not problematic. PTVs made up 0.8% of the total count indicating that organic pollution levels were very low in the Fish River system when there was flow. Moderate pollution levels prevailed mainly due to elevated nutrient levels.

3.5.2 Management resource unit Fish B.2.1: Neckartal Dam to Löwen River

Diatom data was available from an aquatic ecosystems specialist study undertaken by Nepid Consultants (Nepid Consultants, 2010) as part of the ESIA for the Neckartal Dam. During this study three sites (Sites B1–B3) were selected and sampled during August 2009 and February 2010. During 2012 two additional sites were surveyed in this reach as part of the current EFR study (Figure 3).

Site B1

This site is located approximately 400 m downstream of the proposed Neckartal Dam. The SPI scores and ecological classification according to Van Dam et al. (1994) for the two samples are provided in Table 12.

Table 12. Summary of diatom results at Site B1

Variable	***Description***	
	Site B1: August 2009	***Site B1: February 2010***
pH	Circumneutral	Alkaline
Trophy	Hyper-eutrophic	Eutrophic
Salinity	Fresh brackish	Fresh brackish
Oxygen	Very low	Moderate

Variable	***Description***	
	Site B1: August 2009	***Site B1: February 2010***
Nitrogen metabolism	Continuously elevated	Elevated
SPI	16.1	5.8
EC	B	E

The following information is an extract from Nepid Consultants (2010):

During August 2009 the diatom community was dominated by *Achnanthidium* species including *A. saprophila* and *A. eutrophilum* which are usually found in organically enriched, eutrophic fresh waters (Taylor et al., 2007b). *Fragilaria ulna* var. *acus* was also dominant and found in meso–eutrophic alkaline waters. The community indicated that organic pollution and nutrients were problematic at this site and during summer these conditions may become exacerbated.

During February 2010 the biological water quality deteriorated drastically and the SPI score was 5.8, indicating that the water quality was poor. The diatom community was dominated by *Nitzschia* species, indicating a highly polluted water body with readily available nutrients (van Dam et al., 1994). Salinity was elevated at this site and this was evident by the dominance of *N. frustulum* and *N. liebetruthii* which usually occurs in electrolyte rich to brackish waters, and is tolerant of highly polluted waters. Although the pollution levels were not as high as during the winter it is assumed, based on the high abundance of *Nitzschia* species, that pollution levels would increase to similar levels if not worse during the summer and that the diatom species were still adapting to the deteriorating conditions which is not reflected by the resulting pollution scores of Van Dam et al. (1994) (Table 17).

The Fish River is a seasonal system, and salinity levels are expected to be naturally high due to the geology of the area and high evaporation rates. Samples were collected in slow-flowing water, but about one month after the river had been in spate. *Hantzschia amphioxys* was present in the sample, and indicated that there was a flushing event as this species occurs in periodically dry habitats and gets washed in from soils most of the time (Taylor et al., 2007b). Nutrient levels, and organic pollution were elevated at this site and oxygen saturation was moderate. The moderate levels of pollution were attributed mainly due to goats, which were abundant in the area.

From the results it is evident that during summer organic pollution and elevated nutrient levels impact heavily at the site. The site seemed to recover during the winter months when temperatures were lower. The overall biological water quality PES was estimated at a C.

Site B2 (EFR Fish 2)

This site is located approximately 26 km downstream of the Neckartal Dam site, at Seeheim. The SPI scores and ecological classification according to Van Dam et al. (1994) for the two samples are provided below.

Table 13. Summary of 2009 and 2010 diatom results at Site B2 (EFR Fish 2)

Variable	***Description***	
	Site B2: August 2009	***Site B2: February 2010***
pH	Circumneutral	Alkaline
Trophy	Hyper-eutrophic	Oligo–Eutrophic
Salinity	Fresh brackish	Fresh brackish
Oxygen	Very low	Moderate
Nitrogen metabolism	Continuously elevated	Elevated
SPI	14.9	6.4
EC	B/C	D/E

During August 2009 the SPI score at this site was 14.9 (Nepid Consultants, 2010) indicating that the water quality at the site was good. As with Site B1, oxygen saturation was very low, and organic pollution was the major impact at this site. Dominant species were similar to site B1 with *E. microcephala* also dominant usually occurring in calcareous waters with moderate electrolyte content (Taylor et al., 2007b). Due to the high abundance of *Achnanthidium* species the SPI score may have been over estimated.

During February 2010 the SPI score dropped to 6.4 (Nepid Consultants, 2010) with a species composition and abundance similar to Site B1 for August, with the majority of the species present having an affinity for waters with high electrolyte content. Dominant species included *Nitzschia* species, *Aulacoseira granulata*, *A. granulata* var. *angustissima* and *Nitzschia agnewii,* which all prefer eutrophic waters (Taylor et al., 2007b). As with Site B1 this site had moderate oxygen saturation with elevated organically bound nitrogen for February. Pollution levels were slightly higher at this site than if compared to Site B1. The most likely cause of the elevated nutrient levels was the high numbers of goats in the area.

As with Site B1 recovery during the winter months seem good, although organic pollution was problematic. Nutrient levels were continuously high due to high algal production and the overall water quality PES was estimated at a C EC.

During June 2012 flow was present at the time of sampling and the dominant hydraulic biotope was Fast Shallow. The water was clear with some sedimentation present and algal growth on rocks was visible. The SPI score and ecological classification according to Van Dam et al. (1994) are provided below.

Table 14. Summary of June 2012 diatom results at B2 (EFR Fish 2)

Variable	***Description***
pH	Circumneutral
Trophy	Indifferent

Variable	*Description*
Salinity	Fresh brackish
Oxygen	Continuously high
Nitrogen metabolism	Elevated
SPI	17.8
EC	A/B

The diatom-based water quality was high with a SPI score of 17.8. The diatom community was very similar to EFR Fish 1 and was dominated by *Achnanthes* and *Achnanthidium* species which have a preference for well-oxygenated clean waters. *E. microcephala* was sub-dominant indicating that oxygen saturation was high. *Fragilaria* species, which occur in oligotrophic to eutrophic waters were sub-dominant. PTVs made up 2.3% of the total count indicating that organic pollution levels were slightly higher than at EFR Fish 1. Nutrients were also higher at EFR Fish 2 than EFR Fish 1 although these levels were not problematic. Salinity levels remained relatively stable between the two EFR sites. Moderate pollution levels prevailed mainly due to elevated nutrient levels.

3.5.3 Management resource unit Fish B.2: Löwen River to Fish River confluence

Site B3

Site B3 is situated in the Löwen River, 400 m downstream of Naute Dam and was assessed as part of the ESIA for the Neckartal Dam. Water originates from the Naute Dam due to a constant leak which has resulted in wetland habitat below the dam wall. Further downstream irrigation water enters the system from the irrigation scheme in the area. The SPI scores and ecological classification according to Van Dam et al. (1994) for the two samples are provided below.

Table 15. Summary of diatom results at Site B3

Variable	*Description*	
	Site B3: August 2009	*Site B3: February 2010*
pH	Alkaline	Alkaline
Trophy	Eutrophic	Eutrophic
Salinity	Fresh brackish	Fresh brackish
Oxygen	Low	Low
Nitrogen metabolism	Periodically elevated	Periodically elevated
SPI	9.2	10.1
EC	D	C/D

Pollution tolerant valves made up 46% (Nepid Consultants, 2010) of the sample indicating that this site was very heavily polluted. The dominant species included a range of *Achnanthidium* species as well as *Eolimna minima* and *Nitzschia* species. *E. minima* tolerate heavily polluted waters while the dominance of *Nitzschia* species indicated a highly polluted water body with readily available nutrients (van Dam et al., 1994).

The biological water quality in the Löwen River during February 2010 was moderate (SPI score of 10.1). The dominant species, *Amphora pediculus* and *E. minima* tolerate heavily polluted conditions (Taylor et al., 2007b), and it was evident that nutrient loading and organic pollution was problematic at this site. Salinity levels were also elevated, although this could be attributed to local geology and evaporative losses.

The overall biological water quality at this site was a C/D. Nutrient and organic pollution seemed to be the major impacts at this site and recovery during winter was not as good as the other sites. This may have been due to the close proximity of the Naute Dam, which does not allow for flushing of instream habitat. The biological water quality at this site is rather a reflection of the conditions in Naute Dam as the major source of water at the site is from the dam leak. Irrigation return flows may also be impacting this site.

EFR Fish Ai-Ais

This site was sampled during June 2012 and is located in the Fish River approximately 83 km upstream of the confluence with the Orange River. This site is the most downstream site in the Fish River and represents the accumulative impacts within the catchment which includes anthropogenic activities within the Fish River Canyon. The SPI scores and ecological classification according to Van Dam et al. (1994) are provided below.

Table 16. Summary of diatom results at EFR Fish Ai-Ais

Variable	***Description***
pH	Alkaline
Trophy	Eutrophic
Salinity	Brackish fresh
Oxygen	Moderate
Nitrogen metabolism	Continuously elevated
SPI	7.1
EC	D/E

The diatom-based water quality was poor with a SPI score of 7.1. The flow at the site was very low and algal growth on the rocks was visible. Dominant species included *N. frustulum* and *Nitzschia* species. The dominance of these species indicated that nutrient loading was high and that salinity was problematic. The high salinity levels could be due to the geology of the area, but due to the high occurrence of diatom indicators for anthropogenic impact, it was concluded that these activities contributed to some extent to the elevated salinity levels. PTVs made up 68.3% of the total count, indicating that organic pollution levels were very high and problematic. The majority of diatom species have a preference for organically enriched waters. Anthropogenic activities are impacting negatively on the Fish River within this reach and this is evident from indicator species of anthropogenic activities only occurring at this site and not at the upstream EFR sites during 2012.

3.6 Conclusions

3.6.1 Summary of results

A summary of the diatom results (2008-2012) are provided in Table 17 based on a total count of 400 diatom valves. Table 18 provides a summary of the diatom-based ecological classification based on Van Dam et al. (1994) of these results.

Table 17. Summary of diatom results (2008–2012)

Site	*No of species*	*%PTV*	*SPI*	*EC*	*Pollution levels*
August 2009					
B1	25	3	16.1	B	Strongly polluted
B2	22	6.5	14.9	B/C	Strongly polluted
B3	40	46.5	9.2	D	Very heavily polluted
February 2010					
B1	40	65.3	5.8	E	Moderately polluted
B2	41	56.3	6.4	D/E	Strongly polluted
B3	36	29.2	10.1	C/D	Very heavily polluted
June 2012					
EFR Fish 1	14	0.8	17.1	A/B	Moderately polluted
B2 (EFR Fish 2)	28	2.3	17.8	A/B	Moderately polluted
EFR Fish Ai-Ais	53	68.3	7.1	D/E	Very heavily polluted

Table 18. Generic diatom-based ecological classification

Variable	*Site*		
August 2009	B1	B2	B3
pH	Circumneutral	Circumneutral	Alkaline
Trophy	Hyper-eutrophic	Hyper-eutrophic	Eutrophic
Salinity	Fresh brackish	Fresh brackish	Fresh brackish
Oxygen	Very low	Very low	Low
Nutrient levels (Nitrogen)	Continuously elevated	Continuously elevated	Periodically elevated
February 2010	B1	B2	B3
pH	Alkaline	Alkaline	Alkaline
Trophy	Eutrophic	Oligo–Eutrophic	Eutrophic
Salinity	Fresh brackish	Fresh brackish	Fresh brackish
Oxygen	Moderate	Moderate	Low
Nutrient levels (Nitrogen)	Elevated	Elevated	Periodically elevated
June 2012	EFR Fish 1	B2 (EFR Fish 2)	EFR Fish Ai-Ais
pH	Circumneutral	Circumneutral	Alkaline

Variable	*Site*		
Trophy	Indifferent	Indifferent	Eutrophic
Salinity	Fresh brackish	Fresh brackish	Brackish fresh
Oxygen	Continuously high	Continuously high	Moderate
Nutrient levels (Nitrogen)	Elevated	Elevated	Continuously elevated

3.6.2 Management resource unit FISH A: Hardap Dam to Neckartal Dam

The Fish River is a flood-driven system in which the riverine biota are adapted to short periods of high flow, followed by long periods with no surface flows, or no surface water (Nepid Consultants, 2010). Salinity levels are expected to be naturally high due to the geology of the area and high evaporation rates. From the diatom data it is evident that flow plays an important role in the amelioration of water quality throughout the system. This is especially important for the larger pools within the system which become isolated during dry periods. Organic and nutrient loading increases in these habitat types due to high evaporation rates, absence of flow and aquatic biota that use this habitat type as refuge areas. The assessment of this reach is of low confidence as only one site occurred in this reach and the sample was collected during a period of flow. The diatom-based water quality was high due to the fresh inundation. Salinity and nutrient levels were elevated although not problematic and moderate pollution levels prevailed mainly due to elevated nutrient levels. It is expected that these variables will deteriorate under lower flows due to irrigation return flows high in salinity and nutrients. Organic pollution was not problematic at the time of sampling, however it is assumed that this variable will become problematic after prolonged periods of zero flow as is evident in MRU Fish B. There will be further impact from livestock in the area which would contribute to increased loads of nutrient and organic pollution. The overall biological water quality PES was estimated at a C/D.

3.6.3 Management resource unit Fish B2.1: Neckartal Dam to Löwen River

The aquatic fauna in the Fish River is characterised by highly opportunistic and hardy species that are adapted to extreme variations in flow and associated changes in water quality. The aquatic ecosystem is therefore, in general, likely to be highly resilient to change (Nepid Consultants, 2010). The diatom data indicates that water quality in the Fish River varies to great degrees throughout the year and is mainly driven by the flow conditions within the system. From the results it is evident that during summer organic pollution and elevated nutrient levels are high within the reach. There seems to be some measure of recovery during the winter months when temperatures are lower.

The confidence in the assessment for this reach is higher than for MRU Fish A. As with MRU Fish A the diatoms results show great variability, depending on the amount of flow in the system. The diatoms do indicate a general deterioration in biological water quality with organics, and nutrients becoming problematic, but under higher flows the system recovers and there is a general improvement in all water quality variables. Due to the increased grazing pressure within the reach the overall biological water quality PES was estimated at a C/D.

3.6.4 Management resource unit Fish B.2: Löwen River to Fish River confluence

The Löwen River is of poorer water quality and nutrient and organic pollution seems to be the major impacts in this reach as reflected by the diatom results at Site B3 assessed during August 2009 and February 2010. Recovery during winter was not as good as the other sites which may be due to the close proximity of the Naute Dam, which does not allow for flushing of instream habitat. The overall biological water quality entering the MRU was estimated at a C/D.

In the lower reaches of the MRU, anthropogenic activity increase mainly due to the activities associated with the Fish River Canyon. The diatom results collected at Ai-Ais indicated that although the water quality was impaired due to low flows which had resulted in high organic loads as well as nutrient loading, the anthropogenic activities also impact on the Fish River system as reflected by the D/E Ecological Category. These activities will exacerbate deteriorated water quality conditions, especially in the pools. Although salinity is elevated within the reach these levels increase further due to the anthropogenic activities. The overall biological water quality PES for the MRU was estimated at a D EC.

4. Geomorphology

The physical structure of a river ecosystem is determined by geomorphological processes which shape the channel. These processes determine the material from which the channel is formed, the shape of the channel and the stability of its bed and banks. The channel geomorphology in turn determines the substrate conditions for the riverine fauna and flora and the hydraulic conditions for any given flow discharge. Structural changes to the river channel (damage to the riparian zone, sediment inputs from catchment erosion or reservoir induced changes in the flow regime) can cause long term irreversible effects for biota (O'Keeffe, 2000; Kochel, 1988). Geomorphology thus provides an appropriate basis of classification for describing the physical habitat of riparian and aquatic ecosystems.

4.1 Longitudinal zone classification

4.1.1 Aims and methods

The aim of the longitudinal zone classification is to subdivide the longitudinal profile into morphologically uniform zones. Channel gradient is generally well correlated with many channel properties including channel planform or type, bed material and reach type (Rowntree et al., 2000). Changes in gradient down a longitudinal profile usually mark morphological changes and thus provide the basis for the delineation of zones. These breaks are usually due to changes in lithology, but can also be as a result of tectonic activity or the upstream migration of knick points (Dollar, 1998). Zones were delineated on the basis of significant breaks in the longitudinal profile. The zones were then classified using the system of Rowntree and Wadeson (1999) who have developed a hierarchical classification system for Southern African rivers which aims to provide a scale-based framework linking the various components of the river system, ranging from the catchment to the instream habitat. The system consists of six levels:

- the catchment;
- the segment;
- the zone;
- the reach;
- the morphological unit;
- the hydraulic biotope.

The geomorphological zones are used to guide the spatial framework for the delineation of resource units (RUs) (Technical Report 22); which would also include operation rules and zones of altered hydrology, the assessment of habitat integrity, and selection of field sites for detailed study. Information derived from the field sites can then be scaled up to the zone scale to obtain a broad overview of likely condition and impacts for the entire study area.

4.1.2 Longitudinal zones of the Fish River

This section represents the findings of a primarily desktop assessment of the basin. Available published information on geology, geomorphology, EcoRegions and assessment of the morphological characteristics of the river from satellite (Google Earth) imagery was used to refine the longitudinal zones identified from the application of the Rowntree and Wadeson (1999) zone classification.

This desktop assessment was refined following limited field investigations at the EFR Fish 1 and Fish 2, and a short field visit day to boreholes in the region surrounding EFR Fish 2 to assess water table depths and slopes.

The Fish River has a relatively uniform longitudinal slope, but the variation in valley form afforded by the rejuvenated lower reaches result in very different morphologies. A longitudinal zone analysis was undertaken. Zones were delineated by slope (following Rowntree and Wadeson, (1999) and the by valley form and reach characteristics.

Two major zones that were disaggregated into four zones were identified in the analysis (Figure 4 and Table 19). The foothills characteristics of the upper catchment contrast with the confined nature of the lower (canyon) zones. The characteristics of each reach are described below.

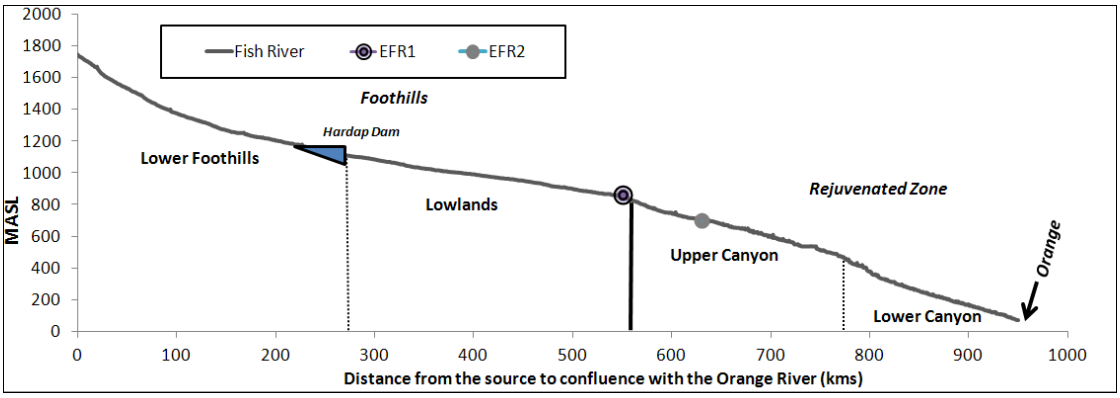

Figure 4. The four geomorphological zones delineated along the Fish River

Table 19. Characteristics of the geomorphological zones of the Fish River

Zone (elevation range)	***Description***	***Length (km)***	***Average slope***	***Zone type[1]***
1: Upper Foothills (above 1135 masl)	Small, narrow river over moderately steep gradient. The zone ends at Hardap Dam.	262	0.0023	Lower foothills
2: Lowlands (1135–860 masl)	From below Hardap Dam to the start of the upper canyon, the river is characterised by a wide macro-channel that is relatively straight. The active channel within the macro-channel switches west and east between large alternating lateral bars.	277	0.0001	Lowland

Zone (elevation range)	*Description*	*Length (km)*	*Average slope*	*Zone type*[1]
3: Upper Canyon (860–420masl)	Moderately incised, narrower river macro-channel, but this sits within a rift canyon. The macro-channel displays more meandering than the upstream zone, although this meandering channel is slightly incised in to the bedrock of the upper canyon floor.	245	0.0018	Rejuvenated foothills
4: Lower Canyon (420–70masl)	The gorge proper - a planform of deeply incised meanders with a very steep, narrow canyon.	165	0.0021	Rejuvenated foothills

1: Based on Wadeson and Rowntree (1999)

a) Upper Foothills zone: The river rises between Rehoboth and Maltahöhe in the centre of the country. The upper reaches of the river are slightly steeper, this zone terminating in Hardap Dam. There are several farm dams within the upper catchment that are, in addition to Hardap Dam, impacting on the flow of the river.

b) Lowlands: Downstream of Hardap Dam the gradient is comparatively low and the river flows within a broader valley. EFR Fish 1 is located at the end of this zone.

c) Upper Canyon: Faults occur in this upper canyon, along which the valley subsided (Figure 5). The upper canyon is thus characterized by a wide valley floor created by rift-faulting, with a shallowly incised river flowing within this (Figure 5). Meander bends formed prior to the uplift are moderately incised. EFR Fish 2 is located within this zone.

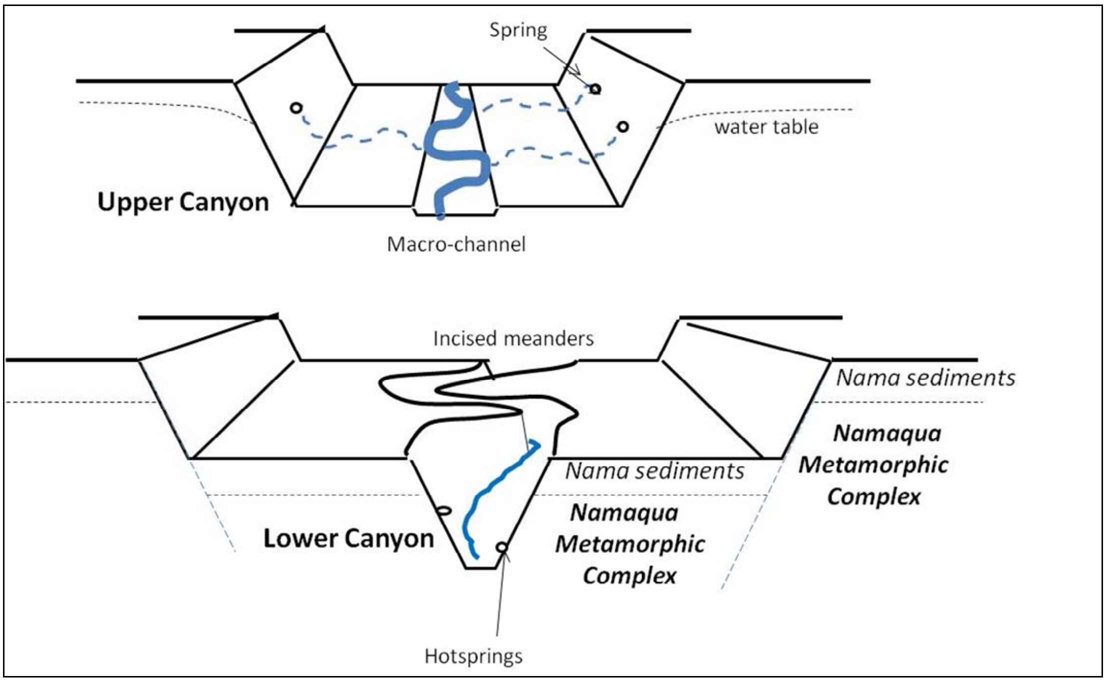

Figure 5. The upper and lower canyon of the fish river

4.1.3 Lower canyon

Downstream of the confluence with the Löwen River, the gradient increases, causing the Fish River to incise more strongly into the underlying rocks. The original intense meandering planform of this reach has been preserved, the meanders having become deeply incised due to uplift and the subsequent incision. The degree of meandering and of channel incision is far higher in the lower canyon than the upper canyon. The incised channel has cut through the Nama sediments and much of the underlying Namaqua complex (Figure 6).[1]

Figure 6. In the lower canyon the Fish River has eroded through the upper Nama sedimentary rocks, exposing the Namaqua Metamorphic complex

4.2 River pool types

The Fish River has a relatively low sediment load. Despite the sparse vegetation cover across the catchment, and erratic, low rainfall, the generally flat topography of the basin results in low sediment production. In addition, sediment is also trapped in large dams (such as Hardap) as well as several smaller earth dams. Due to the reduced flows, pools have become increasingly ecologically important. The active channel morphology of the Fish River, and location and extent of pools within this, as evidenced from historical aerial photographs over the last 50 years, is thus relatively stable. The major factor of pool habitat extent is likely to be the availability of water to fill and maintain pools.

[1] Photo source: http://www.eduvideoafrica.com/?page_id=413

The location of pools in the Fish River tends to follow the thalweg; itself tending to the outer edges of meander and other bends in the river channel. Based on satellite imagery and limited field time at the EFR sites, the following morphological types of riverine pools were identified.

4.2.1 Transient alluvial

The pools form entirely within alluvium, often alongside lateral bars as part of alluvial pool-riffle sequences. The pools are dependent on surface or interflow from upstream areas. These are the least morphologically stable pool types, and appear to be relatively uncommon (most pools are associated with bedrock outcrops) under present flow conditions. Possibly they were more common historically with more flow.

4.2.2 Stable bedrock-controlled

In the lower Fish River, the vast majority of pools are primarily located in the bends of the river, usually in bedrock pool-rapid sequences, and/or associated with tributary junctions. The pools tend to be associated with outcrops of the underlying bedrock or resistant dykes crossing the river. The source of water to maintain these pools during the dry season arises either from:

- Surface and interflow from the upstream (main Fish River channel) and interflow from the tributaries flowing in to the pools; or
- hot springs in the immediate area.

4.2.3 Main stem and tributary interflow pools

These pools are relatively permanent, being fed from interflow and surface flow from the main stem Fish River, as well as possibly from interflow (subsurface flows) moving in the sediment of the tributaries that arise at the edge of the faulting. Springs that are coincident with the level of the regional groundwater were located near EFR Fish 2 (Figure 7) and these small but consistent flows may be contributing, through subsurface inflows, to the pools at the tributary junctions in the mainstream Fish River.

The length and width of the pools does vary with the volume of flows, but the location of these types of pools is fixed by the underlying bedrock template.

Figure 7. Spring in a tributary at the edge of the upper canyon near EFR Fish 2

4.2.4 Hot springs pools (lower canyon)

In the lower canyon, in addition to the bedrock pools fed by upstream inflows, there are also pools that are maintained by inflows from isolated hot springs (such as at Ais-Ais). These pools are permanent, but water quality may be problematic for instream biota due to the salt content from the hot springs.

4.3 Present ecological state

The Present ecological state (PES) of the EFR sites was assessed using the Geomorphological Driver Assessment Index (GAI) (Rountree and du Preez, in prep).

4.3.1 EFR Fish 1

Historical aerial photography and satellite imagery were available from the 1960s until the mid-2000s for this site to document changes in morphology. Although the overall the channel planform is stable, the historical photographic record (Figure 8) documents the loss of isolated woody areas of the riparian zone and more importantly some changes in pool sizes. It is likely that most of the pools in this reach were permanent under natural conditions; these being dependent on small and large floods arising from the wetter upper catchment area as well as inflows from the numerous small tributaries.

The historical photographic record documents the loss of isolated woody areas of the riparian zone, but gross channel planform is stable. The pools are however far more extensive, continuous (connected) and wider in November 1962 in comparison to the pool sizes in either July 1971 and December 2004, but the wet season peak flood in 1962 was in the order of 800 m^3/s in comparison to an approximately 400 m^3/s flood peak in 1971 and 2004. Occasional large floods may thus scour and enlarge the pools, but there is no evidence of progressive reduction in pool sizes despite the reduction in flows following the closure of Hardap Dam. This is possibly because:

- Sufficient flood flows still coming down the system, providing for sufficient (albeit less frequent) maintenance of the pools;
- The sediment load of the river is likely to be relatively low due to the age and gentle slopes across much of the catchment, so the rate of sedimentation of the pools is less than the frequency of large scouring flood events.

Despite the reduction in flows in the Fish River, the gross channel planform is very stable. The PES is in a B/C category (81%). Despite the presence of Hardap Dam upstream, morphological impacts appear to be limited.

4.3.2 EFR Fish 2

The site is located within the upper Canyon, a wide rift valley formation. Within the flat base of this valley, the main Fish River has incised slightly into the bedrock base and the channel forms a series of long bedrock pools interspersed with cobble and bedrock-controlled riffles.

Historical aerial photography and satellite imagery were available for the following dates: 16 December 1962; 25 July 1966; 6 August 1978; 8 September 2004; 7 August 2009 and 14 December 2011.

The channel is relatively stable, but a progressive increase in woody vegetation on the upper floodplain is evident through the photographic record. It is likely that many of the pools in this reach would have been permanent under natural conditions; these being predominantly dependent on small and large floods arising from the wetter upper catchment areas.

The PES is in a B/C category (82%). As with the upstream EFR site, despite the presence of Hardap Dam, morphological impacts appear to be limited and are likely to less in this downstream reach (further from Hardap Dam) due to the ameliorating impacts of tributaries. The pools are however far more seasonal than at EFR Fish 1 – the historical aerial photographic record shows that the pools at EFR Fish 2 almost dry out even in years of very large peak wet season floods.

4.3.3 EFR Fish Ai-Ais

This reach represents the lower Fish River from Löwen River down to the confluence with the Orange River. The PES is expected to be in a B condition, because although the reduced flows from Hardap remain the major problem for geomorphology, flows from tributaries and sediment introduced in the gorge progressively offset the morphological impacts of Hardap Dam in this lowest reach of the river.

5. Riparian vegetation

The Vegetation Response Assessment Index (VEGRAI) Level 4 (Kleynhans et al., 2007) was used to assess the PES of riparian vegetation. Key riparian indicator species were surveyed onto a calibrated hydraulic profile in order to assess flow requirements (see Appendix A for species list).

The following information was used for the assessment of riparian vegetation at the EFR sites:

- Satellite images;
  - EFR Fish 1: Google Earth imagery, 8 September 2004 and historic aerial photos (24 November 1962, 12 July 1971 and 20 December 2004) of the respective reach.
  - EFR Fish 2: Google Earth imagery, 14 December 2011 and historic aerial photos (16 December 1962; 25 July 1966; 6 August 1978; 8 September 2004; and 7 August 2009.
- hydrology specialist report (Technical Report 31);
- geomorphic zone classification;
- fluvial geomorphology report (Chapter 4) and GAI;
- biomes and vegetation types of Namibia: Atlas of Namibia Project (2002);
- data collected during field visit (18 June 2012);
- water quality specialist report (Chapter 2);
- IHI (Index of Habitat Integrity) (Chapter 9).

5.1 EFR Fish 1

Figure 8 indicates the extent of the assessment area for VEGRAI and shows the 5 transects at EFR Fish 1 that were used for the VEGRAI assessment. The length of the reach is approximately 1600 m.

- Transect 1.1: Riffle with some *Tamarix usneoides*.
- Transect 1.2: Bottom of pool.
- Transect 1.3: Middle of pool.
- Transect 1.4: Top of pool.
- Transect 1.5: Pool with tree line.

A comparison of historical aerial photos from 1962, 1971 to 2004 Google Earth images, indicates some change to woody vegetation (structure and cover), with increases in areas and decreases in others (Figure 9).

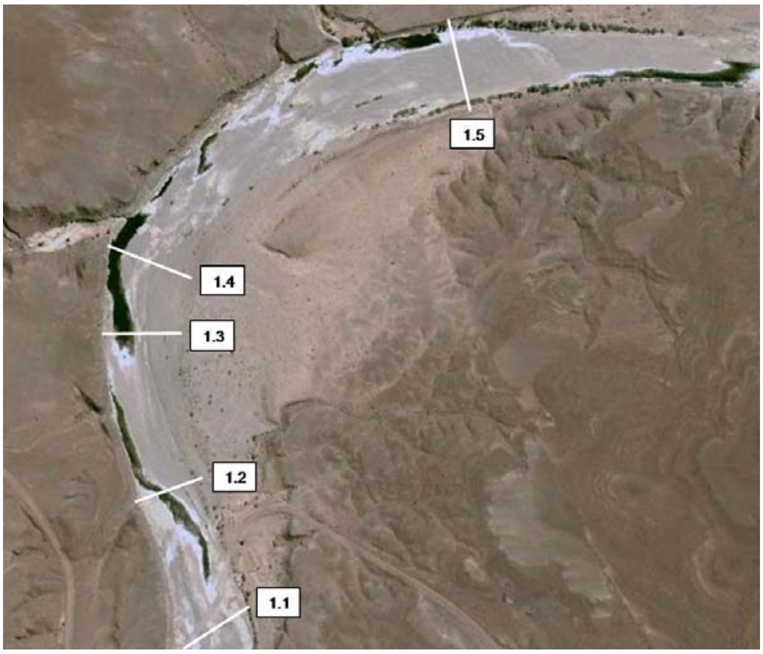

Figure 8. Extent of sampled area for VEGRAI at EFR Fish

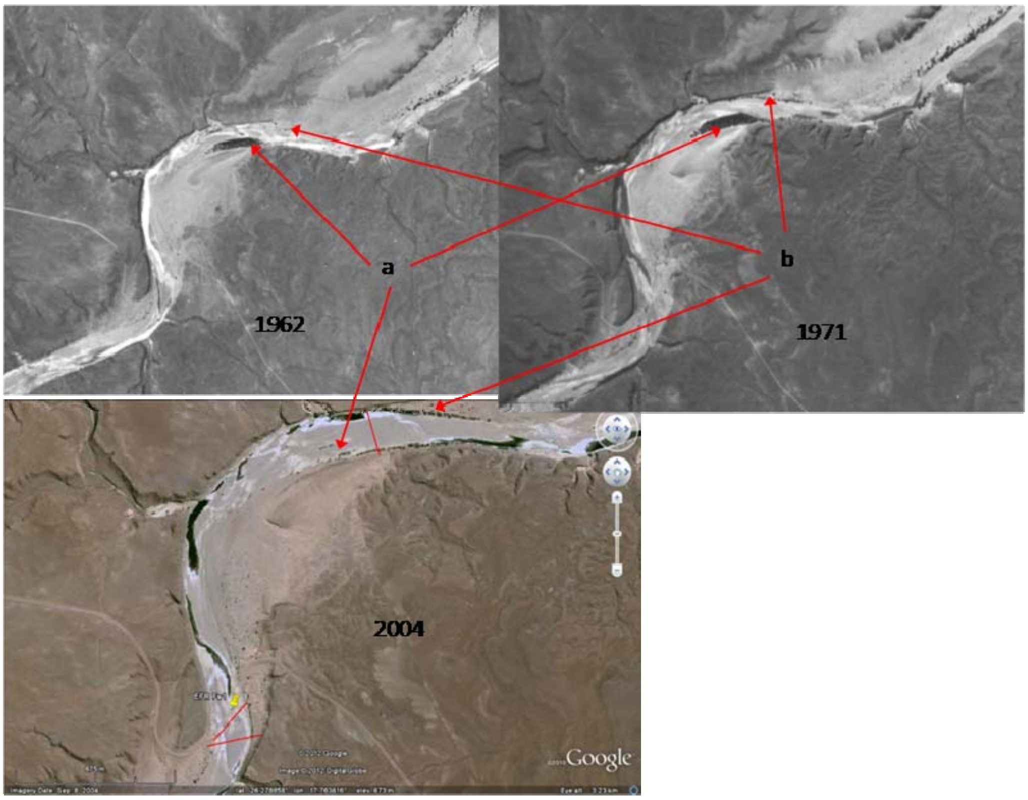

Figure 9. Aerial photos from 1962, 1971 compared to 2004 Google Earth images

The comparison in Figure 9 shows various changes to vegetation structure and cover:

- large clump of trees on the point bar is present in 1962 and 1971 and significantly reduced in 2004. This is likely due to flooding disturbance, especially given the position on the point bar;
- a tree line which has steadily formed along a pool and increased in woody density over the years.

5.1.1 *Reference conditions*

The assessed area is contained within the Nama Karoo Biome and the Dwarf Shrub Savanna vegetation type with a typically sparse shrubland structure. This vegetation type has the following dominant woody species: *Acacia hereroensis, A. reficiens, A. hebeclada, Combretum apiculatum, Ziziphus mucronata* and several *Searsia (Rhus)* species. Similarly the riparian zone should be sparsely vegetated with distinct association of vegetation with pools or riffle areas. Alluvial terraces and banks were likely to be dominated mainly by *A. karoo, Z. mucronata*, or stands of *T. usneoides*. Riffle features are likely to be characterised by a mix of woody species (*T. usneoides,* and *Gomphostigma virgatum*) and sedges (*Cyperus longus,* and *C. marginatus*). Frequently flooded alluvia will be mostly open or sparsely grassed.

The expected reference condition of riparian vegetation for each of the zones is outlined below:

- Marginal zone: Expect a mix of open alluvia or cobble/boulder and sparsely vegetated areas. Vegetation, similarly, should be a mix of woody (*G. virgatum*, *T. usneoides*) and non-woody (*C. marginatus*, *C. longus*) vegetation, although the distribution of sedges is likely to be limited to areas where water availability is longer lasting in the wet season e.g. pools or wet areas upstream of bedrock hydraulic control areas.
- Lower zone: Expect the same as the marginal zone.
- Upper zone: Similar to present state, but expect greater abundance of *Acacia* spp., possibly due to browsing pressure being high.
- Upper zone macro channel bank (MCB): Similar to present state, with the exception of alien weed species and *Prosopis* spp. (which occur in low numbers).
- Floodplain: Similar to present state, with the exception of alien weed species and *Prosopis* spp. (which occur in low numbers).

5.1.2 *Present ecological state*

The PES for EFR Fish 1 is 81.6% (category B/C) for riparian vegetation (Table 20) with an average confidence of 3.6 (high). The breakdown of the overall score into different zones (Table 20) shows that the marginal and lower zones are least impacted (B ecological category (EC)) and the upper zone, bank and floodplain are most impacted B/C EC. A species list is provided in Appendix A.

Table 20. VEGRAI score for EFR Fish 1

Riparian vegetation zones	***PES % and EC***	***Confidence***
Marginal	84.3% (B)	3.7
Lower	82.8% (B)	3.7
Upper	80.0% (B/C)	3.6
Upper MCB	80.0% (B/C)	3.6
Floodplain	79.3% (B/C)	3.6
VEGRAI (%)	81.6%	
VEGRAI EC	B/C	
Average confidence		3.6

The PES of riparian vegetation for each of the zones is described below:

- Marginal zone: Marginal and lower zone similar (as would be expected in seasonal systems) mostly with open sand and cobble/bedrock areas. Vegetation is sparse with a notable absence of sedges and woody species represented by *G. virgatum* and *T. usneoides*.
- Lower zone: Similar to marginal zone.
- Upper zone: Mostly open sand with cobble and bedrock. Vegetation is sparse and mostly dominated by woody species (especially *T. usneoides*), but also with some sparsely grassed areas (*Stipagrostis namaquensis*) higher up the bank and the MCB.
- Upper zone MCB: Alluvial (or in some places a cliff) and dominated by sparse mixed woody and non-woody vegetation. Mostly S. namaquensis, *T. usneoides* and some *A. karoo*.
- Floodplain: Alluvial, left bank only: dominated by *T. usneoides*, *S. namaquensis*, some *A. karoo* and *A. erioloba* higher up.

5.2 EFR Fish 2

Figure 10 indicates the extent of the assessment area for VEGRAI assessment.

Figure 10. Extent of sampled area for VEGRAI at EFR Fish 2

The assessed sampled area stretches from the weir downstream for 2 km, beyond the large pool to the top and including some of the anastomosing section (Figure 11). Two broad habitats fall within the VEGRAI area:

- Pools - with 2 cross-sections.
- Bedrock controlled areas/riffle - 1 cross-section.

A comparison of historical aerial photos from 1962 to 2011 Google Earth images, indicates a significant increase in woody density in areas such as surrounding the large pool and upstream of the weir, which likely indicates extended water storage and reduced flooding disturbance (Figure 11).

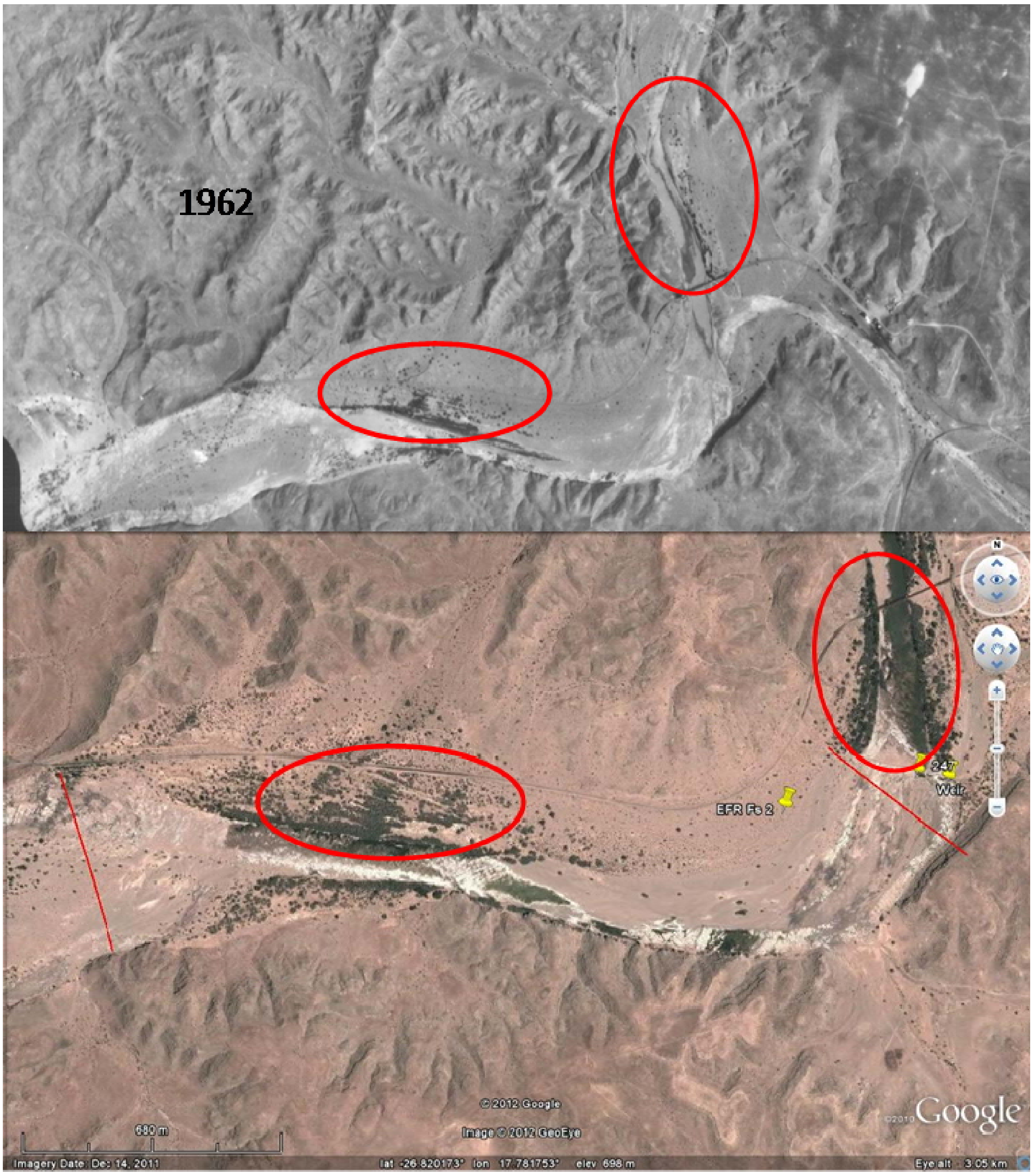

Figure 11. Aerial photos from 1962 (above) compared to 2011 Google Earth images

5.2.1 Reference conditions

The assessed area at EFR Fish 2 is contained within Nama Karoo Biome and the Dwarf Shrub Savanna vegetation type with a typical sparse shrubland structure. This vegetation type has the following dominant woody species: *A. hereroensis, C. apiculatum, A. reficiens, A. hebeclada, Z. mucronata* and several *Searsia (Rhus)* species. Similarly the riparian zone should be sparsely vegetated with distinct association of vegetation with pools or riffle areas. Alluvial terraces and banks were likely to be dominated mainly by *Acacia karoo, Ziziphus mucronata*, or stands of *T. usneoides*. Cobble or riffle features likely to be characterised by a mix of woody species (*T. usneoides* and *G. virgatum*) and sedges (*Cyperus longus,* and *C. marginatus*). Frequently flooded alluvia will be mostly open or sparsely grassed.

The expected reference condition of riparian vegetation for each of the zones is as follows:

- Marginal zone: Expect a mix of open alluvia or cobble/boulder and sparsely vegetated areas. Vegetation, similarly, should be a mix of woody (*G. virgatum*, *T. usneoides*) and non-woody (*C. marginatus*, and *C. lo*ngus) vegetation, although the distribution of sedges is likely to be limited to areas where water availability is longer lasting in the wet season e.g. pools or wet areas upstream of bedrock hydraulic control areas.
- Lower zone: Similar to marginal zone, with reeds around deep permanent pool areas.
- Upper zone: Similar to present state, but expect greater abundance of *Acacia* spp., possibly due to browsing pressure being high.
- Upper zone MCB: Similar to present state, with the exception of alien weed species and *Prosopis* spp. (which occur in low numbers).
- Floodplain: Similar to present state, with the exception of alien weed species and *Prosopis* spp. (which occur in low numbers). Woody density would be less under reference and not likely to have palm trees.

5.2.2 Present ecological state

The PES for EFR Fish 2 is 62.9% (category C) for riparian vegetation (Table 21) with an average confidence of 3.1 (moderate). The breakdown of the overall score into different zones (Table 21) shows that the marginal zone is least impacted (C ECs compared to C/Ds and D ECs in other zones). A species list is provided in Appendix A.

Table 21. VEGRAI score for EFR Fish 2

Riparian vegetation zones	***PES % and EC***	***Confidence***
Marginal	72.6% (C)	3.0
Lower	56.5% (D)	2.9
Upper	60.7% (C/D)	3.3
Upper MCB	61.5% (C/D)	3.3
Floodplain	61.9% (C/D)	3.6
VEGRAI (%)	62.9%	
VEGRAI EC	C	
Average confidence		3.1

The present ecological state of riparian vegetation for each of the zones is as follows:

- Marginal zone: Marginal and lower zones similar (as would be expected in seasonal systems) mostly with open sand and cobble/bedrock areas. Vegetation is sparse with mainly *G. virgatum*, *C. longus* and some *P. australis* around deep pools.

- Lower zone: Similar to marginal zone, but also with *T. usneoides*, especially *T. usneoides* overhang around deep pools.
- Upper zone: Mostly open sand with cobble and bedrock. Vegetation is mostly sparse and dominated by woody species (especially *T. usneoides*), but also with some sparsely grassed areas (*S. namaquensis*) higher up the bank and the MCB and some *A. karoo*. Some densely wooded areas exist around permanent pool areas, mainly dominated by T. *usneoides* thicket (although this is also associated with the dry tributary). An increase in this species is likely the result of reduced flooding and increased herbivory.
- Upper zone MCB: Alluvial (or in some places a cliff) and dominated by sparse mixed woody and non-woody vegetation. Mostly *S. namaquensis*, *T. usneoides* and some *A. karoo*.
- Floodplain: Alluvial and extensive: dominated by *T. usneoides*, *S. namaquensis,* some *A. karoo* and *Z. mucronata*. Some palm trees in places are likely planted or originate from planted stock.

5.3 EFR Fish Ai-Ais

The reach from the Löwen/Fish River confluence to the Orange/Fish River confluence is also likely to be in a B/C category (similar to EFR Fish 1). A large portion of this reach is inside conservation areas so non-flow related impacts, such as herbivory by livestock and vegetation clearing will be mitigated, and similar to those assessed at EFR Fish1 (low). There will still be a response to altered flow as some reduced flooding will still exist due to upstream dams, but tributary contribution will mitigate this impact to some degree. Also, species composition of riparian vegetation has changed from Ai Ais downstream as species such as the fever tree (*A. xanthophloea*) has been planted at the camping site and has spread downstream all the way to the confluence with the Orange River. *P. australis* (reeds) is also over-abundant at Ai Ais due to nutrient enrichment, but the effect downstream is likely to not be extensive, and the impact does not occur upstream.

6. Riverine fauna

The riverine fauna component is not usually included in EFR assessments for perennial rivers as it is not a sensitive indicator. This is however not the case in dry or desert landscapes. Assessment methods for determining the PES of riverine fauna was developed during the GIZ study undertaken during 2010 (Deacon, 2010) and further development of the method has been undertaken during this study.

6.1 Methods

Since there is no established method or model to determine the PES of the Riverine Fauna component, a process was developed for this aspect. The main components of this process that are considered comprise the following aspects:

- expected riverine fauna species to the area;
- probability of occurrence;
- quality of habitat present.

The first two aspects were obtained from literature, which included species atlas projects and field guides. The 'Quality of habitat present' was assessed during the field trip. Google Earth views and photos of the sites were obtained and are used as important reference material.

The current situation, as experienced during the field trip in June 2012, was used to establish the PES. The survey was undertaken during June 2012 in the Fish River. The results of this component of the study (riverine fauna) comprise of detailed assessment of the riverine habitats depicted by rudimentary plan view maps drawn at the sites, backed by photos of the aspects of local habitat. These maps were used to identify potential habitats and associated with potential fauna species prone to utilise these habitats. The habitats were used to supply a benchmark for the PES, and by assessing the probable anthropological changes to the system, the reference conditions could be established. The main survey results were thus incorporated into the PES. The reference conditions were obtained from historical information and related to the maps and photos in the PES section.

6.2 Riverine habitats and associated riverine fauna

This study focussed on the riverine systems in the identified catchments, which are linear systems that flow only during high rainfall periods.

In order to assess the biota according to their intolerance regarding water level or flow changes, the following reasoning was used:

- the dependency can be related directly to the aquatic habitats for shelter, breeding and food, or to the riparian vegetation for these services;

- should the riverine structure and function be compromised by flow requirements, this will also influence the associated fauna.

These attributes are functions of the main riverine habitats, and can be defined by the finer habitats (biotopes) in the following groupings.

a) Aquatic habitats

- Flowing habitats: runs, rapids and riffles. Habitats completely dependent on flow and water level.
- Slow flowing or non-flowing habitats: Instream pools and backwaters. Habitats dependent on water level.
- Connected wetlands: Backwaters and floodplains. Habitats dependent on periodically inundation. Seepage wetland feeding into drainage. Seepage wetland: From damp/wetted soils (floodplain/swamp/vlei (marsh)) to partially shallowly inundated soils (<10 cm) with emergent sedges, hydrophytic grass, tussock grass.

The following biotopes are all relevant to the different aquatic habitats:

- exposed shoreline: Water edge to partially shallowly (<10cm) water inundated soils (sandy, muddy or gritty);
- reed bed, reed islands or dense tall grass: Transitional from damp land, through shallow water to inundated in deeper water;
- grassy edge connected to water: Edge and bank of stream and floodplains. Dense cover of grass and forbs, grass may be inundated shallowly;
- Deep open water: For hunting and shelter.

b) Riparian systems

Trees and embankments which form habitats dependent on groundwater associated with water levels in the river.

- Vertical or remote sand banks - Vertical or remote sand banks: Eroded alluvial sand river banks to form vertical faces or gullies - mostly tunnelling for nesting or shelter; or flat sandbanks removed from river edge.
- Wooded bank: Dense shrubs and tall continuous riparian trees, lodged flood debris, tangled roots and forbs.

In placing riverine fauna into potential habitat groupings, a few rules have been created to assist with this categorisation and is outlined below.

- To be considered as a riverine species, at least a part of the life stage must be dependent on the riverine habitat. For instance, in the case of toads, the adults can live in a terrestrial environment, but the larvae (tadpoles) need an aquatic environment as they develop.

- Although water dependent, certain wetland species are better adapted to a non-riverine environment (pans, dams, etc.) but will periodically utilise the riverine habitat to feed, breed or shelter. Nomadic species, such as ducks and grebes will resort to riverine habitats should their traditional wetland dry up or should they be on transit to other areas.
- The sensitivity of a species could also depend on the sensitivity of its food species to water level/flow changes. Certain riverine species feed on macro-invertebrate, hydrophytes (water-living plants) or fish. These food organisms are also, in varying degrees, dependent on the aquatic environment, and this level of dependency will be reflected in the ecological sensitivity category of the riverine vertebrate.
- In most cases, the habitat utilised for feeding, sheltering or breeding, e.g. vegetation or substrate, are dependent on the level of water in the river. Marginal vegetation, should it be large riparian trees or sedges, are dependent on the water level in the riverine system, either subsurface or surface flows.
- The duration of habitat presence will vary from ephemeral to perennial systems and this will also impact on the viability of the habitat for different species. Ephemeral systems can create flooded areas and pools that remain for a period, and will be utilised by riverine species as long as they are viable. Subsurface water in these systems is sometimes lasting much longer and is important to riparian vegetation.
- Large, irregular flood events create both temporary and semi-permanent habitats which animals will react to. The temporary systems are floodplains, marginal pools and oxbow lakes, while the more permanent ones are vertical sandbanks and floodplain vegetation which is supported by subsurface water.

An important variation regarding the riverine rule is the fact that the Fish River is a riverine systems that drains extremely dry landscapes. The linear ecosystem that comprises the aquatic and riparian zones is an important biotope for more than just true riverine fauna. Terrestrial fauna species present in the riverine system, do not have the choice to move out of the system as their counterparts do in more mesic systems. Thus, should a non-riverine animal species take on the riverine system as an abode, it will become dependent on the biotope, since there is no other option.

6.3 Present ecological state

6.3.1 EFR Fish 1

The PES and associated changes from reference conditions are provided in Table 22. Using the modelled procedure, the PES of the riverine fauna of EFR Fish 1 has been determined as a Category B (86%). Major changes from reference include:

- Exposed shoreline with shallow edges - less due to shrinking pool perimeter.
- Reed bed or reed islands - increase in extent due to less scouring by floods.
- Open water; deep for hunting and shelter - Less open water (in the form of deep pools) for shorter periods

Table 22. EFR Fish 1: PES and changes from reference conditions

Habitats	***Reference conditions***	***PES***
Vertical or remote sand banks.	Extensive sand banks.	Extensive sand banks.
Exposed shoreline - shallow edges.	Large stretches of exposed shorelines.	Stretches of exposed shorelines less due to shrinking pool perimeter.
Reed bed or reed islands.	Few patches of reed beds.	Reed beds increase in extent due to less scouring by floods.
Grassy edge connected to water.	Very little grassy edges.	Very little grassy edges.
Wooded bank - shrubs and tall riparian – continuous.	Moderate continuous riparian corridor.	Moderate continuous riparian corridor.
Seepage wetland feeding into drainage.	Very little seepage wetland.	Very little seepage wetland.
Open water - deep for hunting and shelter.	Good open water in the form of deep pools.	Less open water (25%) for shorter periods in the form of deep pools.

6.3.2 EFR Fish 2

The PES and associated changes from reference conditions are provided in Table 23. Using the modelled procedure, the PES of the riverine fauna of EFR Fish 2 has been determined as a Category B (84%). Major changes from reference include:

- exposed shoreline with shallow edges - less due to shrinking pool perimeter;
- reed bed or reed islands - increase in extent due to less scouring by floods;
- open water; deep for hunting and shelter - Less open water (in the form of deep pools) for shorter periods.

Table 23. EFR Fish 2: Reference conditions of the habitat conditions for riverine fauna

Habitats	***Reference conditions***	***PES***
Vertical or remote sand banks.	Extensive sand banks	Extensive sand banks
Exposed shoreline - shallow edges.	Large stretches of exposed shorelines	Stretches of exposed shorelines a less due to shrinking pool perimeter
Reed bed or reed islands.	No reeds	No reeds
Grassy edge connected to water.	Some grassy islands	Some grassy islands
Wooded bank - shrubs and tall riparian – continuous.	Moderate continuous riparian corridor	Moderate continuous riparian corridor
Seepage wetland feeding into drainage.	Some seepage wetlands	Some seepage wetlands
Open water - deep for hunting and shelter.	Good open water in the form of deep pools	Less open water (25%) for shorter periods in the form of deep pools

Appendix B incorporates plan view maps with habitats of EFR Fish 1 and EFR Fish 2 in the Fish River. Riverine fauna species lists are provided in Appendix A.

6.4 Approach to determine consequences of release options

The conceptual approach to determine the riverine fauna response (excluding instream) to different release options (ROs) are outlined below.

- Identify faunal species depending on the riverine ecosystem: Riverine species refer to animal species where their dependency can be related directly to the aquatic habitats for shelter, breeding and food, or to the riparian vegetation for these services. Since many riverine species are relatively mobile (birds and larger mammal species), they can migrate whenever circumstances becomes harsh. However, certain animal species are less mobile and will thus be influenced more by local environmental changes. These species can be used as key or indicator species.
- Obtain distribution data of these riverine animals: By making use of species distribution maps and atlas data, it can be established which animals should be present in the areas of concern. With detailed distribution records available, the probability of occurrence and even the abundance can be determined.
- Verify the habitat requirements of these assemblages (aquatic, semi-aquatic and riparian): Habitat requirements per animal species can be obtained from a wide spectrum of literature and expert knowledge.
- Map the habitat types at the EFR sites: During the field surveys, different habitat types will be delineated on Google Maps and any other aerial maps available. Views of different water levels per site will enhance the effectiveness of the maps for release option (RO) evaluations.
- Model habitat change with changing water levels: By linking the mapped habitats and its position relating to water levels, changes in habitat extent and functionality could be modelled relating to altering water levels. Links with the fish, macro-invertebrate and riparian vegetation evaluation are essential as these groups determine food availability, and presence of shelter and nesting habitats.
- Establish species change (diversity and abundance) for the riverine fauna reacting to flow scenarios: Whenever the habitat integrity of the site is established, the reaction of the riverine fauna to changes in habitat composition could be determined, signifying the presence or absence of species, or a level of abundance relating to habitat quality.

7. Macro-invertebrates

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7.1 Background

A key component of EFR assessment is the response of macroinvertebrates to modified flow scenarios. Macroinvertebrates are used worldwide to monitor the ecological health of river systems, and are a key component of the Orange-Senqu Biological Monitoring Programme (ORASECOM, 2011). Numerous indices for monitoring freshwater macroinvertebrates have been developed for perennial rivers and streams, but these indices become increasingly unreliable in non-perennial systems, such as the Fish River. Macro-invertebrates in non-perennial systems are able to withstand extreme variations in flow and water quality, and tend to be dominated by mobile insect taxa such Hemiptera, Coleoptera and Diptera, and desiccation resistant life-stages of crustaceans (Boulton et al., 2006). Two important concepts of ecosystem health in such systems are 1) Resistance: which refers to the ability to resist disturbance, and/or to persist during disturbance, and: 2) Resilience: which refers to the ability to recover from disturbance (Sheldon, 2005). These two concepts formed the basis of the method that was developed as part of this project for assessing Present Ecological State in the Fish River. The method was based on the premise that the structure and function of aquatic macroinvertebrates inhabiting naturally seasonal or ephemeral systems that are unimpacted by human activities will maintain high resistance and/or resilience, whereas systems that are impacted will lose their ability to persist and/or recover when flow resumes (i.e. reduced resistance and/or resilience).

7.2 Aims

The aims of this report were to define the PES of macro-invertebrates within three MRUs in the Fish Rivers, and to develop a method to predict the response of macro-invertebrates to modified flow scenarios in the Fish River.

7.3 Available data

The field survey for this report was undertaken between 15–18 June 2012. Macro-invertebrates were collected from three sites in the Fish River and one site in the lower Orange River (Figure 1).

The main sources of information on macro-invertebrates in the Fish River that were used in this assessment comprised the following:

- Paper that summarises the distribution of macro-invertebrates in Namibia, based on published data and museum records (Curtis, 1991).
- 2009-2010: Macroinvertebrates were collected on two occasions in the vicinity of the proposed Neckartal Dam, including EFR Fish 2 (Seeheim), as part of the environmental and social impact assessment of the proposed Neckartal Dam (Nepid Consultants, 2010).

The confidence in available data is provided in Technical Report 27.

7.4 Methods

The available methods for determining the PES is discussed below.

7.4.1 Abundance

The determination of abundance of macro-invertebrates was based on Dickens and Graham (2002) and outlined below.

Abundance of macro-invertebrates in each sample was classified into five categories as follows:

1 Abundance: 1
A Abundance 2 to 9
B Abundance 10 to 99
C Abundance 100 to 1000
D Abundance > 1000

7.4.2 Frequency of occurrence

The frequency of occurrence (FROC) of each macro-invertebrate taxon under natural (reference) conditions was based on historical information and professional judgement and classified into five categories according to Kleynhans (2007) as follows:

1 = Present at very few sites (<10%)
2 = Present at a few sites (10 to 25%)
3 = Present at about 25 to 50% of the sites
4 = present at most sites (50 to 75%)
5 = Present at almost all sites (>75%)

7.4.3 Namibian scoring system

Macro-invertebrates in the Fish River were collected according to the Namibian Scoring System version 2 (NASS2) (Palmer and Taylor, 2004). The NASS2 is based on the South African Scoring System version 5 (SASS5), which was modified slightly by adding tropical taxa that occur in northern Namibia (mainly snails), and excluding taxa that do not occur in Namibia, such as several families of cased caddisfly. Both methods use the same sensitivity values, so the application of either method in the lower Orange River will give identical results.

The NASS2 was developed specifically for perennial streams and rivers and application to non-perennial systems needs to be made with caution. The Fish River immediately downstream of Hardap Dam is maintained by perennial seepage from the dam for about 45 km downstream of the dam (Nepid Consultants, 2010), and thereafter the river is ephemeral. The NASS2 method was applied in this study, but the data were interpreted in the context of an ephemeral river. The NASS2 scores provide an overall indication of river health, but cannot be used to predict the likely biological responses to changes in stream flow.

7.4.4 Habitat suitability

The macro-invertebrates found at a site often reflect the diversity and quality of habitats available, so the interpretation of biomonitoring data was enhanced by recording the quality of habitats sampled. In this study the quality of each habitat sampled was assessed in terms of the suitability for macro-invertebrates using a simple, six-point scale:

0=Absent

1=Very Poor

2=Poor

3=Moderate

4=Good

5=Highly Suitable.

Each habitat category was assigned weighted importance value that varied according to the geomorphological stream type. The weighted values were multiplied by the suitability rating (0–5), and the results were expressed as a percentage, where 100% = all habitats highly suitable. The percentage values were converted to a category (A to F), to allow easy comparison among sites or sampling events.

7.4.5 Hydrological phases

Macro-invertebrate data collected in highly seasonal streams in the northern territories of Australia suggest that there are three main phases of post-flood hydrology that define the composition, abundance and diversity of macro-invertebrates (Leigh, 2012). These are: the length (or duration) of the dry season before sampling, cease-to-flow events, and flow magnitude on the day of sampling (Leigh, 2012). There is insufficient data to test this concept on non-perennial systems in southern Africa, but it is likely that the macro-invertebrates in the Fish River will respond in a similar way. For the purposes of this report, three phases of the hydrological cycle were distinguished as outlined below.

- Early Dry Season: Defined as one to three months post-flood, when surface flow is sufficient to support flow-dependent species, and salinity is relatively low. The diversity of macro-invertebrates under these conditions is expected to be high.

- Late Dry Season: Defined as >3 months post-flood, with surface flow sufficient to support at least some flow-dependent species, but salinity is increasing. The diversity of macro-invertebrates under these conditions is expected to be moderate.
- Dry Season: Defined as > 3 months post flow, but without sufficient surface flow to support any flow dependent species, and salinity is elevated. Surface connectivity is broken leaving isolated pools which are important refugia and foci for recolonisation when flows resume. Small permanent tributaries are also likely to be provide similar functions. The diversity of macro-invertebrates during the dry season is expected to be low, and characterised by the presence of highly resistant taxa, such as crabs, and highly resilient taxa, such as caenids and members of the baetid genus *Cloeon* spp. which have eggs that are desiccation resistant.

The wet season was not considered because of its short duration and the time needed for macro-invertebrates to colonise and composition to stabilise.

7.5 Methods developed during this study

There is no known method for defining the ecological state of macro-invertebrates inhabiting seasonal or ephemeral systems, so a new method was developed for this project. A key ecological feature of ephemeral systems is the permanence and distance between pools, as these provide important refugia when there is no surface flow.

7.5.1 Ecological traits method

The method developed for this study was based on a number of key ecological traits that were rated and weighted in terms of their importance in defining the PES of benthic macro-invertebrates, and by implication, the river health. The method was based largely on understanding of ephemeral rivers in Australia (e.g. Choy et al. 2002; Chessman et al. 2012) and in the American mid-west (Leveck et al., 2008). Each NASS2 taxon was allocated one category for each trait (provided as part of the electronic data). Categories were based mostly on published information on macro-invertebrate family traits (e.g. Merritt and Cummins, 1984; Mandaville, 2002; Poff et al., 2006; Extence et al., 2011). Information gaps were filled using professional judgment. The method comprised the following ecological traits as outlined below.

1) Adult Life Span: The duration of adult life among macro-invertebrates provides a useful indication of variability and unpredictability in environmental conditions. Macro-invertebrates inhabiting non-perennial systems, with highly variable and unpredictable flows, tend to have flexible life history patterns with high levels of resistance or resilience. Human impacts, such as water abstraction, can aggravate this variability and lead to a shift in species composition to species with more rapid life cycles. However, some human impacts, such as release of compensatory flows to meet irrigation demands, can reduce the natural variability in flow and favour species with different life history characteristics. Either way, adult life span provides a simple indicator of how a river ecosystem could change from baseline conditions. For the purposes of this report, four categories of adult life span were recognised as follows:

A = Very Short (<1 week)
B = Short (<1 month)
C = Moderate (>3-6 months)
D = Long (>6 months)

2) Air-Breathing taxa: The proportion of air-breathing macro-invertebrates provides a simple measure of the extent to which oxygen is limiting. Oxygen depletion is often associated with nutrient enrichment that is typically associated with human activities such as sewage works, industrial processes, feedlots and irrigated cultivation. Healthy streams typically have a small portion of air-breathing taxa, whereas streams impacted by organic enrichment are expected to have a high proportion of air-breathing taxa.

3) Functional Feeding Groups: Trophic relations are the glue that bind biological communities and are therefore fundamental for understanding community structure and function (Cummins 1973). A simple trophic classification system originally developed for aquatic insects and comprised four categories: Shredders, Scrapers, Collectors and Predators (Cummins, 1973). Shredders referred to taxa that feed on detritus composed mainly of leaves from riparian vegetation, whereas Scrapers referred to taxa that feed on the epilithic layer on substrates. Collectors referred to taxa that feed on fine detritus, either in the water column or deposited on substrates. This system was subsequently modified and extended to other groups of aquatic organisms, but the concept remained the same. For the purposes of this report the Functional feeding group allocated to each NASS2 taxon was the preferred or most likely category (i.e. primary category). For example, hydropsychid caddisflies were classified as 'Filterers', even though they could also be classified as 'Predators'. Likewise, Chironomidae were classified as 'Collector/Gatherers', even though this family contains species that have a wide range of feeding habits, including predation and scraping. Human activities tend to change the trophic structure of river systems, so functional feeding groups provide a useful indicator of ecological condition. The following functional feeding groups were recognised for the purposes of this report.

CG = Collector/Gatherers
S = Shredders
F = Filterers
SG = Scraper/Grazers
P = Predators
\- = Other/unknown

4) Current Speed Preferences: A characteristic and fundamental feature of river systems is unidirectional flow of water, so most freshwater macro-invertebrates have evolved specific hydraulic preferences. Water resource utilisation inevitably changes the hydrology and therefore the current speeds that typically occur in a river. Changes in current speed preferences of macro-invertebrates therefore provide a useful indicator of ecological change. For the purposes

of this report, current preferences of NASS2 taxa were allocated to one of the following current speed categories:

A = Fast Flow	(<0.6m/s)
B = Moderate Flow	(0.3-0.6 m/s)
C = Slow Flow	(0.1-0.3m/s)
D = Zero to Very Slow	(<0.1 m/s)

5) Habitat Preferences: Most macro-invertebrates have specific habitat preferences and usually these are associated with areas that are either eroding or depositing, or located within a transitional zone of sands and gravels. Human activities can impact on the availability and suitability of instream habitats, usually by reducing the diversity of habitat types, and this can affect the composition and abundance of macro-invertebrates. For the purposes of this report, habitat preferences of each NASS2 taxon was classified into one of five categories as follows:

A = Bedrock and Boulders

B = Cobbles

C = Veg

D = Gravel, Sand, Mud

E = Water Column

6) Thermophily: Water temperature is an important consideration in aquatic ecology because it defines the rate of development, body size and associated fecundity (de Moor, 1994). Water temperature also influences a range of other processes, including solubility of oxygen, microbial activity and toxicity (Dallas, 2004). Changes in river water temperature caused by human impacts, such as impoundment and climate change, can have significant implications, such as changing the transmission period for waterborne disease, such as bilharzia (Pitchford and Visser, 1975). Furthermore, inter-specific competition has been shown to be reduced through time-sharing based on species-specific thermal optima (Vannote and Sweeney, 1980). Limited information is available on thermal optima among macro-invertebrates in southern Africa. In general, human impacts are likely to increase the prevalence of warm, stenothermal taxa, although this is not always likely to hold true. For example, release of cold water from the bottom of an impoundment is likely to provide conditions favourable to cold stenothermal species. For the purposes of this report, three temperature preference categories were recognised:

A = Cold Stenothermal

B = Eurythermal

C = Warm Stenothermal

7) Water Quality Preferences: Water quality preferences of macro-invertebrates are the basis for many biomonitoring indices, including SASS5 and NASS2. These indices work well for perennial rivers, but their application in non-perennial systems is problematic because water quality in such systems is naturally highly variable, and most macro-invertebrate taxa in non-perennial systems are able to tolerate water quality deterioration. Human activities can

aggravate deterioration of water quality, so changes in water quality need to be considered when assessing river health. Important water quality considerations in arid environments are increased salinity from irrigated cultivation, and the release of potentially toxic cyanobacteria from impoundments, particularly in autumn when the lake overturns. The average sensitivity of NASS2 taxa found in non-perennial streams is low and therefore is unlikely to provide a reliable indication of human-induced impacts, but the number of sensitive and highly sensitive taxa provides a simple measure of measuring the biological response to changes in water quality. For the purposes of this report, NASS2 taxa were classified into one of four water quality preference categories as follows:

A = Highly Sensitive

B = Sensitive

C = Tolerant

D = Highly Tolerant

8) Alien Species: Alien aquatic species can have significant impacts on the structure and function of stream ecosystems, and need to be considered when assessing the ecological state of a river. For the purposes of this report, the impacts of alien macro-invertebrates were rated on a five point scale in terms of their abundance and potential impacts on indigenous species.

Each trait was rated separately for each site or ecological zone under consideration, using the same six-point (0–5) rating system as described above. Each trait was also weighted in terms of its percentage importance for defining the ecological state of macro-invertebrates at a particular site or ecological zone. The method is likely to be most reliable and sensitive to change during the early dry season, but the user-defined weightings provides flexibility so that the method can be applied to different hydrological phases. For example, flow-dependent taxa are not expected when there is no surface flow, so under these conditions the trait for 'Current Preference' would be weighted very low or zero. Highest weightings were allocated to life-history traits that are expected to respond strongly to anthropogenic impacts. The output of the weighted traits analysis was expressed as a percentage, which was converted to a PES Category (A to F), as described below.

7.5.2 Additional macro-invertebrate methods investigated

Crabs

Crab populations (*Potamonautes warreni*) were chosen as potential indicators of medium-term ecological conditions in the Fish River because they are resident, slow-growing and long-lived for macro-invertebrates (i.e. strongly resistant). The ecology of freshwater crabs is poorly known, but they probably take a couple of years to reach sexual maturity, and probably live for five to seven years (Savel Daniels pers. comm.). A positive relation was predicted between pool size (permanence) and crab populations, and quantifying this relation would provide a useful tool for predicting how crab populations, and by implication river health, could change under modified flow scenarios. Ten crab traps were baited with chicken liver and left overnight at various localities in the vicinity of site F2 (S26.8208427723, E17.763149151)during the field survey in June 2012. No crabs were caught in the traps, and this was attributed to the cold temperatures (mid-winter), when crabs appear to be inactive in the Fish River. The assessment was therefore discontinued.

Gomphid larvae

During the field survey in June 2012, an opportunity to investigate the response of gomphid larvae to changes in salinity, and hence their resistance to change, was presented about 2.5 km downstream of site F2. Here a saline spring on the right bank joins the river and with dropping water levels a number of isolated pools had been created, each with different salinities, ranging from 109 to >986 mS/m. In this assessment the density of gomphid tracks in each pools was used as surrogate indicator of gomphid population, and rated on a 10-point scale, where 10 = extremely abundant. The salinity and gomphid track density was recorded in 23 such pools. The results showed no relation between salinity and the density of gomphid tracks within the range of salinities investigated, so an alternative method of assessing responses to modified flow scenarios was called for.

7.6 Results

7.6.1 Reference conditions

The expected composition, abundance and FROC of macro-invertebrates in the Fish River was based on information presented in Curtis (1991), and a baseline report on aquatic ecosystems (Nepid Consultants, 2010). Reference NASS2 results were based on species with an expected FROC of 3 or higher. The following reference NASS2 scores (Table 24) were defined for three phases (early, late, dry) of the hydrological cycle (dry season) referred to in Section 7.4.5.

Table 24. Reference NASS2 scores for the Fish River

	Early	***Late***	***Dry***
NASS2 Score	112	84	58
Number of Taxa	23	18	12
ASPT	4.9	4.7	4.8

Early Dry Season

The early dry season is expected to be characterised by taxa with short to very short life cycles (i.e. early colonisers). The most abundant trophic group expected during the early wet season are filter-feeders, including the blackflies *Simulium chutteri* and *S. gariepense*, freshwater sponges and moss animalcules (Bryozoa). Filter-feeders are likely to form the base of secondary production during this phase, and provide food for predators such as gomphid dragonflies, coenagrionid damselflies, water boatmen (Corixidae), and whirligig beetles (Gyrinidae). Air-breathing taxa are expected to be common during this phase.

Late Dry Season

As the dry season progresses water is expected to become increasingly clear, leading to an increase in primary production and increased importance of Scraper-Grazers, such as bulinid snails and hydroptilid caddisflies, and Collector-Gatherers such as caenid mayflies, chironomid midges and seed shrimps (Ostracoda). The abundance of filter-feeders with rapid life cycles, such as *S. chutteri,* are expected to reduce and be replaced by taxa with longer life-cycles, such as hydropsychid caddisflies, or taxa that prefer slow-flowing water, such as *Simulium ruficorne.*

Dry Season

With the cessation of surface flow during the dry season, most filter-feeding macro-invertebrates enter a dormant phase until flows resume, and air-breathing taxa are expected to become more abundant. The dominant trophic group under these conditions are Collector-Gatherers, such as caenid mayflies and Chironomidae, and predators, such as gomphid dragonflies. Extended duration of the dry season is likely to lead to conditions associated with ephemeral rather than seasonal systems. Taxa indicative of ephemeral systems include mosquitoes (Culicidae) and rat tailed maggots (Syrphidae).

7.6.2 Present ecological state

The PES upstream of the proposed Neckartal Dam (MRU Fish A) in June 2012 was rated as Category C (Table 25). The confidence in the assessment was rated as Low (2/5) because of the limited information available. Weighting of ecological traits prioritised the importance of adult life span (18%), the proportion of air-breathing taxa (18%) and filter-feeding (15%).

Table 25 Summary of macro-invertebrate information and PES in MRU Fish A of the Fish River

EFR Fish 1	
Reference	This study
Date	Jun 2012
Days since high flow	79
Hydrological phase	Early Dry
Flow (m^3/s)	Low (0.15)
Biotope suitability	47% (D)
NASS2 score	78
No of taxa	15
ASPT[1]	5.2
Category (A-F)	**74% (C)**

1 Average score per taxon

A total of 15 NASS2 taxa was recorded at EFR Fish 1, compared to 23 expected. Taxa expected but not recorded included sponges, crabs, Bryozoa, Ecnomidae, Dytiscidae, Oligochaeta, Gerridae and Veliidae. The suitability of instream habitats was Poor (47%), and this could partially explain the low diversity. The fauna at was characterised by high numbers of baetid mayflies, and moderate numbers of Caenidae, Simuliidae, and Chironomidae. These taxa all have very short adult life spans (<1 week). No taxa with long adults life spans (>6 months) were recorded, apart from a single empty thiarid shell. Five of the 15 NASS2 taxa were air-breathers, indicating well-oxygenated conditions. The most common functional feeding groups were Collector/Gatherers and Predators. Two filter-feeding taxa only were recorded: Simuliidae in moderate abundance and hydropsychid caddisflies in low abundance. Three species of blackflies were recorded, including the threatened *Simulium gariepense*, which is restricted to large, turbid rivers and is endemic to the Orange River Basin. The blackfly *S. ruficorne* was also recorded. This species is typically associated with slow-flowing water (<0.1 m/s) and high salinity, and is widely distributed throughout Africa and the Arabian Peninsula. All four categories of flow preferences were represented, indicating that current speeds were not limiting. Four categories of habitat preferences were represented. Taxa with a preference for warmer water comprised 13% of the taxa, which is considered low. The diversity of macro-invertebrates sensitive to water quality deterioration was low, with only two sensitive taxa recorded: Naucoridae and Baetidae >2spp. No alien macro-invertebrates were recorded.

The PES downstream of the proposed Neckartal Dam (MRU Fish B) in June 2012 was rated as a B EC (Table 26). No significant difference in macro-invertebrate composition and abundance was observed or expected upstream and downstream of the Löwen River confluence. The confidence in the assessment was rated as Low (2/5) because of the uncertainly concerning the reference state. The same weighting of ecological traits used for EFR Fish 1 was applied.

Table 26 Summary of macro-invertebrate information and PES in MRU Fish B of the Fish River

	B1	***B1***	***EFR Fish 2 (B2)***	***EFR Fish 2 (B2)***	***EFR Fish Ais-Ais***
Reference	Nepid (2010)	Nepid (2010)	Nepid (2010)	This Study	This Study
Date	Aug 2009	Feb 2010	Feb 2010	Jun 2012	Jun 2012
Days since high flow	>100	35	36	78	77
Hydrological phase	Late Dry	Early Dry	Early Dry	Early Dry	Early Dry
Flow (m^3/s)	Trickle	Low	Low	Trickle (0.06)	Low
Biotope suitability	28% (F)	55% (C)	36% (E)	42% (D)	60% (C)
NASS2 score	84	80	95	103	88
No of taxa	14	16	20	20	16
ASPT	6.0	5.0	4.8	5.2	5.5
Category (A-F)				86% (B)	85% (B)

A total of 20 NASS2 taxa was recorded at EFR Fish 2, despite limited suitability of instream habitats, which was rated as Poor (42%). Taxa expected but not recorded were Oligochaeta, Libellulidae and Dytiscidae. The fauna was characterised by high numbers of blackflies comprising four species, dominated by the pest species *Simulium chutteri*. Two taxa with long adult life spans (>6 months) were recorded, but in low numbers only (crabs and thiarid snails). The proportion of air-breathing taxa was low (30%), indicating well-oxygenated conditions. The most abundant functional feeding group was Filterers (*S. chutteri*). All four categories of flow preferences were represented, indicating that current speeds were not limiting. Four categories of habitat preferences were represented. Taxa with a preference for warm water comprised <10% of the taxa, which is considered low. The diversity of macro-invertebrates sensitive to water quality deterioration was moderate, with four sensitive taxa recorded: Aeshnidae, Hydracarina, Naucoridae and Baetidae >2spp. No alien macro-invertebrates were recorded.

A total of 16 NASS2 taxa was recorded at Ai-Ais in June 2012 (Table 26). The same weighting of ecological traits used for EFR Fish1 was applied. Habitat suitability was rated as Moderate (60%). The macro-invertebrate composition was dominated by the pest blackfly *S. chutteri*, which was the only species of blackfly recorded at this site. The proportion of air-breathing taxa was low (25%), indicating well-oxygenated conditions. Two warm stenothermal taxa were recorded: Thiaridae and Tricorythidae, and this constituted 12% of the NASS2 taxa. The diversity of macro-invertebrates sensitive to water quality deterioration was low, with only two sensitive taxa recorded: Tricorythidae and Baetidae >2spp. No alien macroinvertebrates were recorded.

The key reasons for the PES of macro-invertebrates in the Fish River are described below.

- Increased nutrients: The most important driver of the PES of macro-invertebrates in the Fish River is likely to be elevated nutrients and reduced vegetation cover from livestock grazing, trampling and defecation. Grazing and trampling by livestock (mostly goats) have significant impacts on river bank stability, and associated erosion and increased turbidity. Furthermore, defecation by livestock is likely to impact on surface water quality, particularly during low-flow periods. Livestock in the area spend a large part of their day next to the river, where they graze on riparian margins. It is therefore highly likely that nutrient concentrations have increased, and this could have impacted negatively on some of the moderately sensitive taxa recorded in the river, such as Ecnomidae, Elmidae, Naucoridae, Baetidae (>2 spp), Hydropsychidae (>2 spp.) and Bryozoa.
- Increased salinity: Salinity levels are expected to be naturally high due to the geology of the area and high evaporation rates, but large-scale irrigation and impoundment at Hardap is likely to have elevated salinity above their natural range, and this could have influenced the macro-invertebrate composition to some extent.
- Weirs: There are no significant pools upstream of EFR Fish 1, whereas EFR Fish 2 was located downstream of the Seeheim gauging weir, where seepage is certain to maintain instream aquatic biota for as long as the weir has water. The PES results for EFR Fish 2 therefore reflects conditions with unnaturally elevated low flows, and although no more than a trickle, this was sufficient to provide small patches of habitat where flow-dependent species could survive. Seepage from weirs is likely to increase stream flow duration in localised sections of river, and this could explain the different PES results that were obtained at EFR Fish 1 and Fish 2 during this study. There do not appear to be many weirs

in the system, so the significance of this modification in the river as a whole is likely to be low and localised.

- Reduced vegetation cover: There was an almost complete absence of Shredders, reflecting the low importance of leaf litter in driving the ecosystem. Seasonal rivers generally do not have well-developed riparian zones, but the little vegetation that was present was severely impacted by grazing of goats, and it is therefore likely that the availability of leaf litter as a food source for macro-invertebrates has been reduced.
- Alien vegetation: The margins of the Fish River near the proposed development support low populations of Mesquite (*Prosopis* sp.), an alien invasive tree from Mexico and south-western United States. This tree is likely to have altered aquatic ecosystems by increasing evapotranspiration losses and destabilising stream banks. Furthermore, leaf litter from these trees is likely to have altered the food base in the river, and this could have affected the composition and/or abundance of macro-invertebrates.
- Abstraction: Direct abstraction from the river and abstraction from groundwater sources close to the river is likely to reduce the duration of surface flow, and this may have impacted negatively on macro-invertebrates in places. No information was available on the extent of such abstractions, but the overall impact is likely to be localised and of low significance.
- Increased cyanobacteria: Several potentially toxic cyanobacteria have been recorded in water discharged from Hardap Dam (Nepid Consultants, 2010), and these could have significant impacts on downstream ecology, particularly filterers.
- Competition from alien species: The snail *Physa acuta* was is an alien invasive species that was recorded in the Fish River by Curtis (1991). This species was not recorded during the present study, but it is likely to still be present, and may impact and outcompete indigenous snail species.

7.7 Limitations

7.7.1 Reference conditions

The only data available on macro-invertebrates in the Fish River before the construction of Hardap Dam is limited to collections of specific taxa (Curtis, 1991). Reference conditions were therefore based almost entirely on information collected after these rivers had been impounded.

7.7.2 Present ecological state

The composition and abundance of macro-invertebrate taxa in non-perennial systems, such as the Fish River, is driven mainly by the hydrological phase, and this presents a particular challenge of using macroinvertebrates as indicators of ecological state. Furthermore, the ecological traits that characterise macro-invertebrates inhabiting non-perennial systems are also typically associated with human impacts and disturbance, and include small size, rapid life cycles, multiple generations, high fecundity, and tolerance of water quality deterioration. This makes it difficult to distinguish between natural variation and human impacts. In this study the assessment of PES in the Fish River was restricted to conditions during the early dry season only, as this is when data are likely to be most reliable. There was no method available to quantify the PES of macro-invertebrates in non-perennial systems, so the method used in this report for the Fish River is new and has not been tested or undergone any peer review process. The ecological traits that were used were limited to those for which data were available, or could be assumed with reasonable confidence. These factors have a significant influence on reducing the confidence in the assessment of PES in the Fish River.

7.8 Conclusions

The macro-invertebrate fauna in the Fish River is characterised by a low diversity of tolerant taxa, typical of a seasonal system. The most common trophic group during the early dry season were filter-feeders, including freshwater sponges (Porifera), moss animalcules (Bryozoa), and blackfly larvae (Simuliidae). These taxa were generally restricted to sections of river where there was active flow, and these areas were generally few and far between. By far the most common instream habitat was mobile sands, and here the most common taxon was gomphid larvae, represented by a single species, *Paragomphus genei*. This species is almost certainly the most important source of food for fish in the Fish River for most of the time. This species is characterised by rapid development of eggs and larvae, which can be completed in 10 and 60 days respectively (Suhling et al., 2004). This rate of development is faster than any gomphid globally (Suhling pers. comm.). Flows less than about 70 days duration would therefore disrupt the breeding cycle and lead to an impoverished ecosystem.

8. Fish

8.1 Background

Based on available information, twelve (12) indigenous freshwater fish species have previously been recorded in the lower Orange and Fish River System and its tributaries (excludes estuarine species) (Table 26). At least four alien or introduced fish species are known to occur in the lower Orange and Fish River system, while various other species have been kept at the Hardap Dam breeding facility from where some escaped into the Fish River. There are also hybrids between the two yellowfish (*Labeobarbus aeneus* and *L. kimberleyensis*) and the two *Labeo* species (*Labeo capensis* and *L. umbratus*) known to be present in the Fish River system (Table 26).

Table 27. Fish species (abbreviations and scientific names) of the lower Orange and Fish River System

Abbreviation	Scientific names
Native indigenous species	
ASCL	*Austroglanis sclateri* (Boulenger, 1901)
BAEN	*Labeobarbus aeneus* (Burchell, 1822)
BHOS	*Barbus hospes* (Barnard, 1938)
BKIM	*Labeobarbus kimberleyensis* (Gilchrist and Thompson, 1913)
BPAU	*Barbus paludinosus* (Peters, 1852)
BTRI	*Barbus trimaculatus* (Peters, 1852)
LCAP	*Labeo capensis* (Smith, 1841)
LUMB	*Labeo umbratus* (Smith, 1841)
CGAR	*Clarias gariepin*us (Burchell, 1822)
MBRE	*Mesobola brevianalis* (Boulenger, 1908)
PPHI	*Pseudocrenilabrus philander* (Weber, 1897)
TSPA	*Tilapia sparrmanii* Smith, 1840
Hybrids (Fish River)	
BKIM X BAEN (B. cf. KIM)	*Labeobarbus hybrid*
LCAP X LUMB	Labeo hybrid
Alien or introduced species	
CCAR	*Cyprinus carpio* Linnaeus, 1758
MSAL	*Micropterus salmoides*
OMOS	*Oreochromis mossambicus*
TREN	*Tilapia rendalli*

Aspects of importance regarding the fish species of the Fish River (Namibia) is summarised in Appendix C.

8.2 Methodology to determine the ecological state of fish

The FRAI (Kleynhans, 2008) was applied to determine the present ecological status of MRUs represented by an EFR site. All available information on fish distribution in the Fish River was used, together with results gained during a fish survey conducted during June 2012.

The following two aspects are important in terms of the application of the FRAI on the Fish River.

- The FRAI was developed for perennial systems, and for application to river reach (not site). Certain aspects/metrics and rules were therefore altered for the application to the Fish River, which is classified as an ephemeral river with perennial pools.
- FROC values in FRAI generally based on the number of sites within a river reach (fish habitat segment) where a species can be expected/occur. For the purpose of the current study, the site/reach consisted of a stretch of the river that included different pools as well as their connections. Within the site/reach, various sub-sites were sampled which represented different habitats/biotopes present at the EFR site. The FROC for a species was therefore calculated based on this information (i.e. proportion of sub-sites where species expected/occur):
    - 1=Present at very few sub-sites (<10% of sub-sites).
    - 2=Present at few sub-sites (>10-25%).
    - 3=Present at about >25-50 % of sub-sites.
    - 4=Present at most sub-sites (>50- 75%).
    - 5=Present at almost all sub-sites (>75%).

One of the main challenges of this component of the study was the description of the reference condition of the fish assemblages of each MRU. This process was limited by the lack of historical information and the current flow alteration (especially modified flow regime as a result of Hardap Dam) that may have altered the fish population to some extent and especially by introduction of fish species into Hardap Dam, and also keeping and escapees of various fish species from the Hardap Dam hatchery. This is furthermore complicated by the hybridisation between indigenous species, as well as the presence of alien (or introduced indigenous) species. These aspects are further discussed in Appendix D.

8.3 Survey results

A summary of the fish species sampled at each site during the June 2012 survey is provided in Appendix D. Detailed data regarding the June 2012 survey (raw data) is provided on the ORASECOM website (www.orasecom.org).

8.4 Fish reach delineation

One of the primary objectives of the current study is an evaluation of the environmental flow requirements of the Fish River in terms of the construction of the proposed Neckartal Dam. This dam falls within the middle reaches (as described above) of the Fish River between Hardap Dam and the Witputs Waterfall. The selection of the EFR sites was therefore primarily determined by the location of this proposed dam. EFR Fish 1 was selected upstream of the proposed dam, while EFR Fish 2 is situated below the proposed dam. The EcoClassification process was therefore applied separately for reaches that incorporated these two EFR sites. Due to the difference in fish assemblages between the middle and lower reaches, an additional site was also sampled at /Ai-/Ais Hot Springs Resort area in the lower Fish River reach.

In terms of fish, EFR Fish 1 should reflect the PES of the lower section (reach) of MRU A, and is therefore referred to as MRU A2. The PES of the upper part of MRU A can be expected to be different as a result of aspects such as seepage from Hardap Dam, escapees from Hardap Dam fish breeding facility and irrigation return flows.

8.5 Results: EFR Fish 1

8.5.1 Reference conditions

Based on available information, the following six indigenous fish species are expected to occur at the specified FROC in the reach under natural (reference) conditions (Table 28).

Table 28. Fish Species expected under reference conditions at EFR Fish 1

Species	***Comment***	***Reference FROC***
BAEN	Very similar to the scenario described below for BKIM. Although BAEN is not typically expected in ephemeral rivers but will be more suited for those conditions than BKIM (more tolerant). Again the presence of large perennial pools creates favourable conditions for this species to occur and survive over the long-term in the Fish River. This species can therefore be expected to occur throughout the Fish River system under natural conditions.	4
BKIM	Although BKIM is not typically expected in ephemeral rivers, the presence of large perennial pools creates favourable conditions for this species to occur in the Fish River. There is no uncertainty regarding the natural occurrence of this species in the lower Fish River reach, but some uncertainty regarding their natural occurrence in the middle and upper reach (if these could not be colonised from the Orange River as a result of natural migration barriers (Witputs waterfall). There is a slight possibility that this species may have been introduced into Hardap Dam and spread from there into the upper and middle reaches. The earliest record that could be attained for this species in the middle/upper Fish River was in 1971 (after construction of the Hardap Dam in the 1960's). There is however no evidence to support the potential absence of this species in the middle/upper Fish River under natural conditions, and based on its present distribution, it is assumed (for the purpose of this study) that it naturally occurred throughout the Fish River System (during pre-disturbance conditions).	3
BPAU	This species is expected to occur throughout the Fish River system under natural conditions. It was especially abundant in the middle reach during the June 2012 survey.	5
CGAR	Tolerant species with very wide distribution across Southern Africa. Most probably occurred throughout river.	4
LCAP	As described for BKIM and BAEN, this species is not typically expected in ephemeral rivers but the presence of large perennial pools creates favourable conditions for this species to occur and survive over the long-term in the Fish River. This species is	5

Species	*Comment*	*Reference FROC*
	expected to have occurred throughout the Fish River system under natural conditions.	
LUMB	This species prefers slow deep (SD) habitats and has no requirement for fast habitats. The perennial pools in the Fish River should therefore create favourable habitats for this species. As discussed above, this species has not been sampled in the lower Orange River (also during current study), and is also scarce/absent from the lower Orange River. This distribution also raises the question if their presence in the upper Fish River is not due to introductions of this species into Hardap Dam. Due to the lack of historic information, one must consider their presence as natural.	3

Refer to further detailed discussion on each species regarding the rational for inclusion/exclusion of fish species in this river reach (Appendix D).

8.5.2 Present ecological state

The expected change in FROC under present conditions is provided in Table 29.

Table 29. Fish species present under present conditions at EFR Fish 1

Species	*Comment*	*Present FROC*
BAEN	The FROC and abundance most probably decreased as result of especially the flow modification by Hardap Dam (altered floods, low flows, pool volumes). The presence of weirs (and possibly farm dams) may however in some areas compensate for the loss in pools and create increased availability of slow-deep habitats and therefore increase the FROC and abundance in areas. Other impacts in this reach may be associated with increased turbidity (related to farming/overgrazing by goats, as well as low probability of presence of the bottom feeding CCAR).	3
BKIM	Abundance most probably decreased as result of especially the flow modification by Hardap Dam (altered floods, low flows, pool volumes). The presence of weirs (and possibly farm dams) may however in some areas create increased availability of slow-deep habitats and therefore increase the FROC and abundance in areas. Other impacts in this reach may be associated with increased turbidity (related to farming/overgrazing by goats, as well as possibly by the presence of the bottom feeding CCAR).	2
BPAU	Very abundant at EFR sites, no change from natural expected.	5
CGAR	Slight reduction expected as a result of decreased pools.	3
LCAP	The FROC and abundance most probably decreased slightly or remained stable as result of especially the flow modification by Hardap Dam (altered floods, low flows, pool volumes). The presence of weirs (and possibly farm dams) may however in some areas compensate for the loss in pools and create increased availability of slow-deep habitats and therefore increase the FROC and abundance in areas. Other impacts in this reach may be associated with increased sedimentation (fine silts) (related to farming/overgrazing by goats). Increased nutrients and organic pollution may result in increased algal growth that could favour this species at present (potentially explaining current high abundance). Overall the FROC is expected to remain stable in the middle reach.	5

Species	***Comment***	***Present FROC***
LUMB	The FROC and abundance most probably decreased as result of especially the flow modification by Hardap Dam (altered floods, pool volumes). The presence of weirs (and possibly farm dams) may however in some areas compensate for the loss in pools and create increased availability of slow-deep habitats and therefore increase the FROC and abundance in areas. Other impacts in this reach may be associated with increased sedimentation (fine silts) (related to farming/overgrazing by goats) which may impact the food sources of this bottom feeder. Overall a decreased FROC is therefore expected in the middle reach.	2

The FRAI results are provided in Table 30. The guidelines for rating/change are based on a score of -5 to 5 and provided below:

-5 = Extreme loss from reference (absent)

-4 = Serious loss from reference

-3 = Large loss from reference

-2 = Moderate loss from reference

-1 = Small loss from reference

0 = No change from reference

1 = Small increase from reference

2 = Moderate increase from reference

3 = Large increase from reference

4 = Serious increase from reference

5 = Extreme increase from reference (completely dominant)

Table 30. FRAI results for the EFR Fish 1 reach

Metric	***Rating (change)***
Velocity-depth classes (Weight: 100%)	
Response of species with high to very high preference for fast-deep (FD) conditions.	-0.5
Response of species with high to very high preference for fast-shallow (FS) conditions.	-1.0
Response of species with high to very high preference for slow-deep (SD) conditions.	-2.0
Response of species with high to very high preference for slow-shallow (SS) conditions.	-0.5
Cover (Weight: 94%)	
Response of species with a very high to high preference for overhanging vegetation.	0.0
Response of species with a very high to high preference for undercut banks and root wads.	-0.5
Response of species with a high to very high preference for a particular substrate type.	-1.5
Response of species with a high to very high preference for instream vegetation.	0.0
Response of species with a very high to high preference for the water column.	-2.0
Flow dependence (Weight: 73%)	
Response of species intolerant of no-flow conditions.	0
Response of species moderately intolerant of no-flow conditions.	-1
Response of species moderately tolerant of no-flow conditions.	-1
Response of species tolerant of no-flow conditions.	-1
Physico-chemical (Weight: 67%)	
Response of species intolerant of modified physico-chemical conditions.	0
Response of species moderately intolerant of modified physico-chemical conditions.	-2
Response of species moderately tolerant of modified physico-chemical conditions.	-1
Response of species tolerant of modified physico-chemical conditions.	-1
Migrations (Weight: 56%)	
Response in terms of distribution/abundance of spp. with catchment scale movements.	n/a
Response in terms of distribution/abundance of spp. with requirement for movement between reaches or fish habitat segments.	1
Response in terms of distribution/abundance of spp. with requirement for movement within reach or fish habitat segment.	n/a
Introduced species (Weight: 42%)	
The impact/potential impact of introduced competing/predaceous spp.	2.0
How widespread (frequency of occurrence) are introduced competing/predaceous spp.?	2.0
The impact/potential impact of introduced habitat modifying spp.	0.5
How widespread (frequency of occurrence) are habitat modifying spp.?	0.5
FRAI Score (%)	83
FRAI Category	**B**

Metric	***Rating (change)***
FRAI Category Description	Largely natural

8.6 Results: EFR FISH 2

8.6.1 Reference conditions

Based on available information, the reference conditions are the same as for EFR Fish 1 (refer to section 8.5.1). Refer to further detailed discussion on each species regarding the rational for inclusion/exclusion of fish species in this river reach (Appendix D).

8.6.2 Present ecological state

The expected change in FROC under present conditions is the same as for EFR Fish 1 (refer to section 8.5.2). However the alien species, OMOS, was abundant at site. The FRAI results are provided in Table 31. The guidelines for rating/change are based on a score of -5 to 5 as outlined in section 8.5.2.

Table 31. FRAI results for the EFR Fish 2 reach

Metric	***Rating (change)***
Velocity-depth classes (Weight: 100%)	
Response of species with high to very high preference for FD conditions.	-0.5
Response of species with high to very high preference for fast-shallow FS conditions.	-1.0
Response of species with high to very high preference for slow-deep SD conditions.	-2.0
Response of species with high to very high preference for slow-shallow SS conditions.	-0.5
Cover (Weight: 94%)	
Response of species with a very high to high preference for overhanging vegetation.	0.0
Response of species with a very high to high preference for undercut banks and root wads.	-0.5
Response of species with a high to very high preference for a particular substrate type.	-1.5
Response of species with a high to very high preference for instream vegetation.	0.0
Response of species with a very high to high preference for the water column.	-2.0
Flow dependence (Weight: 73%)	
Response of species intolerant of no-flow conditions.	0
Response of species moderately intolerant of no-flow conditions.	-1
Response of species moderately tolerant of no-flow conditions.	-1
Response of species tolerant of no-flow conditions.	-1
Physico-chemical (Weight: 67%)	
Response of species intolerant of modified physico-chemical conditions.	0
Response of species moderately intolerant of modified physico-chemical conditions.	-2

Metric	***Rating (change)***
Response of species moderately tolerant of modified physico-chemical conditions.	-1
Response of species tolerant of modified physico-chemical conditions.	-1
Migrations (Weight: 56%)	
Response in terms of distribution/abundance of spp. with catchment scale movements.	n/a
Response in terms of distribution/abundance of spp. with requirement for movement between reaches or fish habitat segments.	1
Response in terms of distribution/abundance of spp. with requirement for movement within reach or fish habitat segment.	n/a
Introduced species (Weight: 42%)	
The impact/potential impact of introduced competing/predaceous spp.	2.0
How widespread (frequency of occurrence) are introduced competing/predaceous spp.?	2.0
The impact/potential impact of introduced habitat modifying spp.	0.5
How widespread (frequency of occurrence) are habitat modifying spp.?	0.5
FRAI Score (%)	85.2
FRAI Category	**B**
FRAI Category Description	Largely natural

8.7 Results: EFR Fish Ai-Ais

8.7.1 Reference conditions

No information could be sourced regarding the fish in this reach under reference (pre-disturbance) conditions. Natural distribution patterns are furthermore shaped by the presence of natural migration barriers (waterfalls, cascades). Reference conditions were therefore based on the limited records of fish species of the area under present conditions. It is estimated that the fish assemblage of the Lower Fish River is dependant and to a large scale influenced by the Lower Orange River. Based on all the above information it is estimated that eight fish species occurred in this reach under reference conditions. These include BKIM, BAEN, BHOS, BTRI, BPAU, LCAP, MBRE and CGAR. The expected spatial FROC of all species was relatively high (see Table 32 for detailed rationale regarding reference condition of each species). (Moderate confidence = 2).

Table 32. Fish Species expected under reference conditions at EFR Fish Ai-Ais

Species	***Comment***	***Reference FROC***
BAEN	Very similar to the scenario described for BKIM. Although BAEN is not typically expected in ephemeral rivers but will be more suited for those conditions than BKIM (more tolerant). Again the presence of large perennial pools creates favourable conditions for this species to occur and survive over the long-term in the Fish River.	5

Species	***Comment***	***Reference FROC***
BKIM	Although BKIM is not typically expected in ephemeral rivers, the presence of large perennial pools creates favourable conditions for this species to occur in the Fish River. There is no uncertainty regarding the natural occurrence of this species in the lower Fish River reach.	4
BHOS	Although the presence of a waterfall (Witputs) is under present conditions the limit to the distribution of this species in the Fish River, one cannot but entertain the though why this species does not have the same distribution as for instance BAEN, BKIM and BPAU. One theory may be that this species is evolutionary much younger than the other species and may have only developed after the creation of the Witputs migration barrier. Another theory is that this species may have occurred throughout the fish river but due to its lower tolerance level (to water quality and possibly flow) it could not survive extreme conditions (maybe droughts) in the middle and upper reaches. It seems that this species has a high preference for flow, and with the absence of flow during certain critical times during spawning season it will also have a low breeding success rate in the Fish River. It also seems that BHOS may prefer cooler temperatures (gonad development at 13°C), and that the pool temperatures in the Fish River may exceed its tolerance during dry periods and summer. It may, therefore, be reasonable to accept that this species spawn in the Orange River and colonise the Fish River upstream as far as the first barrier (Witputs Water Fall). Since historic data is not available, and the reference conditions are described for pre-disturbance status, one must assume, based on the available data at present, that this species only occurred in the lower reach of the Fish River under reference (pre-disturbance) conditions.	3
BTRI	Since historic data is not available, and the reference conditions are described for pre-disturbance status, one must assume, based on the available data at present), that this species only occurred in the lower reach of the Fish River under reference (pre-disturbance) conditions. Based on the available information is also estimated that this species may have been scarce under reference conditions.	3
BPAU	This species is abundant in the middle and upper reaches but less common in the lower reaches of the river.	3
MBRE	Hay (1991) indicated that this species was abundant and flourished in the Fish River.	4
CGAR	Common species, expected under natural conditions.	3
LCAP	As described for BKIM and BAEN, this species is not typically expected in ephemeral rivers but the presence of large perennial pools creates favourable conditions for this species to occur and survive over the long-term in the Fish River. This species is expected to have occurred throughout the Fish River system under natural conditions.	5

Refer to further detailed discussion on each species regarding the rational for inclusion/exclusion of fish species in this river reach (Appendix D).

8.7.2 Present ecological state

Six of the expected eight indigenous fish species were sampled in the reach during the June 2012 survey, together with one alien/introduced species (OMOS). Two species not sampled during the survey, namely BKIM and BPAU, is still expected to occur in this reach. The abundance and spatial FROC of the indigenous species sampled were generally high for most species (BAEN > LCAP > MBRE > BHOS), while BTRI and CGAR were relatively scarce during the survey. Based on all considerations of impacts and available fish information, it was estimated that the expected reference FROC of BAEN, BKIM, CGAR and LUMB was reduced in this reach due to the impact of various human induced activities. The primary impacts include modified flow regimes (especially related to large dams such as Hardap and Naute), as well as water quality deterioration. Overall the fish assemblage was therefore estimated to currently be in a moderately modified state (PES=C). Refer to Table 33 below for detail regarding the estimated present state of each fish species. (Moderate confidence = 3)

Table 33. Fish species present under present conditions at EFR Fish Ai Ais

Species	***Comment***	***Present FROC***
BAEN	Literature indicates that 'pure' (non-hybrids) of this species is present in the lower reach. This may especially be attributed to the fact that the population in this reach is not as isolated due to connectivity and mixing with the Orange River population.. It is estimated that the status of this species is still good in the lower reach, with a slight decrease from reference FROC. It is mentioned that this species is still common in this reach (Hay, 1991). Impacts are also primarily associated with flow modification (Hardap and Naute Dam) and possibly sedimentation (fine sediment) covering substrates (breeding and feeding substrates).	4
BKIM	Literature indicates that 'pure' (non-hybrids) of this species is present in the lower reach. This may especially be attributed to the fact that the population in this reach is not as isolated due to connectivity and mixing with the Orange River population. It is estimated that the status of this species is still good in the lower reach, with a slight decrease from reference FROC. Impacts are also primarily associated with flow modification (Hardap and Naute Dam, as well as increased turbidity.	2
BHOS	It is estimated that the spatial FROC and abundance of this species has been altered slightly in the lower reach. Impacts are possibly attributed to flow modification (decreased availability of pools, decreased duration of connectivity with Orange River). If one considers the comment by Cambray (1984) that this species have benefitted from river regulation in the lower Orange River, it may have also had an impact on the lower Fish River population, as there is thought to be strong movement between these populations (and the possibility that this species primarily breeds in Orange River and colonise Fish River). Indication are that this species is still abundant in the lower reach, as also observed during the June 2012 survey, and therefore only expected to have been impacted slightly.	2.5
BTRI	It is estimated that the spatial FROC and abundance of this species has been altered slightly in the lower reach. Impacts are possibly attributed to flow modification (decreased availability of pools, decreased duration of connectivity with Orange River). This species was also scarce during the June 2012 survey.	2
BPAU	Not sampled at site Ai-Ais during June 2012. FROC may have been slightly reduced from reference conditions.	2
MBRE	This species still abundant and slight deterioration expected. This species is classified as moderately intolerant in terms of trophic specialization, and one can assume that they have been impacted to some extent by human activities, albeit it very slight (mainly attributed to flow modification).	3.5
CGAR	Similar than under reference conditions.	3

Species	Comment	Present FROC
LCAP	It is estimated that the status of this species is still good in the lower reach, with a slight decrease from reference FROC. Impacts are also primarily associated with flow modification (Hardap and Naute Dam) and possibly sedimentation (fine sediment) covering substrates (breeding and feeding substrates). The healthy population in the Orange River also serves to maintain this population in a healthy state.	4

The alien species, OMOS, was also sampled at the site, and CCAR also most probably occurs at low abundance in reach.

The FRAI results are provided in Table 34. The guidelines for rating/change are based on a score of -5 to 5 as outlined in section 8.5.2.

Table 34. FRAI results for the EFR Fish Ai-Ais reach

Metric	Rating (change)
Velocity-depth classes (Weight: 100%)	
Response of species with high to very high preference for FD conditions.	-1.5
Response of species with high to very high preference for FS conditions.	-1.5
Response of species with high to very high preference for SD conditions.	-1.0
Response of species with high to very high preference for SS conditions.	-0.5
Cover (Weight: 94%)	
Response of species with a very high to high preference for overhanging vegetation.	-0.5
Response of species with a very high to high preference for undercut banks and root wads.	0.0
Response of species with a high to very high preference for a particular substrate type.	-1.0
Response of species with a high to very high preference for instream vegetation.	-1.0
Response of species with a very high to high preference for the water column.	-1.0
Flow dependence (Weight: 73%)	
Response of species intolerant of no-flow conditions.	0
Response of species moderately intolerant of no-flow conditions.	-2
Response of species moderately tolerant of no-flow conditions.	-1
Response of species tolerant of no-flow conditions.	0
Physico-chemical (Weight: 67%)	
Response of species intolerant of modified physico-chemical conditions.	0
Response of species moderately intolerant of modified physico-chemical conditions.	-3
Response of species moderately tolerant of modified physico-chemical conditions.	-1
Response of species tolerant of modified physico-chemical conditions.	-1
Migrations (Weight: 56%)	
Response in terms of distribution/abundance of spp. with catchment scale movements.	n/a
Response in terms of distribution/abundance of spp. with requirement for movement	1

Metric	***Rating (change)***
between reaches or fish habitat segments.	
Response in terms of distribution/abundance of spp. with requirement for movement within reach or fish habitat segment.	n/a
Introduced species (Weight: 42%)	
The impact/potential impact of introduced competing/predaceous spp.	2.0
How widespread (frequency of occurrence) are introduced competing/predaceous spp.?	2.0
The impact/potential impact of introduced habitat modifying spp.	0.5
How widespread (frequency of occurrence) are habitat modifying spp.?	0.5
FRAI Score (%)	76.3
FRAI Category	**C**
FRAI Category Description	Moderately modified

9. Habitat integrity of the Fish River

Habitat integrity refers to the maintenance of a balanced, integrated composition of physico-chemical and habitat characteristics (temporally and spatially) that are comparable to the natural riverine habitat characteristics (Kleynhans et al., 2009). The habitat integrity status for a river provides the template for a certain level of biotic integrity to be realised. Habitat integrity assessments can be seen as a precursor to biotic integrity assessments. Habitat and biotic integrity together constitute ecological integrity. Separate assessments of the instream and riparian habitat integrities are undertaken according to a number of key criteria. The observed habitat condition in terms of these criteria is compared to a perceived unperturbed condition to estimate the change in habitat integrity. A rating system, based on differing weights for each criterion (according to its perceived importance in determining habitat integrity), is used to assess the river's instream and riparian habitat integrities. The sum of these ratings is used to classify the instream and riparian zone facets according to a descriptive integrity category. The instream index of habitat integrity (IHI) and the riparian (IHI) are based on the methods outlined in Kleynhans et al. (2009).

9.1 Data and information

The IHI determination used the following to assess the IHI:

- Personal ground-based observations.
- Local knowledge.
- Hydrological assessments.
- Water quality assessments.
- Land covers assessments.
- Google Earth (high resolution).
- IHI assessments at EFR O4 (Louw and Koekemoer (Eds), 2010).

The confidence ratings (0 - 5 with 5 being very high) in the above is high (4) due to the detailed ground-based observations and the high quality Google Earth imagery available for large sections of the study area. The only low confidence issue is the lack of hydrological information in terms of losses, tributary inflows and groundwater interaction.

9.2 Results

The IHI is assessed for the instream and riparian components. Each of these is assessed for various metrics (Table 35). These metrics are rated on a scale of 0–5 with 5 referring to critical changes from natural conditions and 0 implying no changes from natural. The results are provided as Ecological Categories of A (near natural) to F (critically modified).

The instream and riparian IHI results are summarised in Table 35 and 36.

Table 35. Instream IHI results

Instream IHI	***EFR Fish 1***	***EFR Fish 2***
Base flows	1.0	2.0
Zero flows	2.0	1.0
Floods	3.0	2.0
Hydrology rating	2.0	1.7
pH	1.0	1.0
Salts	2.0	2.0
Nutrients	2.0	2.0
Water temperature	1.0	0.5
Water clarity	1.0	1.0
Oxygen	1.0	1.5
Toxics	1.0	1.0
Physico-chemical rating	1.3	1.3
Sediment	2.0	1.0
Benthic growth	1.0	1.0
Bed rating	1.6	1.0
Marginal	1.0	1.0
Non-marginal	2.0	1.0
Bank rating	1.4	1.0
Longitudinal connectivity	0.0	2.0
Lateral connectivity	0.0	0.0
Connectivity rating	0.0	1.4
Instream IHI %	73.1	73.4
Instream IHI EC	C	C
Instream confidence	3.3	2.9

Table 36. Riparian IHI results

Riparian IHI	***EFR Fish 1***	***EFR Fish 2***
Base flows	0.5	0.0
Zero flows	0.0	0.0
Moderate floods	3.0	2.5
Large floods	3.0	0.5
Hydrology rating	2.1	1.0
Substrate exposure (marginal)	0.0	3.0
Substrate exposure (non-marginal)	0.5	3.0
Invasive alien vegetation (marginal)	0.5	0.5
Invasive alien vegetation (non-marginal)	0.5	0.5
Erosion (marginal)	0.0	1.0
Erosion (non-marginal)	0.5	1.0
Physico-chemical (marginal)	0.5	1.0
Physico-chemical (non-marginal)	0.0	0.0
Marginal	0.5	3.0
Non marginal	0.5	3.0
Bank structure rating	0.5	3.0
Longitudinal connectivity	0.0	0.0
Lateral connectivity	0.5	0.0
Connectivity rating	0.2	0.0
Riparian IHI %	81.0	66.9
Riparian IHI EC	B/C	C
Riparian confidence	*3.1*	*4.2*

9.3 Summary

The results are summarised in Table 37.

Table 37 Instream and riparian IHI summary

Instream IHI	***EFR Fish 1***	***EFR Fish 2***	***Riparian IHI***	***EFR Fish 1***	***EFR Fish 2***
Hydrology rating	2.0	1.7	Hydrology rating	2.1	1.0
Physico-chemical rating	1.3	1.3	Bank structure rating	0.5	3.0
Bed rating	1.6	1.0	Connectivity rating	0.2	0.0
Bank rating	1.4	1.0			
Connectivity rating	0.0	1.4			
Instream IHI %	73.1	73.4	Riparian IHI %	81.0	66.9

Instream IHI	***EFR Fish 1***	***EFR Fish 2***	***Riparian IHI***	***EFR Fish 1***	***EFR Fish 2***
Instream IHI EC	C	C	Riparian IHI EC	B/C	C
Confidence	3.3	2.9	Confidence	3.1	4.2

The key causes and sources of the C EC for the instream IHI are upstream dams resulting in a changed flow regime. The key causes and sources of the B/C and C for the riparian IHI are the change in flow regime from the upstream Hardap Dam and the grazing pressure, mostly due to goats. EFR Fish 1 is in a better condition than EFR Fish 2 due to lower levels of grazing at EFR Fish 1.

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Appendix A Species lists

A.1 Riparian vegetation

The legend pertaining to species list for EFR O5 (Table A1) is provided below.

Invasive Alien

Weed[1] = weed classified as category 1 invader.

NE = naturalized exotic.

Endemic

SA = South Africa.

SnA = southern Africa.

Riparian Indicator

0 = terrestrial, but can be found in riparian zone/wetland/floodplain.

1 = preferential riparian species.

2 = upper zone riparian obligate/floodplain species/wetland obligate (temporary zone).

3 = lower zone riparian obligate/wetland obligate (seasonal zone)/hydrophyte.

4 = marginal zone riparian obligate/rheophyte/helophyte/hydrophyte/wetland obligate (permanent zone)/sudd hydrophyte (an aquatic plant that grows rooted in sudd, which generally is an impenetrable mass of floating vegetable matter).

5 = aquatic (epihydate, pleustophyte, vittate).

Wetland Obligate

E = Estuarine.

L = Lacustrine.

P = Palustrine.

R = Riverine and

0 = opportunistic wetland.

1 = facultative negative (<25%).

2 = facultative wetland (50%).

3 = facultative positive (67-99%).

4 = obligate wetland (>99%).

A.1.1 EFR Fish 1

Species (53)	***Status***						
	Invasive alien	***Endemic***	***Aquatic***	***IUCN[1] listing***	***Riparian indicator***	***Wetland obligate***	***Protected***
Acacia erioloba				Declining	1		y
Acacia karroo				LC	1		
Ageratum houstonianum	Cat 1			LC			
Amaryllis paradisicola		SA		VU	1		
Bolboschoenus glaucus				LC	4	P4	
Cotula coronopifolia			y	LC	4	y	
Cullen tomentosum				LC	1		
Cynodon dactylon				LC			
Cyperus laevigatus				LC	3	y	
Cyperus longus var. *longus*				LC	4	y	
Cyperus longus var. *tenuiflorus*				LC	4	y	
Cyperus marginatus				LC	4	y	
Datua innoxia	Cat 1			x			
Diospyros lycioides subsp. *lycioides*				LC	0		
Ectadium virgatum				NT	2		
Euclea pseudebenus		y		LC	1		y
Ficus cordata subsp. *cordata*				LC	1		
Fimbristylis bisumbellata				LC	3	y	
Gomphocarpus fruticosus subsp. *fruticosus*				LC	3	y	
Gomphostigma virgatum				LC	4		
Gymnosporia linearis subsp. *lanceolata*		SnA		LC	2		
Hemarthria altissima				LC	3	y	
Hoodia gordonii				DD	1		
Juncus punctorius				LC	4	y	
Kohautia cynanchica				LC	1		
Lebeckia linearifolia				LC	1		
Ludwigia octovalvis				LC	4	y	
Lycium bosciifolium				LC			
Lycium cinereum				LC			
Maerua gilgii				LC	2		
Maytenus linearis							
Nicotiana glaucea	weed [1]			x	0		
Nymania capensis		y		LC			

Species (53)	***Status***						
	Invasive alien	***Endemic***	***Aquatic***	***IUCN[1] listing***	***Riparian indicator***	***Wetland obligate***	***Protected***
Olea europaea subsp. *africana*				LC	1		
Persicaria decipiens				LC	4	y	
Persicaria lapathifolia	y			x	4	y	
Phragmites australis				LC	4	y	
Potamogeton pectinatus			y	LC	5	y	
Potamogeton schweinfurthii			y	LC	5	y	
Prosopis glandulosa var. *glandulosa*	Cat 2			x	2		
Prosopis velutina	Cat 2			x	2		
Salix mucronata subsp. *mucronata*				LC	3		
Schoenoplectus scirpoides				LC	4	y	
Schotia afra var. *afra*		SA		LC	1		
Searsia lancea				LC	1		
Setaria incrassata				LC	2		
Sisyndite spartea				LC	2		
Stipagrostis ciliata var. *capensis*				LC	1		
Stipagrostis namaquensis				LC	1		
Tamarix usneoides		y		LC	2		
Veronica anagallis-aquatica				LC	4	y	
Ziziphus mucronata subsp. *mucronata*				LC	1		
Zygophyllum simplex				LC	1		

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A.1.2 EFR Fish 2

Species (22)	***Status***						
	Invasive alien	***Endemic***	***Aquatic***	***IUCN listing***	***Riparian indicator***	***Wetland obligate***	***Protected***
Acacia karroo				LC	1		
Cynodon dactylon				LC			
Cyperus longus var. *tenuiflorus*				LC	4	y	
Cyperus marginatus				LC	4	y	
Dichanthium annulatum var. *papillosum*				LC	2		
Digitaria eriantha							

Species (22)	***Status***						
	Invasive alien	***Endemic***	***Aquatic***	***IUCN listing***	***Riparian indicator***	***Wetland obligate***	***Protected***
Diospyros lycioides subsp. *lycioides*				LC	0		
Eragrostis rotifer				LC	3		
Euclea pseudebenus		y		LC	1		y
Hoodia gordonii				DD	1		
Kohautia cynanchica				LC	1		
Lycium hirsutum		y		LC	2		
Marsilea aegyptiaca				LC	4	y	
Nymania capensis		y		LC			
Phragmites australis				LC	4	y	
Rhigozum trichotomum				LC			
Sisyndite spartea				LC	2		
Stipagrostis ciliata var. *capensis*				LC	1		
Stipagrostis namaquensis				LC	1		
Tamarix usneoides		y		LC	2		
Ziziphus mucronata subsp. *mucronata*				LC	1		
Zygophyllum simplex				LC			

A.2 Riverine fauna

The species lists of the riverine fauna of the Orange and Fish River systems are provided in the tables below.

Habitat preference	***Frog species: Description***
Family: Bufonidae	
Karoo toad (*Vandijkophrynus gariepensis*)	
Habitat Preference	Dry thornbush areas in the catchment of the Orange River; sandy areas in the arid Karoo scrub, fynbos and grassland occurring up to high altitudes. Also in mountainous and rocky areas - under rocks, in burrows under rocks and abandoned termitaria. Well adapted to arid and cold conditions in both winter- and summer-rainfall regions. Inhabits springs and temporary water sources. Forage in more arid areas. Breeding - variety of water bodies, both permanent and temporary: streams, dams, rain pools, pans, seepages and spongy bogs. Tadpole metamorphosis complete after 20 days.
Breeding Habitat	Inhabits springs and temporary water sources. Breeding - variety of water bodies, both permanent and temporary: streams, dams, rain pools, pans, seepages and spongy bogs. Tadpole metamorphosis complete after 20 days.
Tadpoles	Tadpole metamorphosis complete after 20 days.
Riverine	Breeding - variety of water bodies, both permanent and temporary: streams.

Habitat preference	***Frog species: Description***
habitat	
RSA Status	Least concern. Not threatened.
Guttural toad (*Amietophrynus gutturalis*)	
Habitat Preference	Savanna, Grassland and Thicket biome: Breeds in open shallow pools, vleis, dams, rivers, streams or other more or less permanent water. Common in suburban gardens and farmland. Excavate burrows in soft ground. Tadpole metamorphosis complete after 5-6 weeks.
Breeding Habitat	Breeds in open shallow pools, vleis, dams, rivers, streams or other more or less permanent water. Tadpole metamorphosis complete after 5–6 weeks.
Tadpoles	Tadpole metamorphosis complete after 5–6 weeks.
Riverine habitat	Breeds in open shallow pools in streams or other more or less permanent water.
RSA Status	Population trend: Increasing. Not threatened. Least concern. Relatively secure as it is widely distributed, locally abundant and highly adaptable to human settlement.
Family: Xenopodinae	
Common platanna *(Xenopus laevis*)	
Habitat Preference	Most of the biomes. Restricted to aquatic habitats. Historically occurred in streams, rivers and their pools. Currently in man-made water bodies. Breeds in any more or less permanent bodies of water. Breeding = non-breeding habitat. Eutrophic waters seem to produce the highest densities. Burrow into dry mud to aestivate when pools dry up. Washed down during heavy rains into dry river courses. Breeds in remnant pools.
Breeding Habitat	Breeding and non-breeding habitats the same. Restricted to aquatic habitats. Historically occurred in streams, rivers and their pools. Currently in man-made water bodies. Breeds in any more or less permanent bodies of water. Breeding = non-breeding habitat. Eutrophic waters seem to produce the highest densities. No records of breeding in flowing water. Washed down during heavy rains into dry river courses. Breeds in remnant pools.
Tadpoles	Hatch in 2-3 days; metamorphosis within 2 months.
Riverine habitat	Restricted to aquatic habitats. Historically occurred in streams, rivers and their pools. Breeding = non-breeding habitat. Eutrophic waters seem to produce the highest densities. Burrow into dry mud to aestivate when pools dry up. No records of breeding in flowing water. Washed down during heavy rains into dry river courses. Breeds in remnant pools.
RSA Status	Not threatened. Least concern. Not threatened in any part of its range. Unprotected. Population trend: Increasing. Common and widespread.
Family: Ranidae **Subfamily: Petropedetinae**	
Namaqua caco (*Cacosternum namaquense*)	
Habitat Preference	Occurs mainly in upland succulent Karoo vegetation. Breeds opportunistically during rainy weather, at any time July to April, in temporary rain-filled rock pools, seeps and springs and also dams and quarries. Breeds in temporary pools in otherwise dry river beds in Namaqualand. Pools of spring rainwater collect in depressions, fill with muddy water, soon fringed with short grass. Breed rapidly and when they metamorphose, the young frogs are almost as large as the adults.
Breeding Habitat	Breeds opportunistically during rainy weather, at any time July to April, in temporary rain-filled rock pools, seeps and springs and also dams and quarries. Breeds in temporary pools in otherwise dry river beds in Namaqualand. Breed rapidly and when they metamorphose, the young frogs are almost as large as the adults.

Habitat preference	***Frog species: Description***
Riverine habitat	Breeds in temporary pools in otherwise dry river beds in Namaqualand.
RSA Status	Not threatened

Family: Ranidae
Subfamily: Raninae

Common river frog (*Amietia angolensis*)

Habitat Preference	Grassland and Savanna biomes; grassland streams and forest fringes. Wide range of wetland habitats. Adults occur in the grassy edges of rivers and streams, escape into the water. Banks of slow flowing streams or other permanent bodies of water favouring those with aquatic vegetation. Edges of pools, dams, streams and slow-flowing rivers. Jump in water and hide in soft mud to escape. Spend day floating amongst vegetation or basking on rocks above water level. Call from floating vegetation or from shallow water at the edge.
Breeding Habitat	Breeds in both standing and flowing water: edges of pools, streams and slow-flowing rivers. Both standing water in flat areas, and running water transversing slopes of more than 14 degrees.
Tadpoles	Tadpoles complete development in 9-12 months, but take up to 2 years if food is in short supply or water is very cold.
Riverine habitat	Adults occur in the grassy edges of rivers and streams, escape into the water. Edges of pools, dams, streams and slow-flowing rivers. Jump in water and hide in soft mud to escape. Breeds in both standing and flowing water: banks of slow flowing streams or other permanent bodies of water favouring those with aquatic vegetation.
RSA Status	Not threatened. Least concern. Widespread – found in all rivers, ponds, farm dams and other wetlands in its range. Not generally threatened. Population trend: stable.

Tandy's sand frog (*Tomopterna tandyi*)

Habitat Preference	Nama Karoo grassland and savanna. It is a species of dry savannah, bush land and grassland, and it is often found in agricultural areas. It is particularly associated with loose sandy soils where temporary pans form. It breeds in temporary shallow water, ditches, streams and dams, and is commonly found in farm dams. Loose sandy soils along small streams, pans and temporary rain pools. Call from exposed positions at pools edge; beneath vegetation in flooded areas.
Breeding Habitat	Breeds in small streams, temporary rain pools, pans and vleis in savanna and grassland.
Riverine habitat	Loose sandy soils along small streams. Call from beneath vegetation in flooded areas. Breeds in small streams. It breeds in temporary shallow water and streams.
RSA Status	Not threatened. Least concern. Widespread and common; does not require conservation action. Population trend: stable.

Habitat and status	***Reptile species: Description***
Family:Varanidae	
Water monitor (*Varanus niloticus niloticus*)	
Total Habitat	Near water: rivers, dams, pans and major lakes. Major river valleys. Shelter in holes in banks, in animal burrows or in crevices between rocks or under rocks, marginal vegetation. Basking in sun on rocks, outcrops, tree stumps, branches of overhanging trees or amongst vegetation on banks - never far from water. Escape into water – swim swiftly. Forage in marginal vegetation. Hibernate in large rock crag on rocky cliff or koppie bordering river. Young – marginal reed beds. Eggs deposited in hole dug deep into a living termite nest or sandbank by female, roughly covered over – termites seal up securely.
Status: Southern African endemic includes Botswana, Mozambique, Zimbabwe and Namibia	Protected by Provincial legislation (CITES, Appendix 11). Widespread, status considered secure.
Diet	Crabs and mussels; frogs, fish, birds and their eggs, eggs of terrapin and crocodile, insects

Habitat and status	***Bird species: Description***
1. Pelicans	
Great white pelican *(Pelecanus onocrotalus)*	
Biotope (Geographical area)	Shallow warm, fresh or moderately alkaline water bodies with adequate supplies of fish. Shallow lakes, flood plain pans, estuaries, sheltered coastal bays, lagoons. Roost on dry land.
Breeding	Nests usually on islands or in swamps. On ground or reeds.
Riverine link	Shallow warm, fresh or moderately alkaline water bodies with adequate supplies of fish. Flood plain pans. Roost on dry land. Nests usually on islands or in swamps. On ground or reeds.
Pink-backed pelican *(Pelecanus rufescens)*	
Biotope (Geographical area)	Permanent wetlands for foraging and trees for breeding. Large freshwater or alkaline lakes. Wide range of wetlands, including lakes, slow-flowing rivers, saline pools, lagoons, estuaries, sheltered bays.
Breeding	Breed in colonies, usually in flooded trees. Nest built in tree canopy often over water.
SA status	NEMA (TOPS): Endangered species.
Riverine link	Permanent wetlands for foraging and trees for breeding. Wide range of wetlands, including slow-flowing rivers sheltered bays. Breed in colonies, usually in flooded trees. Nest built in tree canopy often over water.
2. Cormorants and darters	
Little Grebe *(Tachybaptus ruficollis)*	
Biotope (Geographical area)	More permanent waters: lakes, ephemeral pans and dams; emergent or overhanging vegetation, weedy shores. Backwaters in slow flowing rivers and streams. More permanent water. Infrequent: slow-flowing streams. Rarely in estuaries and sheltered bays.
Breeding	Nest - floating heap of water plants, either on open water or concealed in vegetation.
Diet	Small frogs, especially platannas, Daphnia and water insects.

Habitat and status	***Bird species: Description***
SA status	Common resident or nomad.
Riverine link	More permanent waters: Infrequent: slow-flowing streams. Backwaters in slow flowing rivers and streams - emergent or overhanging vegetation, weedy shores. Nest - floating heap of water plants, either on open water or concealed in vegetation.
Whitebreasted cormorant (*Phalacrocorax lucidus*)	
Biotope (Geographical area)	Coastal and fresh waters: Dams and impoundments, streams and rivers. Mainly aquatic, in both salt and freshwater. Interior - streams and rivers.
Breeding	Colonial nester. Nest fixed to tree - islands, trees along rivers.
Diet	Mainly fish; also frogs, crustaceans and mollusks.
SA status	Common resident.
Riverine link	Coastal and fresh waters: Streams and rivers. Mainly aquatic, in both salt and freshwater. Interior - streams and rivers. Colonial nester. Nest fixed to tree - islands, trees along rivers.
African Darter (*Anhinga melanogaster*)	
Biotope (Geographical area)	Freshwater wetlands, rivers and streams; avoids fast-flowing and turbulent water; adapted to artificial wetlands. Still and slow-moving freshwater bodies with open water. Scarce on fast flowing rivers and in areas with dense floating vegetation. Prefers areas with dead trees, rocks or banks where it can rest after feeding.
Breeding	Nest built in tree fork, often over water or on an island; also in large reedbed.
Diet	Mainly fish; also frogs and arthropods.
SA status	Common resident.
Riverine link	Freshwater wetlands, rivers and streams; avoids fast-flowing and turbulent water. Still and slow-moving freshwater bodies with open water. Scarce on fast flowing rivers and in areas with dense floating vegetation. Prefers areas with dead trees, rocks or banks where it can rest after feeding. Nest built in tree fork, often over water or on an island; also in large reedbed.
3. Egrets, herons and bitterns	
Grey heron (*Ardea cinerea*)	
Biotope (Geographical area)	Bodies of shallow open water. Wetlands – rivers, dams, pans, marshes and estuaries – provided there is sufficient shallow water to feed in. Mountainous areas: keep to valleys. Tall trees, reed beds and cliffs for roosting. Also marine intertidal zone, estuaries, lagoons. Rarely in dry grasslands.
Breeding	Tall trees, reed beds and cliffs for breeding and roosting. Nest placed in tree fork on bush or 1.5-2.0m above water in a reedbed.
Diet	Hunts by stand-and-wait in shallow water, or walk slowly to disturb prey. Fish (1-110 g in weight, mostly 10-20g), frogs, crabs, insects, spiders, centipedes, reptiles, small mammals and birds, mollusks and worms; rarely plant material.
SA status	Relatively uncommon; resident. Breeding resident (Har97). Numbers augmented by Palearctic migrants (Har97). Expansion in range – artificial water. bodies (Har97). Common.
Riverine link	Bodies of shallow open water. Wetlands – rivers; provided there is sufficient shallow water to feed in. Mountainous areas: keep to valleys. Rarely in dry grasslands. Tall trees, reed beds and cliffs for breeding and roosting. Nest placed in tree fork on bush or 1.5-2.0m above water in a reedbed. Hunts by stand-and-wait in shallow water, or walk slowly to disturb prey.
Little egret (*Egretta garzetta*)	
Biotope (Geographical area)	Open areas of shallow water: margins of lakes, dams, rivers, marshes, saltpans, estuaries and mangrove swamps. Breeds near water in trees or bushes. Edges of

Habitat and status	***Bird species: Description***
	rivers and lakes, estuaries, pans, marshes, and saltpans. Also mangroves, open coastal.
Breeding	Nest placed in tree or bush above water or reedbed.
Diet	Hunts by walking or running through shallow water, stabbing at prey. Fish (of up to 14g, mostly <1g), frogs, small lizards, insects, mollusks, crustaceans.
SA status	Fairly common resident.
Riverine link	Open areas of shallow water: rivers, marshes. Breeds near water in trees or bushes. Edges of rivers. Nest placed in tree or bush above water or reedbed. Hunts by walking or running through shallow water, stabbing at prey.
Yellowbilled egret (*Egretta intermedia*)	
Biotope (Geographical area)	Shallow water or wet grasslands. Margins of lakes, rivers, saltpans and estuaries; especially seasonal waterbodies, marshes and flooded grasslands. Prefers shallow water, but also forages in dry grassland close to water.
Breeding	Breeds in reedbeds or trees.
Diet	Mainly fish and frogs, other small vertebrates, insects and spiders.
SA status	Uncommon to locally common; local movements, possibly migratory in part.
Riverine link	Shallow water or wet grasslands. Margins of lakes, rivers, saltpans and estuaries; especially seasonal waterbodies, marshes and flooded grasslands. Prefers shallow water, but also forages in dry grassland close to water. Breeds in reedbeds or trees.
Great Egret (*Egretta alba)*	
Biotope (Geographical area)	Shallow open water at lakes, rivers, floodplains, flooded grasslands, marshes, saltpans and estuaries.
Breeding	Breeds in reedbeds or trees. Nest on platform 2-3m above water in reedbed or 1-5m up in a tree standing in water or island.
Diet	Hunt in day in shallow water, occasionally in deeper water or on dry land. Mostly fish (1-45g, mostly 5-10g), frogs, insects and small mammals.
SA status	Uncommon resident.
Riverine link	Shallow open water at rivers. Breeds in reedbeds or trees. Nest on platform 2-3m above water in reedbed or 1-5m up in a tree standing in water or island. Hunt in day in shallow water, occasionally in deeper water or on dry land.
Goliath heron (*Ardea goliath*)	
Biotope (Geographical area)	Open water: lakes, dams, large wide rivers and estuaries with extensive shallows and where there are extensive reeds or papyrus. Nests on islands. Shallow margins of large water bodies.
Breeding	Nest in tall tree, but also on ground on islands, mats of trampled reeds, and in flooded bushes or trees.
Diet	Forages in shallows up to breast depth, often from floating vegetation. Hunting among floating vegetation. Fish (90-980g, mostly 500-600g), frogs, small reptiles and mammals, crustaceans, carrion.
SA status	Uncommon resident generally, but common and conspicuous on larger rivers.
Riverine link	Open water: large wide rivers with extensive shallows and where there are extensive reeds or papyrus. Nests on islands. Shallow margins of large water bodies. Nest in tall tree, but also on ground on islands, mats of trampled reeds, and in flooded bushes or trees. Forages in shallows up to breast depth, often from floating vegetation. Hunting among floating vegetation.
Purple heron (*Ardea purperea*)	
Biotope (Geographical area)	Larger water bodies and wetlands: Reedbeds, marshes, reed-fringed rivers and lakes; flooded areas with tall grasses, rushes and sedges. Dense emergent vegetation, especially reed beds fringing shallow wetlands; also mangroves.

Habitat and status	*Bird species: Description*
Breeding	Nest in reedbeds on platform.
Diet	Hunts in reedbeds. Fish, frogs, small reptiles, small mammals and birds (weavers, ducklings.)
SA status	Uncommon to common resident.
Riverine link	Larger water bodies and wetlands: Reedbeds, marshes, reed-fringed rivers; flooded areas with tall grasses, rushes and sedges. Dense emergent vegetation, especially reed beds fringing shallow wetlands. Nest in reedbeds on platform. Hunts in reedbeds.
Squacco heron (*Ardeola ralloides*)	
Biotope (Geographical area)	Freshwater habitats: dense emerging/fringing vegetation in the quiet backwaters of ponds and the edges of slow-flowing rivers and streams. Adequate reed cover and a few bushes or trees are prerequisites. Flooded grasslands and ephemeral pans with emergent vegetation.
Breeding	Nest: A platform placed in bush or tree over water or in reedbed. <1 m above water.
Diet	Forages by walking slowly at water's edge or in shallows. Mainly Insects, also spiders, crabs, molluscs, fish, frogs, and rarely small birds
SA status	Uncommon to locally common resident
Riverine link	Freshwater habitats: dense emerging/fringing vegetation in the quiet backwaters and the edges of slow-flowing rivers and streams. Adequate reed cover and a few bushes or trees are prerequisites. Nest: A platform placed in bush or tree over water or in reedbed. <1 m above water.
Green-backed heron (*Butorides striata*)	
Biotope (Geographical area)	Densely vegetated rivers, estuaries, streams, lakes, ponds, swamps and mangroves. Wooded areas around margins of rivers, streams, lakes, estuaries, mangroves reedbeds, and swamps where vegetation overhangs water. Occasional - mudflats, temporarily flooded grassland and seashore.
Breeding	Nest placed on lateral branch of tree or dense shrub, 0.3-7 m above ground or water.
Diet	Fish, frogs, small reptiles, insects, crustaceans, spiders, molluscs, red-billed quelea
SA status	Uncommon resident
Riverine link	Densely vegetated rivers, streams. Wooded areas around margins of rivers, streams, reedbeds, where vegetation overhangs water. Occasional - mudflats, temporarily flooded grassland. Nest placed on lateral branch of tree or dense shrub, 0.3-7 m above ground or water.
Black-crowned night heron (*Nycticorax nycticorax*)	
Biotope (Geographical area)	Dense vegetation along the edges of shallow, still or slow-moving water such as rivers, lakes, pans, marshes or seasonal floodplains. Well-vegetated and slow-moving water - estuaries, mangroves. Roosts in trees and reedbeds.
Breeding	Nest: Usually in reedbeds; less often in tree or bush over water.
Diet	Motionless on shoreline when hunting. Fish, frogs, reptiles, young and eggs of birds, crustaceans, insects, molluscs, small mammals, rarely adult birds
SA status	Common resident
Riverine link	Dense vegetation along the edges of shallow, still or slow-moving water - rivers. Well-vegetated and slow-moving water. Roosts in trees and reedbeds. Nest: Usually in reedbeds; less often in tree or bush over water. Motionless on shoreline when hunting.
Little bittern (*Ixobrychus minutus*)	
Biotope	Breeding birds confined to *Typha* and *Phragmites* reedbeds in standing water.

Habitat and status	*Bird species: Description*
(Geographical area)	Migrants in sedges or rank emergent vegetation in shallow water. At edges of wooded streams and rivers. Rank vegetation along ponds.
Breeding	Nest placed in live bulrushes or dense reeds above water.
Diet	Forage along edges of channels or reedbeds with cover. Fish, frogs, arthropods, molluscs, small reptiles.
SA status	Non-breeding Palearctic migrant.
Riverine link	Breeding birds confined to *Typha* and *Phragmites* reedbeds in standing water. Migrants in sedges or rank emergent vegetation in shallow water. At edges of wooded streams and rivers. Rank vegetation along ponds. Nest placed in live bulrushes or dense reeds above water. Forage along edges of channels or reedbeds with cover.
4. Storks, cranes and spoonbills	
Yellow-billed stork (*Mycteria ibis*)	
Biotope (Geographical area)	Dams, large marshes, swamps, estuaries, margins of lakes and rivers, seasonal wetlands. Wetlands, including alkaline and freshwater lakes, rivers, pans, flood plains, flooded grasslands, small pools or streams.
Breeding	Nest placed on top of tree (Acacia, fig) 3-7 m above ground or water.
Diet	Forages in shallow water free of emergent vegetation. Fish, frogs, insects, worms, crustaceans, small mammals.
SA status	Non-breeding infra African migrant.
Riverine link	Margins of rivers, seasonal wetlands. Wetlands, including rivers, flood plains, flooded grasslands, small pools or streams. Nest placed on top of tree *(Acacia,* fig) 3-7 m above ground or water. Forages in shallow water free of emergent vegetation.
Black stork (*Ciconia nigra*)	
Biotope (Geographical area)	Shallow water: streams, rivers, marshes, floodplains, coastal estuaries, flooded grassland; large and small dams; dry land. Shallows of rivers, pools in dry riverbeds. Uncommon in seasonal pans lacking fish.
Breeding	Nest up cliff above water: 10-100 m.
Diet	Mainly fish, also frogs, tadpoles, arthropods, small mammals, nestling birds, and tortoises. Optimal foraging habitat probably in dried-up river course where remaining aquatic life is concentrated in small pools.
SA status	National Environmental Management: Biodiversity Act (NEMBA) (TOPS): Vulnerable species; Uncommon to rare nomadic.
Riverine link	Shallow water: streams, rivers, marshes, floodplains, flooded grassland. Shallows of rivers, pools in dry riverbeds. Uncommon in seasonal pans lacking fish. Nest up cliff above water: 10-100m. Optimal foraging habitat probably in dried-up river course where remaining aquatic life is concentrated in small pools.
African spoonbill (*Platalea alba*)	
Biotope (Geographical area)	Shallow aquatic habitats: freshwater wetlands, marshes, pans, temporary flooded grasslands, floodplains, rivers, dams. Almost exclusively shallow aquatic habitats, favouring lake and river margins, seasonally and permanent pans, coastal lagoons and estuaries.
Breeding	Favours swamps with stands of tall reeds and sedges. Nest almost always on partly submerged trees, bushes, reeds, or rocky islets.
Diet	Small fish, aquatic invertebrates.
SA status	Locally common nomadic.
Riverine link	Shallow aquatic habitats: freshwater wetlands, floodplains, rivers. Almost exclusively shallow aquatic habitats, favouring river margins. Breeding: Favours

Habitat and status	***Bird species: Description***
	swamps with stands of tall reeds and sedges. Nest almost always on partly submerged trees, bushes, reeds, or rocky islets.
5. Ibis and hamerkop	
Glossy ibis (*Plegadis falcinellus*)	
Biotope (Geographical area)	Grassland habitats, associated with freshwater habitats: shallow inland waters, lake and river-edge marshes, seasonal pans, flooded grassland. Riparian marshes, shallow rivers.
Breeding	Favours swamps with stands of tall reeds and sedges. Nest in most dense patches of reeds or rushes, large reedbed islands.
Diet	Forages in shallow water or on soft ground. Insects, crustaceans, worms, molluscs, fish, frogs, and small reptiles.
SA status	Locally common to rare Increasing in numbers.
Riverine link	Grassland habitats, associated with freshwater habitats: shallow inland waters, river-edge marshes. Riparian marshes, shallow rivers. Nest in most dense patches of reeds or rushes, large reedbed islands. Forages in shallow water or on soft ground.
Hamerkop (*Scopus umbretta*)	
Biotope (Geographical area)	Large perennial waterbodies (lakes, dams and rivers), vleis and ephemeral wetlands, perennial and seasonal rivers with pools. Edges and shallow waters of lakes, pans, swamps and marshes, rivers, streams and seasonally flooded ponds, including relatively small puddles.
Breeding	Nest in sturdy tree or on cliff ledge. Adjacent to or over water.
Diet	Hunts at water's edge. Mainly adults and tadpoles of *Xenopus*; also fish and some invertebrates; rarely small mammals.
SA status	Common resident
Riverine link	Large perennial waterbodies: Perennial and seasonal rivers with pools. Edges and shallow waters of rivers, streams and seasonally flooded ponds, including relatively small puddles. Nest in sturdy tree or on cliff ledge. Adjacent to or over water. Hunts at water's edge.
6. Ducks and geese	
Fulvous duck (*Dendrocygna bicolor*)	
Biotope (Geographical area)	Larger inland waters: floodplains, plentiful aquatic vegetation. Shallow water bodies. Thickly vegetated with aquatic grasses and other plants. Feed in partly flooded / marshy wetland.
Breeding	Nest: Rank grass close to water, sedges and reeds over water.
Diet	Seeds and fruit of aquatic plants; very little animal material.
SA status	Nomadic probably summer migrant to SA. Not threatened.
Riverine link	Any inland water: Larger inland waters: floodplains, plentiful aquatic vegetation. Shallow water bodies. Thickly vegetated with aquatic grasses and other plants. Nest: Rank grass close to water, sedges and reeds over water.
Whitefaced duck (*Dendrocygna viduata*)	
Biotope (Geographical area)	Inland waters, mainly in savanna and grassland. Expanses of shallow water with emergent vegetation: backwaters of larger rivers, grassy floodplains, small ephemeral pans. Feeds in water - usually in shallows of permanent or seasonal wetlands, or flooded grasslands; on land - natural grasslands.
Breeding	Ephemeral wetlands. Dense grass or sedges - sometimes over water or island. Dense, long grass or sedges near water edge. Grassy island surrounded by shallow water.

Habitat and status	***Bird species: Description***
Diet	Feeds in water - buds, seeds, grain, tubers, insect larvae; grass, algae, fruit, mollusks, crustaceans
SA status	Common resident. Nomadic when breeding. Not threatened.
Riverine link	Inland waters; expanses of shallow water with emergent vegetation: backwaters of larger rivers, grassy floodplains. Breeding: Ephemeral wetlands. Dense grass or sedges - sometimes over water or island. Dense, long grass or sedges near water edge. Grassy island surrounded by shallow water. Feeds in water.
Whitebacked duck (*Thalassornis leuconotus*)	
Biotope (Geographical area)	Quite, clear inland waters with emergent of floating vegetation, natural pans, open vleis, floodplains and river backwaters. Diving to bottom muds in open water.
Breeding	Seasonal pans and floodplains. Ephemeral pans with stable water levels and isolated stands of sedges, rushes or reeds, and are well covered with aquatic grasses.
Diet	Waterlily seeds, other parts of water plants, aquatic animals; young feed on insect larvae and seeds.
SA status	Uncommon resident or nomadic at times. Not threatened.
Riverine link	Quite, clear inland waters with emergent of floating vegetation, open vleis, floodplains and river backwaters. Diving to bottom muds in open water. Breed: Seasonal pans and floodplains. Breeding: Seasonal pans and floodplains. Ephemeral pans with stable water levels and isolated stands of sedges, rushes or reeds, and are well covered with aquatic grasses.
Egyptian goose (*Alopochen aegyptiacus*)	
Biotope (Geographical area)	Inland waters: rivers, dams, lakes, marshes, pans, and estuaries with some exposed shoreline; wetland edges. Rich aquatic plant growth. Naturally: Restricted to flood plains and large rivers with broad sandbanks. Currently: Cropfields and cereal fields.
Breeding	Nests usually on ground, typically in dense vegetation or among rocks; often on small islands in water bodies. Always near water. Also old nests of other birds.
Diet	Grass, leaves, seeds, grain, aquatic rhizomes, tubers.
SA status	Very common resident.
Riverine link	Inland waters: rivers with some exposed shoreline; wetland edges. Rich aquatic plant growth. Naturally: Restricted to flood plains and large rivers with broad sandbanks. Nests usually on ground, typically in dense vegetation or among rocks; often on small islands in water bodies. Always near water. Also old nests of other birds.
South African Shelduck (*Tadorna cana*)	
Biotope (Geographical area)	Shallow, stagnant, temporary waters, often brackish and warm. Small farm dams, large estuaries and coastal lagoons. Wing-moult habitat: Large impoundments. Breeding habitat: open country near a small body of water. Shallow, brackish seasonal pans, rivers. Exposed, muddy shoreline water and extensive, open, shallow water. Continuous short vegetation.
Breeding	Burrow-nesting: pre-existing hole in ground; probably related to sparse vegetation fringing arid country wetlands.
Diet	Winter: crop seed and algae; Summer: also insects and crustacean.
SA status	Southern African endemic. Common; migrates to larger bodies of water for wing-moult.
Riverine link	Rivers with exposed, muddy shoreline water and extensive, open, shallow water. Continuous short vegetation. Burrow-nesting: pre-existing hole in ground; probably related to sparse vegetation fringing arid country wetlands.

Habitat and status	***Bird species: Description***
Spurwinged goose (*Plectopterus gambensis*)	
Biotope (Geographical area)	Inland waters / wetland: larger bodies of water, floating vegetation; croplands. Flightless moult: Dams and dense swamp. Breeding: smaller system or secluded bay, emerging fringing vegetation. Rivers - shallow areas in open.
Breeding	Nest: Shallow scrape in ground near water. Island, dense grass or reeds, sometimes in burrow.
Diet	Grass shoots and seeds, tubers, fruit, aquatic plants.
SA status	Common to very common resident.
Riverine link	Rivers - shallow areas in open. Nest: Shallow scrape in ground near water. Island, dense grass or reeds, sometimes in burrow.
Comb Duck (*Sarkidiornis melanotos*)	
Biotope (Geographical area)	Inland waters: seasonal flooded pans and vleis. Rivers - shallow areas in open.
Breeding	Nest in cavity of tree (dead, hollow), rotten palm stump, old hamerkop nests. 4-12m above ground.
Diet	Mainly seeds of grass, water lilies, locusts, aquatic insect larvae, plant propagules.
SA status	Locally common; seasonal movements.
Riverine link	Rivers - shallow areas in open. Nest in cavity of tree (dead, hollow), rotten palm stump, old hamerkop nests. 4-12m above ground.
African black duck (*Anas sparsa*)	
Biotope (Geographical area)	Rivers with running water, pools with wooded banks. Mainly perennial rivers and streams, from fast-flowing mountain streams to wide sandy river mouths, preferring shallow stony bottom streams with wooded banks. Moult: lodged branches undercut banks.
Breeding	Nest on ground in dense grass or other ground cover on river bank, or in lodged flood debris, tangled roots or hollow stump.
Diet	Mainly chironomid larvae and pupae gleaned from under stones in rapids; aquatic insects, plant material, fruit, seeds, small fish and crabs.
SA status	Uncommon localized resident.
Riverine link	Rivers with running water, pools with wooded banks. Mainly perennial rivers and streams, from fast-flowing mountain streams to wide sandy river mouths, preferring shallow stony bottom streams with wooded banks. Moult: lodged branches undercut banks. Nest on ground in dense grass or other ground cover on river bank, or in lodged flood debris, tangled roots or hollow stump.
Yellowbilled duck (*Anas undulata*)	
Biotope (Geographical area)	Inland waters: Sluggish or still waters and still waters of rivers and streams; mostly with marginal vegetation such as reeds. Avoid fast flow and saline/ acidic water bodies. Usually floats near emergent aquatic vegetation, occasionally on open water.
Breeding	Breeds on a variety of freshwater wetlands. Shallow seasonal waterbodies. Nest amongst rushes reeds, dense grass or sedges, often within dense patch of vegetation, screened from above. Close to water - within 20 m.
Diet	Plant material: seeds, stems, tubers and leaves of aquatic plants, grass; also insects and their larvae.
SA status	Very common resident.
Riverine link	Inland waters: Sluggish or still waters and still waters of rivers and streams; mostly with marginal vegetation such as reeds. Avoid fast flow and saline/ acidic water bodies. Usually floats near emergent aquatic vegetation, occasionally on open water. Nest amongst rushes reeds, dense grass or sedges, often within dense patch

Habitat and status	*Bird species: Description*
	of vegetation, screened from above.
7. Finfoot and jacanas	
African Jacana *(Actophilornis africanus)*	
Biotope (Geographical area)	Aquatic habitats: seasonal pans and floodplains; along fringes of slow-flowing, meandering rivers – emergent, floating hydrophytes to forage. Permanent, seasonal and ephemeral shallow, freshwater wetlands and margins of slow-flowing rivers with low emergent vegetation. Favours areas dominated by water lilies and pondweed. Walks on floating plants or swim when hydrophytes provide insufficient support.
Breeding	Nest: Platform of aquatic plants over still water, exposed or well-hidden when vegetation is available.
Diet	Insects, aquatic larvae, snails and seeds.
SA status	Common to abundant resident; local movements apparent.
Riverine link	Aquatic habitats: along fringes of slow-flowing, meandering rivers – emergent, floating hydrophytes to forage. Favours areas dominated by water lilies and pondweed. Walks on floating plants or swim when hydrophytes provide insufficient support. Nest: Platform of aquatic plants over still water, exposed or well-hidden when vegetation is available.
10. Hawks and eagles	
Osprey (*Pandion haliaetus*)	
Biotope (Geographical area)	Inland and coastal waters. Widespread. Coastal along the sea shore, and at estuaries and lagoons; inland on lakes and large rivers. Perch high.
Breeding	Extralimital
Diet	Fish: mostly up to 300 g, but up to 3000 g.
SA status	Mostly uncommon non-breeding Palaearctic migrant. Some may breed.
Riverine link	Widespread. Inland on lakes and large rivers. Feed on fish mostly up to 300 g, but up to 3000 g. Not breeding in SA. Perch high.
African fish eagle (*Haliaeetus vocifer*)	
Biotope (Geographical area)	Widespread. Coastal along the sea shore, and at estuaries and lagoons; inland on lakes and large rivers. Usually associated with large water bodies, either flowing or still, including estuaries. Sometimes along open coastline. May remain on seasonally dry rivers once last pools dry up, subsisting on birds and scavenging carcasses. Absent from rivers that flow for only a few weeks a year.
Breeding	Nest in tall tree (including dead and drowned trees) or on cliff. 12-15 m above ground.
Diet	Mainly fish, carrion, nestlings and eggs of water birds and quelea, some adult water birds, rarely dassies, monkeys, monitor lizards, frogs, terrapins, insects.
SA status	Uncommon resident.
Riverine link	Widespread. Inland on lakes and large rivers. Usually associated with large water bodies, either flowing or still. May remain on seasonally dry rivers once last pools dry up, subsisting on birds and scavenging carcasses. Absent from rivers that flow for only a few weeks a year. Nest in tall tree (including dead and drowned trees) or on cliff. 12-15m above ground.
14. Crake, rails and flufftails	
Black crake (*Amaurornis flavirostris*)	
Biotope (Geographical area)	Rank grass, sedges, reedbeds, bulrushes, papyrus, swampy thickets, bushes and other vegetation beside flowing, still or open fresh and estuarine waters. Occurs in tangled growth in which birds climb, roost and nest. In thin cover along very small

Habitat and status	*Bird species: Description*
	streams in arid regions.
Breeding	Nest well hidden and placed in vegetation just above water, sometimes on ground in grass tuft near water or floating among stiff grass stems.
Diet	Forage in open along muddy shorelines, on floating vegetation, in short grass and cultivation near water, on dry and burned ground. Insects, crustaceans, mollusks, worms, small fish, nestlings, heron's eggs, seeds, water plants.
SA status	Common resident.
Riverine link	Rank grass, sedges, reedbeds, bulrushes, papyrus, swampy thickets, bushes and other vegetation beside flowing, still or open fresh waters. Occurs in tangled growth in which birds climb, roost and nest. In thin cover along very small streams in arid regions. Nest well hidden and placed in vegetation just above water, sometimes on ground in grass tuft near water or floating among stiff grass stems. Forage in open along muddy shorelines, on floating vegetation, in short grass and cultivation near water, on dry and burned ground.
15. Coot, moorhens and gallinules	
African Purple Swamphen ***(Porphyrio [p.] madagascariensis)***	
Biotope (Geographical area)	Fresh to brackish, sheltered, still to slow-flowing rivers and still waters fringed or overgrown by reeds, rushes, bulrushes, sedges, etc. All marshes and swamps with permanent water, and ephemeral and seasonal flooded wetlands.
Breeding	Nest in dense vegetation over water on platform of beaten down vegetation.
Diet	Forages by clambering around swamp vegetation, pulling down stems of plants with bill. Roots, tubers, stems, flowers, insects, nestlings, eggs of birds, young ducklings, carrion.
SA status	Fairly common resident.
Riverine link	Slow-flowing rivers and still waters fringed or overgrown by reeds, rushes, bulrushes, sedges, etc. Nest in dense vegetation over water on platform of beaten down vegetation.
Common Moorhen (*Gallinula chloropus*)	
Biotope (Geographical area)	Wetlands with emergent fringing vegetation, including lakes, dams, ponds, pans, rivers, streams, canals, swamps and marshes. Flooded grassland. Temp ponds on floodplains. Sheltered sites with some open water, avoids very open situations.
Breeding	Nest usually well concealed in sedges, reeds or bulrushes, lower branches of tree, all above water level.
Diet	Water plants, seeds, berries, mollusks, worms, arachnids, insects, tadpoles, carrion.
SA status	Common resident.
Riverine link	Wetlands with emergent fringing vegetation, including rivers, streams and marshes. Flooded grassland. Sheltered sites with some open water, avoids very open situations. Nest usually well concealed in sedges, reeds or bulrushes, lower branches of tree, all above water level.
Redknobbed coot (*Fulica cristata*)	
Biotope (Geographical area)	Open freshwater of lakes, lagoons, ponds, pans and vleis, floodplains, reedy swamps. Occasionally on rivers and tidal lagoons. Favouring wetlands with emergent vegetation and pondweed. Spend much time swimming on open water.
Breeding	Nest on shallow (>1 m) to deep water, out in the open or among emergent vegetation, sometimes on water lily leaves or mat of reeds.
Diet	Mainly water plants and grass; also insects and seeds.
SA status	Abundant resident, highly nomadic.
Riverine link	Open freshwater of lakes, lagoons, ponds, pans and vleis, floodplains, reedy swamps. Occasionally on rivers and tidal lagoons. Favouring wetlands with

Habitat and status	*Bird species: Description*
	emergent vegetation and pondweed. Spend much time swimming on open water. Nest on shallow (>1 m) to deep water, out in the open or among emergent vegetation, sometimes on water lily leaves or mat of reeds.
17. Plovers	
Common Ringed Plover (*Charadrius hiaticula*)	
Biotope (Geographical area)	Estuaries and inland wetlands: Muddy, sandy and gritty substrate. Gently sloping shorelines and eutrophic water conditions – vegetation no influence. Inland on mud- and sandbanks along rivers and at wetlands, favouring wide, bare shorelines with little emergent vegetation. Roosts on bare, open shoreline.
Breeding	Extralimital.
Diet	Mollusks, crustaceans, insects.
SA status	Common non-breeding Palaearctic migrant
Riverine link	Inland wetlands: Muddy, sandy and gritty substrate. Gently sloping shorelines and eutrophic water conditions – vegetation no influence. Inland on mud- and sandbanks along rivers and at wetlands, favouring wide, bare shorelines with little emergent vegetation. Roosts on bare, open shoreline.
Kittlitz's plover (*Charadrius pecuarius*)	
Biotope (Geographical area)	Open dry mud and short grass, usually close to water. Natural pans – dry mud and short grass. Also estuaries, salt-marshes and flood plains.
Breeding	Breeds next to water bodies with wide, barren shorelines. Natural depression or old scrape.
Diet	Insects, worms, crustaceans, mollusks.
SA status	Common resident, nomadic.
Riverine link	Open dry mud and short grass, usually close to water. Flood plains. Breeds next to water bodies with wide, barren shorelines. Natural depression or old scrape.
Threebanded plover (*Charadrius tricollaris*)	
Biotope (Geographical area)	Any freshwater habitat with an open shoreline. Open shores of any freshwater habitat, favouring pools, streams and seeps. Also at tidal pools, estuaries and lagoons.
Breeding	Nest: Simple scrape in sand, dry mud or shingle, usually close to water.
Diet	Forage on open shore. Insects, worms, crustaceans, mollusks.
SA status	Common resident, nomadic.
Riverine link	Any freshwater habitat with an open shoreline. Open shores of any freshwater habitat, favouring pools, streams and seeps. Nest: Simple scrape in sand, dry mud or shingle, usually close to water. Forage on open shore.
White-fronted Plover (*Charadrius marginatus*)	
Biotope (Geographical area)	Sandy shores of marine and larger inland waters (lakes, pans, rivers). Mainly sandy shores and coastal dunes, estuaries along large rivers and lakes; also on rocky coasts and intertidal mudflats. Roosts mainly away from water on broad, open shorelines.
Breeding	Nest: Simple scrape in sand, gravel or shingle, usually near to high water mark.
Diet	Mainly insects; also crustaceans, arachnids, worms, mollusks.
SA status	Common resident; may have local movements.
Riverine link	Sandy shores of larger inland waters (lakes, pans, rivers). Mainly sandy shores along large rivers and lakes, mudflats. Roosts mainly away from water on broad, open shorelines. Nest: Simple scrape in sand, gravel or shingle, usually near to high water mark.

Blacksmith plover (*Vanellus armatus*)	
Biotope (Geographical area)	Moist short grasslands and mudflats on edges of pans, lakes, rivers, and estuaries.
Breeding	Nest: typically close to water or in seasonally inundated areas.
Diet	Insects, worms, mollusks.
SA status	Common resident, nomadic.
Riverine link	Moist short grasslands and mudflats on edges of pans, lakes, rivers, and estuaries. Nest: typically close to water or in seasonally inundated areas.
18. Sandpipers and other waders	
Common Greenshank (*Tringa nebularia*)	
Biotope (Geographical area)	Aquatic habitats: coastal sites and inland wetlands with shallow margins. Vleis, pans, and rivers.
Breeding	Extralimital.
Diet	Insects, worms, crustaceans, mollusks, tadpoles, fish fry.
SA status	Common non-breeding Palaearctic migrant
Riverine link	Aquatic habitats: coastal sites and inland wetlands with shallow margins. Vleis, pans, and rivers.
Wood sandpiper (*Tringa glareola*)	
Biotope (Geographical area)	Marshy shorelines: ephemeral pans, vleis, marshes, streams, floodplains and upper reaches of estuaries. Muddy, sandy or gravel borders of dams and ponds, inundated short grassland, sandy and muddy riverbeds, natural pans, mixed rocky and sandy beaches, salt marshes, estuaries, tidal and non-tidal lagoons and mangroves. Marsh-like conditions favoured over open shore-lines.
Breeding	Extralimital.
Diet	Insects, crustaceans, molluscs, worms, fish fry.
SA status	Common non-breeding Palaearctic migrant.
Riverine link	Marshy shorelines: vleis, streams, floodplains. Muddy, sandy or gravel borders of inundated short grassland, sandy and muddy riverbeds.
Common sandpiper (*Actitis hypoleucos*)	
Biotope (Geographical area)	Any aquatic habitat, but favours streams and rivers shores with sandy, gravelly, stony or rocky substrata, estuaries, tidal creeks in salt marsh, mangroves. Open water edges: streams, rivers, marshes, vleis, coastal lagoons and upper reaches of tidal estuaries. Prefer wet conditions adjacent to water rather than wading in water.
Breeding	Extralimital.
Diet	Insects, crustaceans, mollusks, leeches, fish fry.
SA status	Fairly common non-breeding Palearctic migrant.
Riverine link	Any aquatic habitat, but favours streams and rivers shores with sandy, gravelly, stony or rocky substrata. Open water edges: streams, rivers, marshes, vleis. Prefer wet conditions adjacent to water rather than wading in water.
19. Snipes and whimbrels	
Painted snipe (*Rostratula benghalensis*)	
Biotope (Geographical area)	Pans and marshy river flood plains. Exposed mud adjacent to cover. Marshes, muddy edges of swamps, lake edges, and riverbanks with thick vegetation cover. Favours waterside habitats with substantial cover and receding water levels with exposed mud among vegetation.
Breeding	Nest usually hidden in short sedges or grasses.

Diet	Worms, grasshoppers, crickets, crustaceans, snails and seeds.
SA status	Uncommon resident.
Riverine link	Marshy river flood plains. Exposed mud adjacent to cover. Marshes, muddy edges of swamps, lake edges, and riverbanks with thick vegetation cover. Favours waterside habitats with substantial cover and receding water levels with exposed mud among vegetation. Nest usually hidden in short sedges or grasses.
21. Stilts, godwits and curlews	
Black-winged stilt (*Himantopus himantopus*)	
Biotope (Geographical area)	Extensive open, shallow waters: coastal lagoons and saltpans. Inland and coastal wetlands, ranging from flooded fields, flood plains and papyrus swamps. Typically roosts communally in open areas.
Breeding	Nest: Usually on damp mud, mats of vegetation close to edge of receding water, often on island.
Diet	Insects, worms, crustaceans, mollusks, seeds.
SA status	Locally common resident, nomadic.
Riverine link	Extensive open, shallow waters. Inland wetlands, flood plains. Typically roosts communally in open areas. Nest: Usually on damp mud, mats of vegetation close to edge of receding water, often on island.
23. Terns, gulls and other seabirds	
Whitewinged tern (*Chlidonias leucopterus*)	
Biotope (Geographical area)	Inland and coastal wetlands: Shallow vleis formed by summer rains in grassland habitat. Including ephemeral bodies. Roost on low, bare, muddy or sandy islets.
Breeding	Extralimital
SA status	Common to abundant non-breeding Palaearctic migrant.
Riverine link	Inland wetlands: Shallow vleis formed by summer rains in grassland habitat. Including ephemeral bodies. Roost on low, bare, muddy or sandy islets.
35. Kingfishers	
Malachite kingfisher (*Alcedo cristata*)	
Biotope (Geographical area)	Strictly aquatic environments – availability of fish. River and stream banks – hung by trees, shrubs and recumbent riverine grasses and weedy vegetation. Prefer well-vegetated, slow-flowing rivers and streams, but not with canopy closed over river. Sheltered shores, coastal lagoons, tidal estuaries, mangrove swamps.
Breeding	Perennial or seasonal wetlands. Small water courses in breeding season when steep banks required for nest tunnels. Burrow: Earthen bank - along stream, earth mound, soil around upturned roots of fallen tree, wall of aardvark burrow. Low (<1 m high).
Diet	Fish, insects, tadpoles, frogs, crustaceans.
SA status	Common resident.
Riverine link	Strictly aquatic environments – availability of fish. River and stream banks – hung by trees, shrubs and recumbent riverine grasses and weedy vegetation. Prefer well-vegetated, slow-flowing rivers and streams, but not with canopy closed over river. Breeding: Perennial or seasonal wetlands. Small water courses in breeding season when steep banks required for nest tunnels. Burrow: Earthen bank - along stream. Low (<1 m high).
Giant kingfisher (*Ceryle maxima*)	
Biotope (Geographical area)	Any water body with sufficient food and overhanging branches to hunt from, - streams, rivers, estuaries, seashores. Perch under canopy in trees alongside streams or at edges of pools. Large rivers and small streams.
Breeding	Nests in hole made in high alluvial bank, usually one overhanging a flowing river.

	Seldom less than 2m in height, usually 3m, upper third of bank.
Diet	Fish, crabs, frogs.
SA status	Fairly common resident.
Riverine link	Large rivers and small streams with sufficient food and overhanging branches to hunt from. Perch under canopy in trees alongside streams or at edges of pools. Nests in hole made in high alluvial bank, usually one overhanging a flowing river. Seldom less than 2m in height, usually 3m, upper third of bank.
Pied kingfisher (*Ceryle rudis*)	
Biotope (Geographical area)	Aquatic environments – availability of fish. Any water body with small fish, including large rivers and perennial streams, estuaries, lakes, temporarily flooded areas, rocky coasts and intertidal zone of coast. Less common along well-wooded, fast flowing streams.
Breeding	Nest: Burrow in vertical alluvial sandbank being cut by flowing water, sometimes quite close to the water level. Usually positioned in the least accessible positions available: over water, in a high bank, and near the top of the bank.
Diet	Mainly fish, crustaceans, insects.
SA status	Common resident.
Riverine link	Aquatic environments – availability of fish. Any water body with small fish, including large rivers and perennial streams. Less common along well-wooded, fast flowing streams. Nest: Burrow in vertical alluvial sandbank being cut by flowing water, sometimes quite close to the water level. Usually positioned in the least accessible positions available: over water, in a high bank, and near the top of the bank.
54. White-eyes	
Orange river white-eye (*Zosterops pallidus*)	
55. Warblers, apalis and eremomelas	
African reed-warbler (*Acrocephalus baeticatus*)	
Biotope (Geographical area)	Usually in moist or wet areas, including edges of reeds, bulrushes, sedges, tall herbs and forbs, and tall grass and shrubs along river banks. Marshland: Outskirts of reed-beds where there is a mixture of grass, sedges, rushes and tall willow herbs.
Breeding	Nest bind to reeds, grass, sedges, well-hidden; 0.3-3.0m above dry or damp ground but usually over water.
Diet	Insects.
SA status	Common breeding intra-African migrant
Riverine link	Usually in moist or wet areas, including edges of reeds, bulrushes, sedges, tall herbs and forbs, and tall grass and shrubs along river banks. Marshland: Outskirts of reed-beds where there is a mixture of grass, sedges, rushes and tall willow herbs. Nest bind to reeds, grass, sedges, well-hidden; 0.3-3.0m above dry or damp ground but usually over water.
Lesser swamp-warbler (*Acrocephalus gracilirostris*)	
Biotope (Geographical area)	Marshland: Phragmites over water. Reeds and bulrushes in standing water in estuaries, lagoons, rivers, marshes.
Breeding	Nest on upright reed stems, sedge, bulrush, arum lily.
Diet	Insects, small frogs.
SA status	Locally common resident.
Riverine link	Marshland: Phragmites over water. Reeds and bulrushes in standing water in rivers, marshes. Nest on upright reed stems, sedge, bulrush, arum lily.

58. Wagtails	
African pied wagtail (*Motacilla aguimp*)	
Biotope (Geographical area)	Along margins, rocky patches and sandbanks of large rivers, pans and dams. Usually near water, preferring wide rivers and open water bodies with sandy banks or exposed rocks and boulders. In drier areas restricted to perennial rivers.
Breeding	Nest usually built close to water, on ground, in grass tussock, reeds or other vegetation, including flood debris and tree stump over water, in crevices or on rock ledge or cliff.
Diet	Insects
SA status	Common to scarce; mostly resident; non-breeding migrant to much of Transvaal in winter.
Riverine link	Along margins, rocky patches and sandbanks of large rivers. Usually near water, preferring wide rivers and open water bodies with sandy banks or exposed rocks and boulders. In drier areas restricted to perennial rivers. Nest usually built close to water, on ground, in grass tussock, reeds or other vegetation, including flood debris and tree stump over water, in crevices or on rock ledge or cliff.
Cape wagtail (*Motacilla capensis*)	
Biotope (Geographical area)	Almost anywhere where there is water with open ground nearby. Wide range of natural environments: require merest trickle of water; open streams in forest habitats, rivers and waterfalls.
Breeding	Nest concealed in vegetation on ground, often in recess in a steep bank or donga, or in bush or tree.
Diet	Wades in shallow water, picking prey in or over water, sometimes forages on floating vegetation. Mainly insects, sandhoppers and food scraps. Small fish and tadpoles.
SA status	Common resident.
Riverine link	Almost anywhere where there is water with open ground nearby. Wide range of natural environments: require merest trickle of water; open streams in forest habitats, rivers and waterfalls. Nest concealed in vegetation on ground, often in recess in a steep bank or donga, or in bush or tree. Wades in shallow water, picking prey in or over water, sometimes forages on floating vegetation.
68. Bishops	
Yellow-crowned bishop (*Euplectes afer*)	
Biotope (Geographical area)	Grassland birds: When breeding, closely associated with marshes or seasonally flooded areas.
Breeding	Nests in tall grass (temporarily flooded) standing in water. 0.15-0.4 m above water surface.
Diet	Seeds, insects; nestlings fed small caterpillars.
SA status	Locally common resident and nomad
Riverine link	Grassland birds: When breeding, closely associated with marshes or seasonally flooded areas. Nests in tall grass (temporarily flooded) standing in water. 0.15-0.4 m above water surface.
Southern red bishop (*Euplectes orix*)	
Biotope (Geographical area)	Primarily grassland birds: Nests in reedbeds. Rarely found far from water; strikingly absent from areas without permanent surface water. Found in areas cleared for cultivation. Typically where there is access to perennial water.
Breeding	Nests in reeds, sedges, or bulrushes standing in water, usually 1-2.5 m above water.
Diet	Seeds, grain; nestlings fed insects.

SA status	Very common resident and nomad. Artificial wetlands increased numbers. Common to abundant.
Riverine link	Primarily grassland birds: Nests in reedbeds. Rarely found far from water; strikingly absent from areas without permanent surface water. Typically where there is access to perennial water. Nests in reeds, sedges, or bulrushes standing in water, usually 1-2.5 m above water.

Habitat and status	***Mammal species: Description***
Family: Mustelidae	
Cape clawless otter (*Aonyx capensis*)	
Habitat	Predominantly aquatic; freshwater an essential requirement: Rivers, lakes, swamps and dams. Widespread. Tributaries of rivers into small streams - habitat with food. Litters born in holes in banks of rivers. Estuarine and sea water.
Status (SA)	TOPS NEMBA: Protected species. IUCN Least concern. Population trend: Stable.
Diet	Most important: Crabs and frogs; Lower in order: fish, insects, birds, reptiles, mammals, and mollusks.
Riverine relations	Predominantly aquatic; freshwater an essential requirement: River. Widespread. Tributaries of rivers into small streams - habitat with food. Litters born in holes in banks of rivers.
Family: Viverridae	
Water mongoose/Marsh mongoose (*Atilax paludinosus)*	
Habitat	Well-watered terrain: Rivers, streams, marshes, swamps, wet vleis, dams and tidal estuaries - adequate cover of reed beds or dense stands of semi-aquatic grasses. Coastally in mangrove swamps in brackish water.
Status (SA)	Least concern.
Diet	Order: Amphibia and eggs, Crustacea (crabs), rodents, insects, fish.
Riverine relations	Well-watered terrain: Rivers, streams, marshes, swamps, wet vleis - adequate cover of reed beds or dense stands of semi-aquatic grasses.

Appendix B Riverine fauna habitat plan views

The river plan views linked to habitats are provided below. This appendix also includes diagrammatic maps showing aerial view of the sites.

B.1 EFR Fish 1

Five hydraulic cross-sections were surveyed during the site visit. Four of these cross-sections were linked to habitat and are provided in Figure B1.

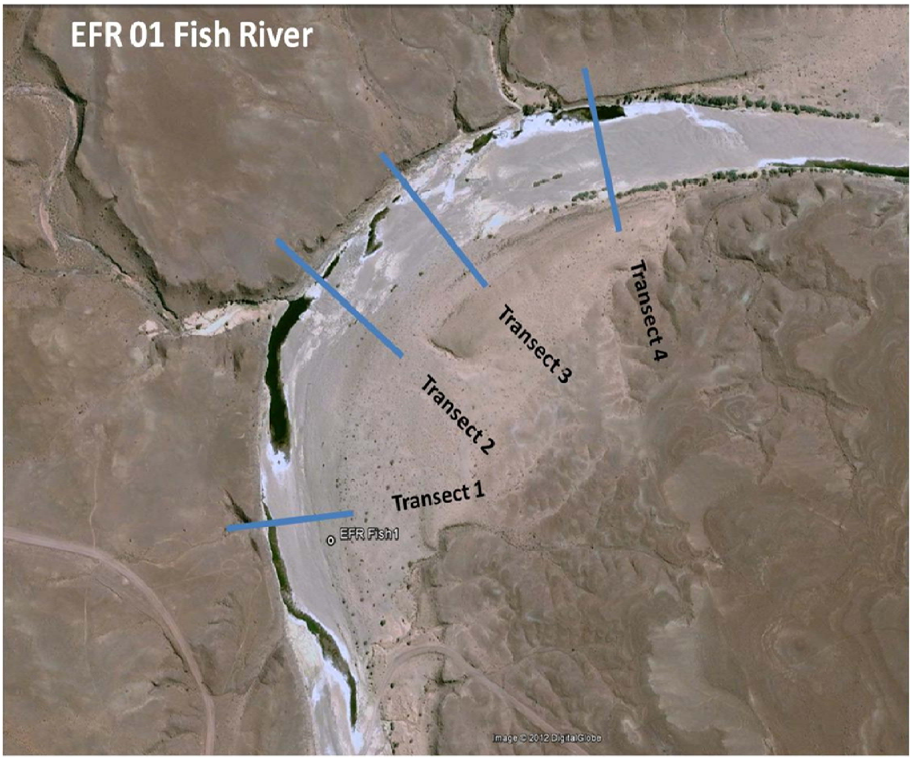

Figure B1. EFR Fish 1: Google Earth view of study area and transect positions

Figures B2and B3 illustrates the height of different habitats above or below the water level as experienced during the site visit. The purpose of the figures is to relate the impacts of the different release options (ROs) to the change in habitats and was used during the evaluation of the impact on riverine fauna (as presented in Technical Report 27). Brackets associated with different habitats and corresponding distances in cm or m indicates the height above the water level.

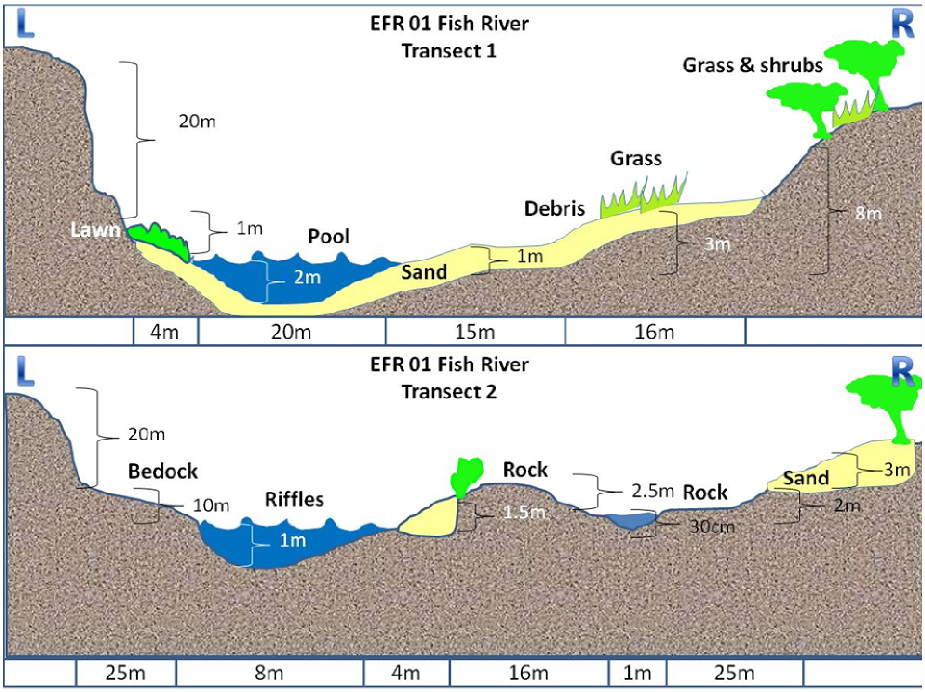

Figure B2. EFR Fish 1: Transect 1: Schematic view of riverine habitat types

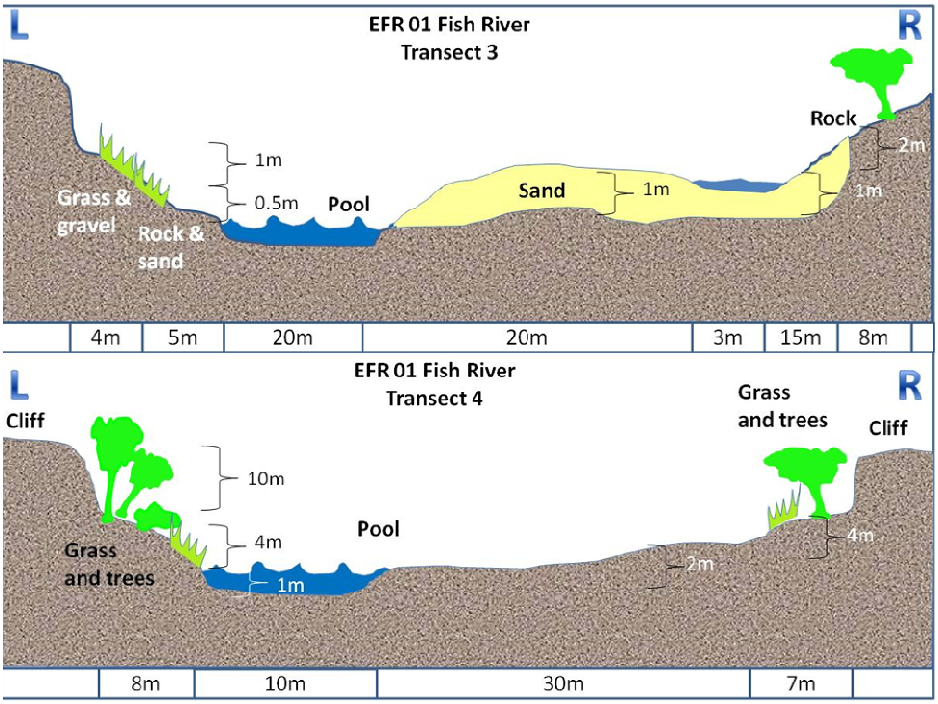

Figure B3. EFR Fish 1: Habitat diversity and associated height above/below water level

B.2 EFR Fish 2

Six hydraulic cross-sections were surveyed during the site visit. Four of these cross-sections were linked to habitat and are provided in Figure B4.

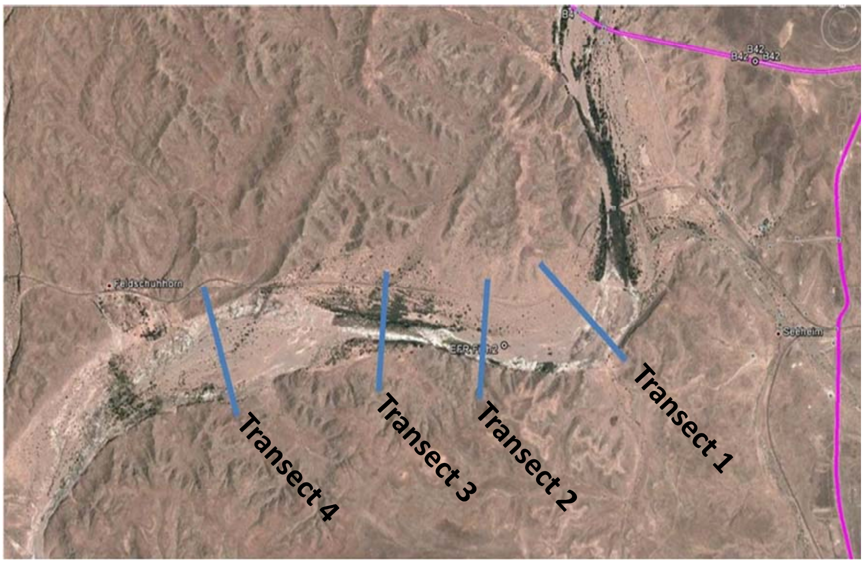

Figure B4. EFR Fish 2 - Google Earth view of study area and transect positions

The diagrammatic maps showing an aerial view of the site is provided in Figure B5 to Figure B10.

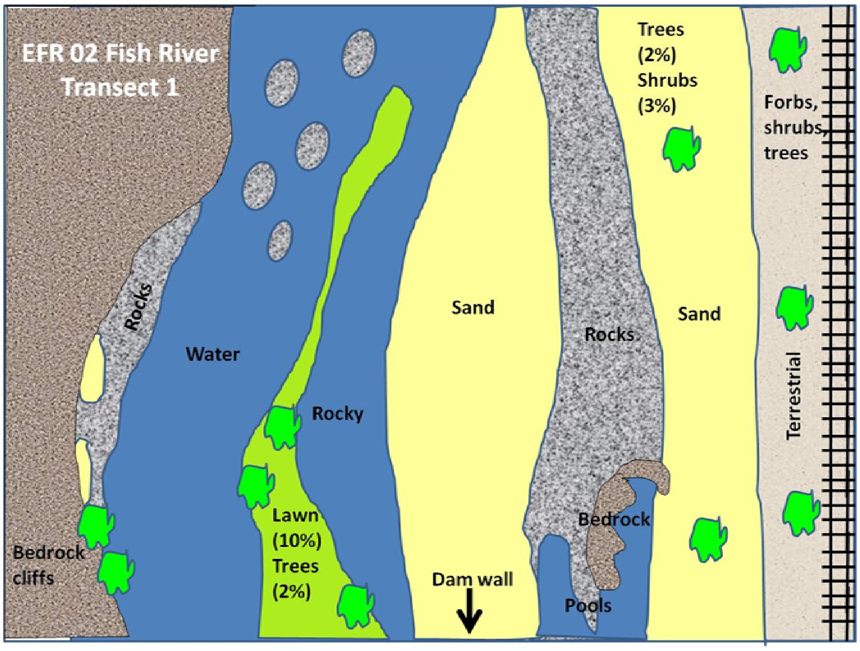

Figure B5. EFR Fish 2: Transect 1 - Schematic view of riverine habitat types

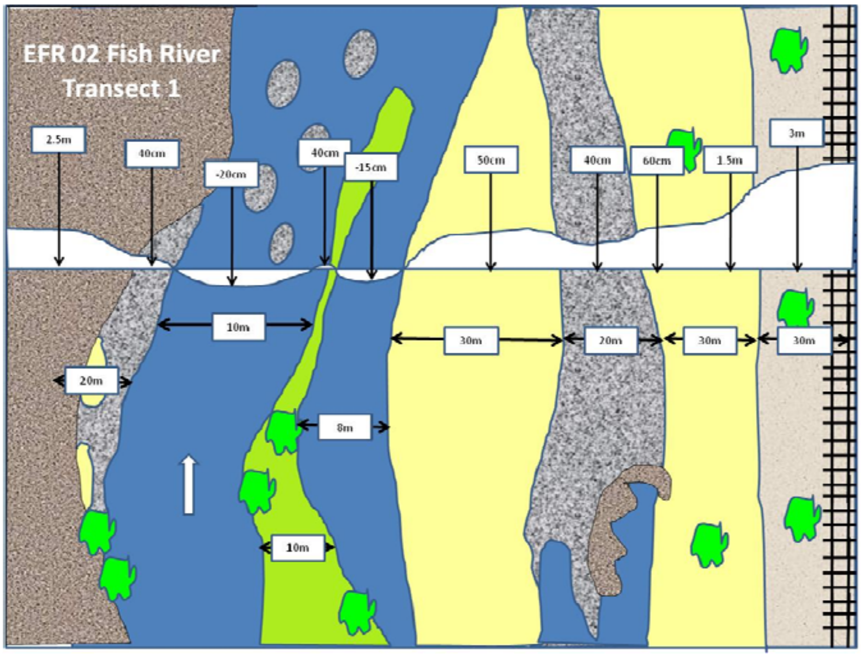

Figure B6. EFR Fish 2: Transect 1 - Habitat diversity and associated height above/below water level

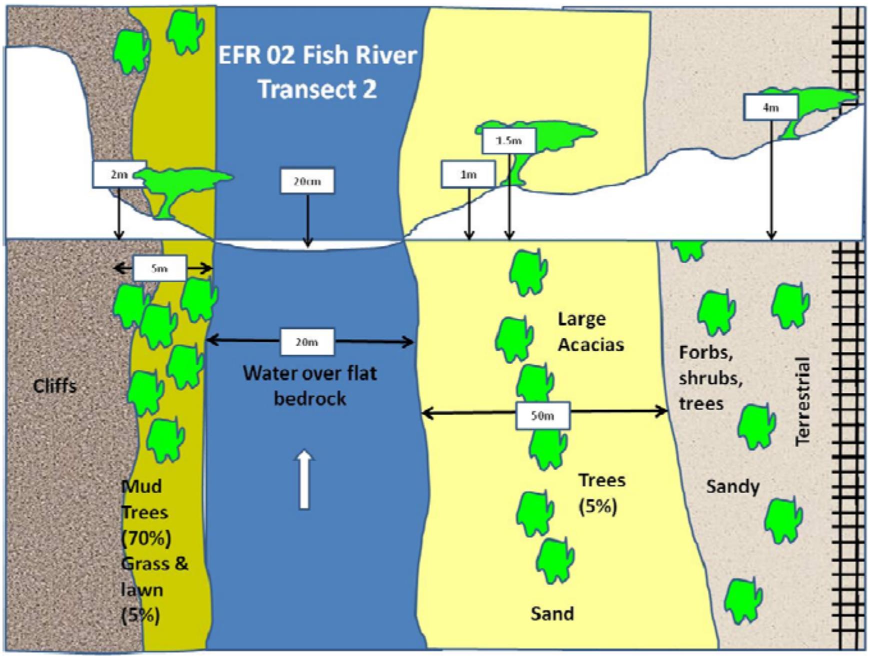

Figure B7. EFR Fish 2: Transect 2 - Habitat diversity and associated height above/below water level

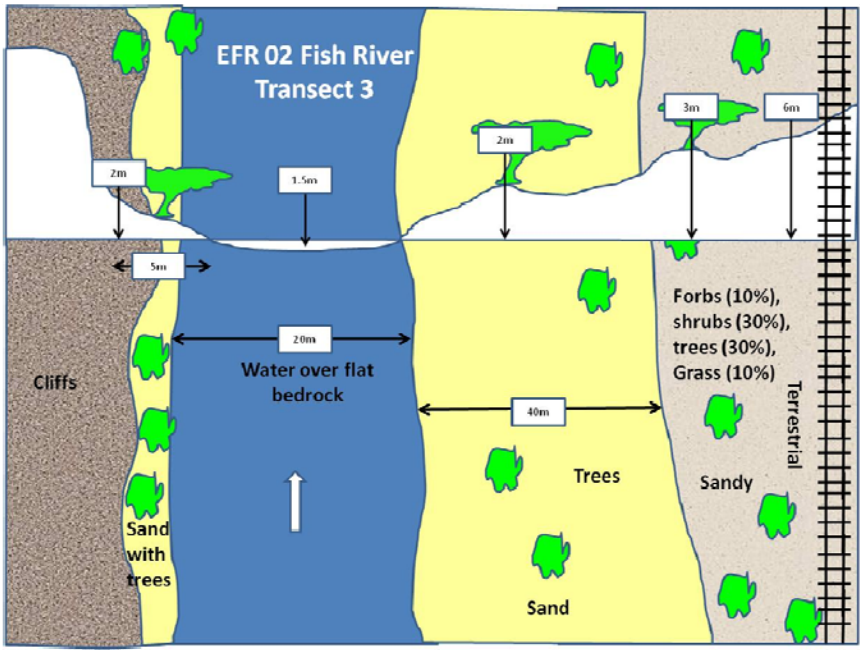

Figure B8. EFR Fish 2:Transect 3 - Habitat diversity and associated height above/below water level

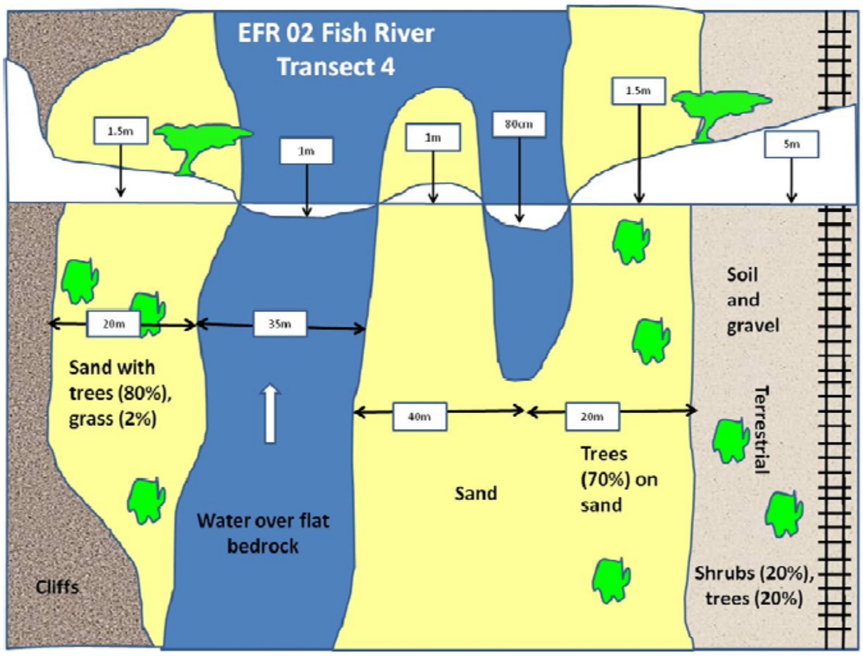

Figure B9. EFR Fish 2: Transect 4 - Habitat diversity and associated height above/below water level

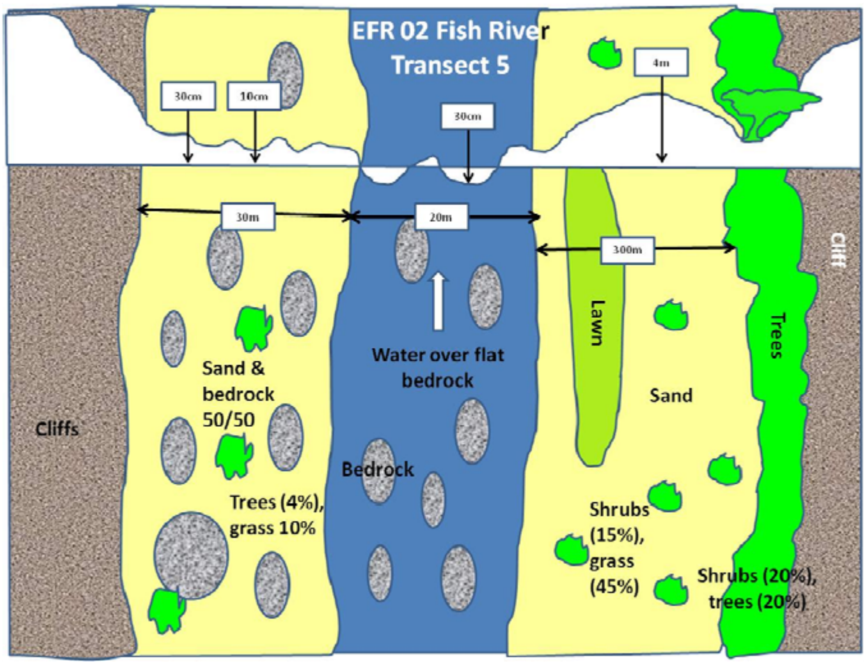

Figure B10. EFR Fish 2: Transect 5 - Habitat diversity and associated height above/below water level

Appendix C Issues regarding reference fish species and fish identification in the Fish River

Aspects of importance regarding the fish species of the Fish River (Namibia) is summarised in the section below. This information was utilised during the ecological flow requirement study.

C.1 Fish species

Labeobarbus Kimberleyensis **(BKIM and B. cf. KIM)**

- Listed by IUCN (2007) as Near Threatened (Impson and Swartz, 2007). NEMBA (2004): Vulnerable. Should the B. cf. KIM in the Fish River be a potentially new or sub-species, it will be of even higher (elevated) conservation status (due to it being isolated populations or a new endemic species). This however needs further investigation.
- Endemic to Orange-Vaal (including Fish River) System (South Africa-Namibia).
- Hay et al., (1999) indicates that B. cf. KIM is the only yellowfish in Hardap Dam (no indication that pure BAEN or BKIM occur in dam).
- Hay (1991) indicates that there was no significant difference between BKIM sampled at KUB (upstream of Hardap) and those in the lower reaches. He however indicated that B. cf. KIM at Sunnyside in the central reaches (close to EFR Fish 1) showed a significant difference from upstream sites, and is probably a mixture of pure and hybrid individuals (differs from both pure and hybrid individuals).
- Hay, 1991 states the high concentration of B. cf. KIM near Hardap Dam indicates its preference for lentic conditions. Although this species (and especially adults) have a preference for slow-deep habitats, they do require fast habitats for breeding purposes. The high abundance in the vicinity of Hardap may therefore be associated with the abundance of habitat available in the dam.
- Hay (19991) indicates that B cf. KIM it is not dependent upon an annual spawning migration for reproduction (author: 'This is not generally the case but may be true in the Fish River where they will spawn only when conditions area suitable, i.e. duration of flow is adequate, such as during wet years'). Hay (1991) also states that 'it does not seem to have a negative effect on the system as it does not find the isolated pools favourable for reproduction' (author: uncertain about this statement).
- Hay (1991): BKIM and BAEN in lower Fish River probably mainly pure populations.

Flow requirement considerations (in the ephemeral Fish River)

- Large semi-rheophilic fish species, generally very good indicator species for setting flows (in perennial rivers).
- Spawning may not be required every year.
- Spawning requirement in lower reach not crucial as they can (and most probably do) spawn in the Orange River and recolonise this reach from there.
- Presence of various juvenile individuals during June 2012 survey indicates that they probably do breed successfully in the lower Fish River.
- Flows in fish river should be adequate to maintain perennial pools (adequate depth and water quality) and during wet years adequate duration of flow (7 to 10 days) to allow successful spawning.
    - Need gravel beds and FS and FD for spawning – mid to late summer.
    - Eggs hatch (incubation period) within 2–3 days (no sudden pulse/releases that may wash eggs out).
    - Feed and free swimming 3–4 days later.
    - Total flow duration needed for spawning – 5–7 days.
- Frequency of flows for spawning conditions should be determined by natural wet cycle (hydrology) for this river (average age of approximately 12 years, sexual maturity probably at age of 1–2 years).
- Migratory requirement: Potamodromous: Flows should also be adequate to allow connectivity between pools (depth of 150 mm should be adequate for large BKIM). Conditions for migration/dispersal should be attained during floods. Spawning migrations occur in mid-late summer.

***Labeobarbus aeneus* (BAEN)**

- IUCN (2007) red list status: Least Concern.
- Endemic to Orange-Vaal (including Fish River) System (South Africa-Namibia).
- Hay et al., (1999) referred only to B. cf. KIM in Hardap Dam (no indication that pure BAEN or BKIM occur in dam).
- BAEN most abundant large Barbus species in the lower Fish River (Hay, 1991).
- Hay (1991): BKIM and BAEN in lower Fish River probably mainly pure populations.

Flow requirement considerations (in the ephemeral Fish River): (similar to BKIM)

- Large semi-rheophilic fish species, generally very good indicator species for setting flows (in perennial rivers).
- Spawning may not be required every year.

- Spawning requirement in lower reach not crucial as they can (and most probably do) spawn in the Orange River and recolonise this reach from there.
- Presence of various juvenile individuals during the June 2012 survey indicates that they probably do breed successfully in the lower Fish River.
- Flows in the Fish River should be adequate to maintain perennial pools (adequate depth and water quality - this species is expected to be more tolerant to water quality than BKIM) and during wet years adequate duration of flow (6 to 14 days) to allow successful spawning.
  - Need gravel beds and FS/FD for spawning – mid to late summer.
  - Eggs hatch within 2–8 days.
  - Feed and free swimming 4–6 days later.
  - Total flow duration needed for spawning, 6–14 days.
- Frequency of flows for spawning conditions should be determined by the natural wet cycle (hydrology) for this river (average age of approximately 12 years, sexual maturity probably at age of 1–2 years).
- Migratory requirement: Potamodromous: Flows should also be adequate to allow connectivity between pools (depth of 120 mm should be adequate for large BAEN) during wet years (conditions for migration/dispersal should be attained during floods).

Barbus hospes **(BHOS)**

- IUCN (2007) Red data listing as Least Concern (Impson and Swartz, 2007) (previously rated as rare, near threatened (low risk).
- Endemic to lower Orange and Lower Fish River (South Africa-Namibia) (downstream of Augrabies falls).
- Numerous in lower Fish River (from Kochas Drift).
- "Witputs waterfall" upstream barrier for this species.
- Hay et al (1997): Survival of BHOS in Fish River probably depends on a healthy population in Orange River. BHOS is exposed to severe environmental conditions and its habitat consists of isolated pools interconnected by periodic floods. Juveniles absent at all sites. Migration from Orange River may account for high abundance (Hay et al., 1997).
- Gonad development noted at 3.5 to 4 cm. Gonad development observed at temperatures as low as 13ºC (indicate that stimulation for gonad development may be due to factors other than temperature).
- As can be expected, mortality rate higher in Fish River than Orange River.
- Stomach contents (Fish River): Mainly algae and sand grains, indicating substrate feeder.
- Cambray (1984) indicates BHOS prefers riverine conditions, and benefited from river regulation (Lower Orange River) and spawns twice during a season.
- Anatomically BHOS is more suited to strong swimming than any other small Barbus species in Southern Africa.

- Hay et al (1997): Fact that Fish River only flows seasonally might influence breeding success.

Flow requirement considerations (in the ephemeral Fish River)

- Very limited information is available regarding the biology of BHOS.
- It can be expected that it has similar requirements to species such as BTRI, being a small semi-rheophilic fish species (requiring flow for some of its life stages, i.e. breeding, but can survive without flow in pools).
- Cambray (1984) indicates it spawns twice during a season (most probably an observation from the Orange River).
- As stated previously, it is uncertain whether this species actually breeds in the Fish River, and it is therefore uncertain whether spawning habitats should be catered for when considering ecological flow requirements.
- One can assume that it may spawn in the Fish River when conditions are suitable, but of more importance it would rather be to ensure adequate survival (refuge) habitats (pools) and connectivity with the Orange River (duration and volume).
- Migratory requirement: Uncertain, but probably potamodromous: Flows should also be adequate to allow connectivity between pools and with Orange River (depth of 50 mm should be adequate for large individuals) during wet years. These conditions for migration/dispersal would most probably be attained during floods.

***Barbus trimaculatus* (BTRI)**

- IUCN (2007) Red data listing as Least Concern.
- Similar to BHOS and MBRE, this species only occurs in the lower reach of the Fish River ("Witputs waterfall" upstream barrier for this species)
- Populations of BTRI in the Orange River have distinct body pigmentation, suggesting that the Orange River population is genetically distinct (DWAF, 1996b). This may therefore also be true for the Fish River population.
- Hay (1991) sampled only eight individuals at Kochas Drift and Ai-Ais. A low abundance was also observed during the June 2012 survey (two individuals). It also has a low abundance in lower Orange River.
- Hay (1991) attributes low abundance to its dependence on rapids for breeding. This is however difficult to believe if one considerers the relative high abundance of other species with a similar preference for flow (BAEN, BKIM, and possibly BHOS). BTRI is classified as moderately intolerant in terms of trophic specialization, and one can therefore also assume that their low abundance may be related to the trophic status of a reach (generally feeds on insects and other small organisms including zooplankton (daphnia) and algae).

Flow requirement considerations (in the ephemeral Fish River):

- As stated for BHOS (and BKIM and BAEN in lower Fish River), it is uncertain whether BTRI actually breeds/spawns in the Fish River, and it is therefore uncertain whether spawning habitats should be catered for when considering ecological flow requirements.
- Requires inundated marginal vegetation during summer to spawn.
- One can assume that it may spawn in the Fish River when conditions are suitable. It is important to ensure adequate survival (refuge) habitats (pools) and connectivity with the Orange River (duration and volume).
- Migratory requirement: Potamodromous: Flows should also be adequate to allow connectivity between pools and with Orange River (depth of 30 mm should be adequate for migrating large individuals) during wet years. These conditions for migration/dispersal would most probably be attained during floods.

***Barbus paludinosus* (BPAU)**

- IUCN (2007) Red data listing as Least Concern.
- Relatively common Barbus species in many of Southern African rivers.
- Present in Hardap Dam in upper Fish River (Hay et al., 1999).
- Recorded along entire stretch of Fish River (Hay et al. 1999). Present throughout the system (Hay, 1991).

Flow requirement considerations (in the ephemeral Fish River):

- BPAU is a small semi-rheophilic fish species, with a generally low value as indicator species for setting flows (in perennial rivers).
- Overall tolerant species (tolerance rating of 1.9), moderately tolerant to no flow and it only has a moderate to low preference for fast habitats. High requirement for slow shallow (SS) and SD with overhanging and aquatic vegetation.
  - Spawning: amongst inundated vegetation during summer (ensure adequate inundation of vegetation).
  - Nursery areas: shallow, slow flowing vegetated backwaters.
- Frequency of flows for spawning conditions should be determined by natural wet cycle (hydrology) for this river. Migratory requirement: Potamodromous: This species thrive in pools, and requirement for spawning migrations are expected to be low.

***Mesobola brevianalis* (MBRE)**

- IUCN (2007) Red data listing as Least Concern.
- Only present in lower Orange (below Augrabies) and lower Fish River. "Witputs waterfall" upstream is a barrier for this species.
- Abundant and seems to flourish in the Fish River (Hay, 1991).

- (Hay et al. 1999): 'Another Limpopo/Orange River linkage through the Molopo River is indicated by the presence of MBRE in the lower Orange River')
- Skelton *(*1993*)* states that this species 'prefer well-aerated flowing waters of perennial rivers'. This is not the general condition prevailing in the Fish River, but this species seems to still do very well in this system.

Flow requirement considerations (in the ephemeral Fish River)

- MBRE has a low requirement/preference for FS and FD, high preference for Slow Deep (SD) and Slow Shallow (SS) open water. Small schooling species in open water – usually in pools below riffle/run.
- Low flow dependence rating of 1.1 indicates low requirement for flow, together with preference for slow habitats may indicate limnophilic behaviour. High requirement for oxygen rich water however indicate their possible dependence on flow to maintain adequate physico-chemical conditions. May especially be important for early life stages (limited biological information available to make confident decision). Very limited information is available regarding the biology of this species.
- Breeds in early summer.
- Migratory requirement: Uncertain, but probably potamodromous: Flows should also adequate to allow connectivity between pools and with Orange River (depth of 15 mm should be adequate for large individuals) during wet years. These conditions for migration/dispersal would most probably be attained during floods.

***Labeo capensis* (LCAP)**

- IUCN (2007) Red data listing as Least Concern.
- Endemic to Orange-Vaal (including Fish River) System (South Africa-Namibia).
- Present in Hardap Dam in upper Fish River (Hay et al., 1999). Most abundant fish in Hardap.
- Most abundant large species in Fish River (Hay, 1991).
- Hay (1991): Inhabits wide range of habitats and does not have a specific spawning migration (?). He states this is obvious from the fact that it is abundant in Fish River. It does, however, need flow over shallow rocky rapids for spawning during the summer rain season (Skelton, 1993). Therefore its abundance in the Fish River as this is the main habitat type, and would be abundant during floods/high flows.

Flow requirement considerations (in the ephemeral Fish River)

- Large semi-rheophilic fish species, generally good indicator species for setting flows (in perennial rivers).
- Spawning requirement in lower reach is not crucial as they can (and most probably do) spawn in Orange River and re-colonise this reach. They will however utilise the opportunity when available.

- The presence of juvenile individuals during the June 2012 survey indicates that they probably do breed successfully in the lower Fish River when conditions are favourable.
- Flows in Fish River should be adequate to maintain perennial pools (adequate depth and water quality) and during wet years adequate duration of flow (approx. 10 days) to allow successful spawning.
  - Needs rocky rapids for spawning – summer.
  - Eggs hatch within 3–4 days.
  - Feed and free swimming 4–5 days later.
  - Total flow duration needed for spawning: 7–9 days.
  - Rapid growth.
- Frequency of flows for spawning conditions should be determined by natural wet cycle (hydrology) for this river (average age of approximately 8 years).
- Migratory requirement: Potamodromous: Flows should also be adequate to allow connectivity between pools (depth of 120 mm should be adequate for large LCAP) during wet years (conditions for migration/dispersal should be attained during floods).

***Labeo umbratus* (LUMB)**

- IUCN (2007) Red data listing as Least Concern.
- Endemic to Orange-Vaal (including Fish River) System (South Africa-Namibia).
- Skelton and Cambray (1981): Very scarce during 1980 survey in middle and lower Orange.
- Benade (1993): Traditionally widespread in the Orange River System above Augrabies, but it has become restricted to mainly upper Orange River dams. Main impacts on LUMB are probably flow regulation, and siltation of breeding habitats (egg smothering).
- Jubb (1967) indicates its distribution range in the Orange River as upstream of Augrabies Falls. Some records in the FROC database (Kleynhans et al. 2007) for this species below the Augrabies Falls (therefore, there may be a possibility of colonization from the Fish River). This once again raises the question whether it was introduced from Hardap Dam?
- Introduced OMOS may compete with LUMB in the lower Orange River for food (detritus/algae/soft plants) and therefore be a possible contributing factor to their scarcity/absence.
- Present in Hardap Dam in upper Fish River (Hay et al., 1999).
- Sampled by Hay (1991) in upper Fish River (Sunnyside to Kub). No specimens sampled in lower Fish River.
- LCAP x LUMB and LUMB are only present in the vicinity of Hardap Dam (Hay, 1991). This may be an indication that it probably does not breed in the Fish River, other authors state that it breeds mainly in tributaries.

Flow requirement considerations (in the ephemeral Fish River)

- Large semi-rheophilic fish species, generally poor indicator species for setting flows (in perennial rivers).
- Flows in Fish River should be adequate to maintain perennial pools (adequate depth and water quality).
- Breeding requirements:
    - Spawning: Prolonged spawning season and breeds prolifically in large pools and in impounded waters. Moggels (LUMB) migrate upstream and move out of the channel onto adjacent **flooded grassland** for spawning where the substrate is heavily vegetated with grass and small bushes. Where weirs hinder their upstream spawning migration, moggels are known to spawn over **gravelly and rocky substrates** in the channel. They **require greater local rainfall** to create favourable breeding conditions than does LCAP.
    - Eggs hatch within 2 days.
    - Feed and free swimming 2–4 days later.
    - Total flow duration needed for spawning: 4–6 days.
- Migratory requirement: Potamodromous: Flows should also be adequate to allow connectivity between pools (depth of 100 mm should be adequate for large LUMB) during wet years (conditions for migration/dispersal and breeding should be attained during floods).

LCAP x LUMB Hybrid

- Present at sites Tsess (just upstream of EFR Fish 1) to Kub (upstream of Hardap Dam).

***Clarias gariepinus* (CGAR)**

- IUCN (2007) Red data listing as Least Concern.
- Recorded along entire stretch of Fish River (Hay et al., 1999). More abundant in upper reaches (upstream of Hardap).
- Present in Hardap Dam (Hay et al., 1999).

Flow requirement considerations (in ephemeral Fish River)

- Adequate depth for migration (longitudinal continuity).
- Need vegetation – shallow grassy verges for spawning – summer.
- Eggs hatch within 1–2 days.
- Feed and free swimming 2–3 days later.
- Total flow duration needed for spawning: 3–5 days.
- Rapid growth.
- Migratory requirements: Potamodromous. Known to migrate up to 60 km upstream in Fish River catchment.

***Tilapia sparrmanii* (TSPA)**

- IUCN (2007) Red data listing as Least Concern.
- One record in middle-upper (pool below Hardap Dam) Fish River indicated by Hay et al. (1999). This is also the same and only site where TREN was recorded for the Fish River (Hay et al., 1999). Hay (1991) indicates that it possibly escaped from the Hardap Dam breeding facilities. There is a high probability that this species is naturally absent from the middle/upper Fish River. Hay (1991) indicates that it probably occurs in the lower Fish River, as it was sampled in 1971 at Ai-Ais.

Flow requirement considerations (in ephemeral Fish River)

- TSPA is a small limnophilic. Generally not a good indicator for setting flows.
- Maintenance of pools with overhanging vegetation should be adequate to maintain this species.
- Spawning: Males construct simple saucer-shaped nests in which eggs are guarded and tended by both parents.
- Larvae: Newly hatched larvae attach to substrates by head glands but wriggle constantly for aeration. After 7 days fry are free swimming, remain in shoal and guarded by parents.
- Undertake seasonal upstream migration and breeds before and during these migrations.

***Austroglanis sclateri* (ASCL): Excluded from Fish River**

- Listed in Namibia only in the Orange River (Hay et al., 1999).
- No known record for the Fish River (also not sampled during June 2012 survey).
- Not expected in Fish River (reference or present) and therefore excluded from fish species list.

***Pseudocrenilabrus philander* (PPHI): Excluded from Fish River**

- No records exist for this species in the Fish River according to Hay et al., 1999).
- This species was also not sampled at any of the Fish River sites during the recent (June 2012) survey, although its preferred habitats were abundant. It, therefore, seems that this species did not occur naturally (under reference conditions) or under present conditions in the system. Their current presence in the Lower Orange River (sampled in June 2012) indicates that they may or will possibly occupy the lower reaches of the Fish River (similar to TSPA distribution).
- This species was not considered for the current study as it is not expected in the middle and upper reaches of the Fish River.

***Oreochromis mossambicus* (OMOS) (alien)**

- IUCN (2007) classification of near threatened as a result of hybridization (by esp. O. *niloticus*). This conservation status is of no relevance in the Fish River since it is an alien translocated species to the system.

- OMOS is an alien species introduced into the Fish River (not indigenous to Namibia). First introduced from the Cape in 1947 (Hey et al., 1999).
- Recorded throughout Fish River (Hay et al., 1999).
- Present in Hardap Dam in upper Fish River (Hay et al., 1999).
- Poses a serious threat of genetic pollution in rivers where other Oreochromis spp. occur naturally (none in Fish/Orange River, therefore, reducing the level of threat by this alien species).
- There is some indication that it was put into Hardap Dam by anglers (1964-1969).
- A 1971 annual report of the Nature Conservation department (Bloemhof, 1972) indicates that this species was introduced into farm dams (by nature conservation).
- Since this species is alien, its requirements should not be considered in the EFR. Where applicable, requirements or constraints could be set to limit/inhibit this species.

***Cyprinus carpio* (CCAR) (alien)**

- Present in all ephemeral rivers of Namibia. Introduced by settlers. Although invasion is serious, it is not as critical as OMOS, as it does not appear to overpopulate the system (Hay et al., 1999).
- Hay (1991) only collected ten specimens (from Gibeon to Ai-Ais). He suggests that breeding of carp does not occur in the Fish River.
- Sediment/bottom feeder (Causes increased turbidity, affecting esp. predatory spp. such as large BKIM in the Fish River. It is also has a negative impact on natural habitat through its feeding behaviour).
- Since this species. is alien, its requirements should not be considered in the EFR. Where applicable, requirements/constraints could be set to limit/inhibit this species.

***Micropterus salmoides* (MSAL) (alien)**

- Only present in central Namibia (Hay et al. 1999).
- One record indicated off channel in upper Fish River catchment (probably in dam).
- This species is not currently considered to occur in the Fish River or if present, at very low FROC and abundance.
- There is some indication that anglers transferred some bass from S. von Bach Dam (Okahandja) into Hardap Dam.
- A 1971 annual report of the Nature Conservation department (Bloemhof, 1972) indicates that this species was introduced into farm dams (by nature conservation).
- It is critical that this species should not be allowed to be introduced/translocated into the Fish River. This species can be expected to cause radical changes in the indigenous fish populations. It will compete for the status of top predator with BKIM, and it may result in a decrease in abundance and even loss of smaller species and juveniles of larger species.

***Tilapia rendalli* (TREN) (introduced/alien)**

- One record of this species in the Fish River below Hardap Dam. Escaped from Nature Conservation breeding facility.
- Warm water species, and not expected to survive and still occur in the Fish River.
- Alien species (not native to Fish River), not expected under reference conditions and uncertain if still occur under present conditions. Excluded from assessment.

C.2 Migration barriers

- **Significant and permanent** manmade migration barriers include Hardap Dam in the main Fish River and Naute dam in the Löwen River (tributary). These barriers act as permanent barriers and will not be drowned out during floods.
- Some **smaller weirs** (such as at EFR Fish 2) along the river and its tributaries may also act as migration barriers during low flows, but may be drowned out during floods, and therefore is not permanent barriers to fish movement (These weirs, however also create deeper pools, simulating and acting as surrogates for natural perennial pools that may have been lost due to alterations (flow, sediment regime, etc.).
- **Natural barriers**: Various natural barriers in the form of waterfalls and/or cascades are present in the Fish River. Two waterfalls occur between Tses and Khomas (approx. 10 m high) and a smaller (approx. 5 m high) near Witputs (Hay, 19991, Nepid, 2010). There seems to be a definite/distinct cut-off in the fish river for the distribution of some species (BHOS, BKIM?). Dr. Hay indicated that this may be the result of natural migration barrier/s (cascades/waterfalls) in the Witputs area. It is therefore evident that perennial pools must occur (and be maintained) in the middle and upper Fish River, since fish cannot recolonise the river from the Orange River. The exact location of these migration barriers is not known and could not be located.)

The "Witputs waterfall" seems to be the upper limit for distribution of BHOS, BTRI and MBRE. This distribution is also proof that the fish do not re-colonise the Fish River from the Orange River. The fish do, however, require suitable refuge and breeding habitats along the Fish River to allow for survival. The species present upstream of the Witputs waterfall are also those that are tolerant enough to withstand the poor conditions that may prevail in the pools for long periods (high salinity, low oxygen). It is estimated that this barrier is downstream of the Löwen River confluence, and since there is limited data for the Löwen River (Naute dam) the "barrier indicator species" (BHOS, BTRI and MBRE) are not considered for the EFR.

Appendix D Fish information used during the ecological classification process

D.1 Summary of available data

- Hay (1991): Recorded 15 fish species in the Fish River (including two hybrids confined to the area near Hardap Dam). A waterfall near Witputs prevented the dispersal of some small species upstream. Three exotic species have been recorded in the Fish River (OMOS, CCAR and TREN). BHOS, a red data species, is abundant in the system.
- Hay et al. (1999): Distribution of fish in ephemeral rivers in Namibia is sporadic and depends on very good rains. The species composition of these rivers is limited to BPAU, CGAR, OMOS, and CCAR. When these rivers recede to pool habitats, the conditions for survival of fish deteriorate and it is only the most tolerant species which are able to survive.
- Hybridization among the two Labeo, and among the two Labeobarbus species in the Fish River has been recorded (Van Vuuren, Van Der Bank, Hay etc.).
- Nepid (2010): Indicates the presence of a potentially undescribed Labeo species in the Löwen River (Fish River Tributary) (DNA analyses not available yet to confirm this).
- DNA barcoding results of fish samples collected during the current study (2012-06) are also not available at the time of reporting.
- Fish species kept at Hardap Dam breeding facility: OMOS, TREN, OMAC, OAND, TSPA, CGAR, CCAR, MSAL, ONIL?, HVIT, and PRET (and Freshwater Crayfish - *Cherax quadricarinatus*).
- Fish survey (1971) in Fish River (Hardap Dam, Seeheim, Sunnyside and Ai-Ais): BKIM, BPAU, CGAR, CCAR, MBRE, LCAP, LUMB, OMOS, and TSPA. The absence (no mention) of BAEN indicates that there could already at that stage have been confusion regarding BAEN and BKIM as a result of hybridization. This may be an indication that the hybridization between these species may not be the result of manmade barriers (Hardap Dam) but rather natural conditions (ephemeral system, isolated pools create natural barriers for long periods, almost like having hundreds of dams in a system). Hybridization may therefore be a strongly/unique natural phenomenon in the Fish River The same 1971 year report indicates the presence of BKIM, OMOS, LCAP, LUMB, CGAR and CCAR in Hardap Dam. Again no mention is made of BAEN. Bloemhof (1974) however indicates aspects of *B. holubi* (BAEN). Production of CCAR and MSAL stopped in 1985.
- Could it be possible that there was naturally a unique yellowfish species in the Fish River above the Witputs Waterfall, and through human activities the two yellowfishes (BAEN and BKIM) was introduced which led to hybridisation?

- Setting EFRs: The **lower Fish River** (below water fall) contains the highest fish species richness, as well as three unique species (BHOS, BTRI and MBRE) for the Fish River system. The fish in this reach are, however, less dependent on the flows and conditions in the Fish River than are the fish in the other two upstream reaches, since they can recolonise the lower Fish River form the Orange River. This reach/these species, should however still be considered during the EFR process, albeit at lower importance levels.

The following species have been kept or bred at Hardap Dam hatchery:

- Tilapia/*Oreochromis niloticus* – Aquaculture species (1997–2000).
- Fresh water crayfish (*Cherax quadricarinatus*) from Australia for aquaculture (up to 1996).
- *H. vittatus* - Tigerfish – for Aquarium and possible breeding programme – (up to 2000) – not expected to survive due to low water temperatures.
- Guppies –from Singapore – (1996) for mosquito control as requested from government – fish however destroyed due to it being an alien species.
- *Tilapia rendalii*, *Oreochromis macrochir* and *Oreochromis andersonii* – brought from the Okavango River and Lake Liambezi (Caprivi) during the eighties for aquaculture – not expected to have survived due to low temperatures.

Personal communication with Dr. C. Hay (2012):

- 'It is difficult to establish whether the yellowfish breed in the Fish River or not, possibly IF THE RIVER FLOWS FOR LONG ENOUGH. BKIM will not easily breed'. Based on the results of the June 2012 survey it was confirmed that yellowfish DO breed in the Fish River (juveniles at sites EFR Fish 1 and EFR Fish 2). This was also the case for BKIM or B. cf. KIM. It is, therefore, evident that the yellowfish will breed in the fish river WHEN CONDITIONS ARE FAVOURABLE. This may not be an annual occurrence (such as in a perennial/seasonal system), explaining the relative low abundance of yellowfish (esp. adults) at the sites during the 2012 survey.
- There seems to be a definite/distinct cut-off in the fish river for the distribution of some species (BHOS, BKIM?). Dr. Hey indicates that this may be the result of natural migration barrier/s (cascades/waterfalls). It is therefore evident that perennial pools must occur (and be maintained) in the middle and upper Fish River, since fish cannot recolonise the river from the Orange River. The exact location of these migration barriers is not known and could not be located.
- 'Yellowfish (BAEN and BKIM) occurred naturally in the Fish River. Hardap Dam played a role in the hybridization of these two species (and also LCAP and LUMB).'
- 'Potential good indicators of the status of pools: BPAU and LCAP (and BHOS in lower Fish River).'
- 'Oxygen levels play an important role in pools (especially where abundant alga), and general water quality'.

Hybridization (Van Vuren *et al*, 1989):

- Known hybridization occurs in the Fish River between the two Labeobarbus species (BKIM x BAEN) and the two Labeo species (LCAP x LUMB) (Hay, 1991; Van Vuren et al., 1989).
- Indicated that morphometric and meristical data alone are insufficient to distinguish between closely related species and their hybrids.
- Results show that hybridization between fish species has occurred in Hardap Dam because of the disruption of biological cycles in fish populations and the construction of obstructions in rivers.
- Barbus population in Hardap dam consist clearly of a hybrid population.
- Labeo hybrid population also identified in Hardap Dam.
- Hybridization not considered significant to be taken into account regarding EFR assessment. Hybridization in Fish River is primarily the result of human influences, and hence a negative impact on the fish assemblages (compared to naturally isolated populations). (However, there is various natural barriers?). The flow requirements of the hybrids were therefore not considered as it can be assumed that their requirements will be close to if not completely similar to the pure species.

D.2 Conclusion

- According to South African National Biodiversity Institute (SAIAB) (following taxonomic lab analysis) no hybrid fish were sampled in the Fish River during the June 2012 survey.
- One scenario may be that there was fish (yellowfish) throughout the fish river that occurred naturally, but then the Hardap Dam was built and yellowfish and *Labeos* from elsewhere were stocked. It may then be possible that these fishes differed from the natural stock in the river, and that the two populations interbred/hybridised resulting in the current confusion of hybrids and pure specimens. DNA/genetic analysis could shed more light on this.
- The fish population should, however, be treated as natural, as the fish seems to be adapted to the conditions of the Fish River. It could be argued that for the fish to be present and adapted to the conditions of the Fish River, they were there from the start - i.e. before the dams.
- It would, therefore, be important to maintain the current habitat for fish with the emphasis on the minimum depth for pools and the maintenance of cover habitats such as rock ledges and submerged rock slabs and tables for the yellowfish. Marginal veg. maintenance (i.e. *Gomphostigma* sp., *Phragmites* spp.) is of importance for the fish especially the smaller species (BPAU), as the roots seem to provide preferred cover. It is also important to maintain spawning habitat during spawning season (gravel beds and cobbles such as at Site 1 downstream).

D.3 Survey results

Species present in the Fish River at the time of sampling are provided in Table D1 and shaded grey. The fish species differ in their preference for different velocity-depth categories and cover features These preferences are shaded in grey in Table D2. They furthermore have different tolerance levels to changes in their environment (Table D3). These aspects play an important determining role in the fish assemblages expected under reference condition and present under current conditions at a site or river reach. This information was therefore used explicitly in determining reference conditions as well as in the interpretation of the present ecological state.

Table D1 Fish species sampled during the field survey (June 2012) at selected sites in the Fish River

Species	***EFR Fish 1***	***EFR Fish 2***	***EFR Fish Ai-Ais***
ASCL			
BAEN			
BHOS			
BKIM			
BPAU			
BTRI			
CGAR			
LCAP			
LUMB			
MBRE			
OMOS*			
PPHI			
TSPA			

* Alien species

Table D2 Habitat preference of expected indigenous fish species in terms of velocity-depth categories and cover features (from Kleynhans, 2003)

Species	***SD***[1]	***SS***[2]	***FD***[3]	***FS***[4]	***Overhang veg***	***Bank undercut***	***Substrate***	***Aquatic macrophytes***	***Water column***
ASCL	3.4	2.3	2.3	3.8	0.3	3.5	4.4	0.1	0.9
BAEN	3.5	2.5	3.5	4	0.7	1.5	4	2	4
BHOS	?	?	?	?	?	?	?	?	?
BKIM	3.7	2	4.3	3.8	0	0	1.8	0	3.3
BPAU	3.9	3.9	2.2	2.6	4.2	2.4	1.9	3.6	3.5
BTRI	3.9	3.2	2.3	2.7	3.9	2.6	2.3	2.8	2.8
CCAR	4.7	3.2	2.1	1.5	2.7	3	3	2.6	3
CGAR	4.3	3.4	1.2	0.8	2.8	2.9	2.8	3	2.6

Species	SD[1]	SS[2]	FD[3]	FS[4]	Overhang veg	Bank undercut	Substrate	Aquatic macrophytes	Water column
LCAP	4.2	3	3.3	2.5	0.5	2	4.2	1.5	3.2
LUMB	4.5	2.7	1	0.9	0.6	0.1	4.2	0.8	2.5
MBRE	4.3	4.2	0.2	0.5	1.8	0.5	0.7	1	5
MSAL	4.5	3	0.8	0.8	3.1	3	3.1	3.2	1.7
OMOS	4.6	3.8	1.4	0.8	3	1.9	2.1	2.8	3.9
TSPA	3	4.3	0.9	1.5	4.5	1.9	2.5	3.6	1.1

1: <0.3 m/s; >0.5 m   2: <0.3 m/s; <0.5 m
3: >0.3 m/s; >0.3 m   4: >0.3 m/s; <0.3 m

Habitat scores are outlined below:

0 = no preference, irrelevant

>0 - 0.9 = very low preference - coincidental?

>1 - 1.9 = low preference

>2 - 2.9 = moderate preference

>3 - 3.9 = high preference

>4 - 5 = very high preference

Table D3 Relative intolerance ratings of expected fish species in terms of various aspects (Kleynhans, 2003)

Species	Trophic specialisation	Habitat specialisation	Flow requirement	Requirement: Unmodified wq	Average overall intolerance rating
ASCL	2.9	2.3	3.2	2.6	2.7
BAEN	2.5	1.8	3.3	2.5	2.5
BHOS					
BKIM	3.8	3.4	3.8	3.6	3.6
BPAU	1.6	1.4	2.3	1.8	1.8
BTRI	3.1	1.4	2.7	1.8	2.2
CCAR	1.2	1.4	2.1	1.1	1.4
CGAR	1	1.2	1.7	1	1.2
LCAP	3.4	3.1	3.5	2.8	3.2
LUMB	2.8	2	2.7	1.6	2.3
MBRE	3.1	2.2	1.1	2.8	2.3
MSAL	3.2	2	1.1	2.3	2.2
OMOS	1.2	1.9	0.9	1.3	1.3
TSPA	1.6	1.4	0.9	1.4	1.3

0 - 1.9 = Tolerant   >2 - 2.9 = Moderately tolerant
>3 - 3.9 = Moderately intolerant   >4 - 5.0 = Intolerant
? – Uncertain/Not available