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Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

RESERVE DETERMINATION STUDIES FOR SELECTED SURFACE WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE USUTU/MHLATUZE WATER MANAGEMENT AREA
WP 10544

LAKE SIBAYA INTERMEDIATE EWR
VOLUME 4 - ECOSPECS AND MONITORING PROGRAMME FINAL
JANUARY 2016

Report No. RDM/WMA6/CON/COMP/1913

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DEPARTMENT OF WATER AND SANITATION

CHIEF DIRECTORATE: WATER ECOSYSTEMS
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- Jane Turpie
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Fish

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Birds

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Cate Brown and Jessica Hughes reviewed the document.

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ABBREVIATIONS AND ACRONYMS

ADU	Avian Demography Unit
AEC	Alternative Ecological Category
BHN	Basic Human Needs
DFS	Desired Future State
CWAC	Coordinated Wetland Counts
DIN	Dissolved inorganic nitrogen
DIP	Dissolved inorganic phosphate
DO	Dissolved oxygen
DRIFT	Downstream Response to Imposed Flow Transformation
DSS	Decision Support System
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
EMC	Ecological Management Class
EWR	Environmental Water Requirements
GPS	Geographic Positioning System
IFR	Instream Flow Requirement
LWR	Lake Water Requirement Approach
NWRCS	National Water Resources Classification Strategy
PES	Present Ecological Status
REC	Recommended Ecological Condition
VEGRAI	Riparian Vegetation Assessment Index
WMA	Water Management Area

GLOSSARY OF TERMS

- **Ecological Categories.** A distinction is made between Management Classes, which form part of the National Classification System, and Ecological Categories, which forms part of the Ecological Water Requirement assessment.
- **Ecological Category** (EC) replaces former terms used, namely: Ecological Reserve Category (ERC), Desired Future State (DFS) and Ecological Management Class (EMC).
- **Ecological Water Requirements** (EWR) should be used instead of the term Instream Flow Requirements (IFR) for various reasons, including international acceptance of the former term.
- **Ecosystem Integrity**: refers to the integrated composition of physicochemical, habitat and biotic characteristics on a temporal and spatial scale that are comparable to the characteristics of natural ecosystems of the region.
- **Preliminary Reserve** refers to Reserve signed off by the Minister or her representative in the absence of the Classification Process having been undertaken in the basin.
- **Recommended Ecological Condition** (REC) The target maintenance Ecological Condition for a water resource based solely on ecological criteria.
- **Reserve** refers to the EWR for maintaining a particular ecological condition where operational limitations and stakeholder consultation are taken into account. The Reserve includes both ecological and Basic Human Needs (BHN) requirements.

1 INTRODUCTION

1.1 Background to the study

The Chief Directorate: Resource Directed Measures (RDM); Department of Water and Sanitation (DWS), issued an open tender invitation for the "*Appointment of a Professional Service Provider to undertake Reserve Determinations for selected Surface water, Groundwater, Estuaries and Wetlands in the Usuthu to Mhlatuze Basins*". The focus on this area was a result of the high conservation status and importance of various water resources in the basin and the significant development pressures affecting the availability of water in the area.

Reserve determinations are required to assist the DWS in making informed decisions with respect to the magnitude of the impacts of the proposed developments on the water resources in the Water management Area (WMA), and to provide the input data for Water Resource Classification of the area, and eventual gazetting of the Reserve (DWAF1999a).

In July 2013, DWS appointed Tlou Consulting to undertake the project.

1.1.1 Study objectives

The objectives of the overall study are to:

- determine the Ecological Reserve (DWAF 1999a) at various levels of detail, for the Nyoni, Matigulu, Mlalazi, Mhlatuze, Mfolozi, Nyalazi, Hluhluwe, Mzinene, Mkuze, Assegaai and Pongola Rivers;
- determine the Ecological Reserve, at an Intermediate level, for the Pongola Floodplain;
- determine the Ecological Reserve, at an Intermediate level, for the St Lucia/Mfolozi, Estuary System;
- determine the Ecological Reserve, at a Rapid level, for the Mlalazi Estuary;
- determine the Ecological Reserve, at a Rapid level, for the Amatikulu Estuary;
- determine the Ecological Reserve, at an Intermediate level, for Lake Sibaya;
- determine the Ecological Reserve, at a Rapid level for Kosi Lake and Estuary;
- classify the causal links between water supply and condition of key wetlands;
- incorporate existing EWR assessments on the Mhlatuze (river and estuary) and Nhlabane (lake and estuary) into the study outputs;
- determine the groundwater contribution to the Ecological Reserve, with particular reference to the wetlands;
- determine the Basic Human Needs Reserve for the Usuthu/Mhlatuze WMA;
- outline the socio-economic water use in the Usuthu/Mhlatuze WMA;
- build the capacity of team members and stakeholders with respect to EWR determinations and the ecological Reserve.

The objective of the Lake Sibaya Intermediate EWR assessment was to describe the present condition of the lake and then, through scenarios, to predict how this could change with changes in water level.

1.2 This report

This report is Volume 4 of four volumes of the Lake Sibaya Intermediate determination:

Volume 1: EcoClassification Report
Volume 2: EWR Assessment Report
Volume 3: Specialists reports
Volume 4: EcoSpecs and monitoring programme.

This report Volume 4: EcoSpecs and monitoring programme provides:

- an overview of the study area (Section 1.3);
- an overview of the approach adopted for the EWR assessment (Section 2);
- a summary of the EcoClassification results (Section 3);
- a description of the indicators used in the assessment (Section 4); and
- a description of the EcoSpecs and monitoring recommendations per discipline (Section 5).

1.3 The study area

Lake Sibaya is located in the northern part of the Mkuze region of the Usuthu Mhlatuze catchment near the coast Figure 1.1.

For the purposes of this study Lake Sibaya was subdivided into five EWR zones, the: Main Basin, Northern Arm, Western Arm, Southwestern Basin and Southern Basin (Figure 1.2) and zone codes for each are provided in Table 1.1.

The morphology of Lake Sibaya is a result of sedimentary processes, driven by fluctuating water levels and wind driven currents that determine the processes of infilling and shoreline progradation. Importantly, the lake's morphology is driven by lake water level, with the highest levels of erosion, and hence sediment deposition in the lake, occurring at high water levels (Miller 1998).

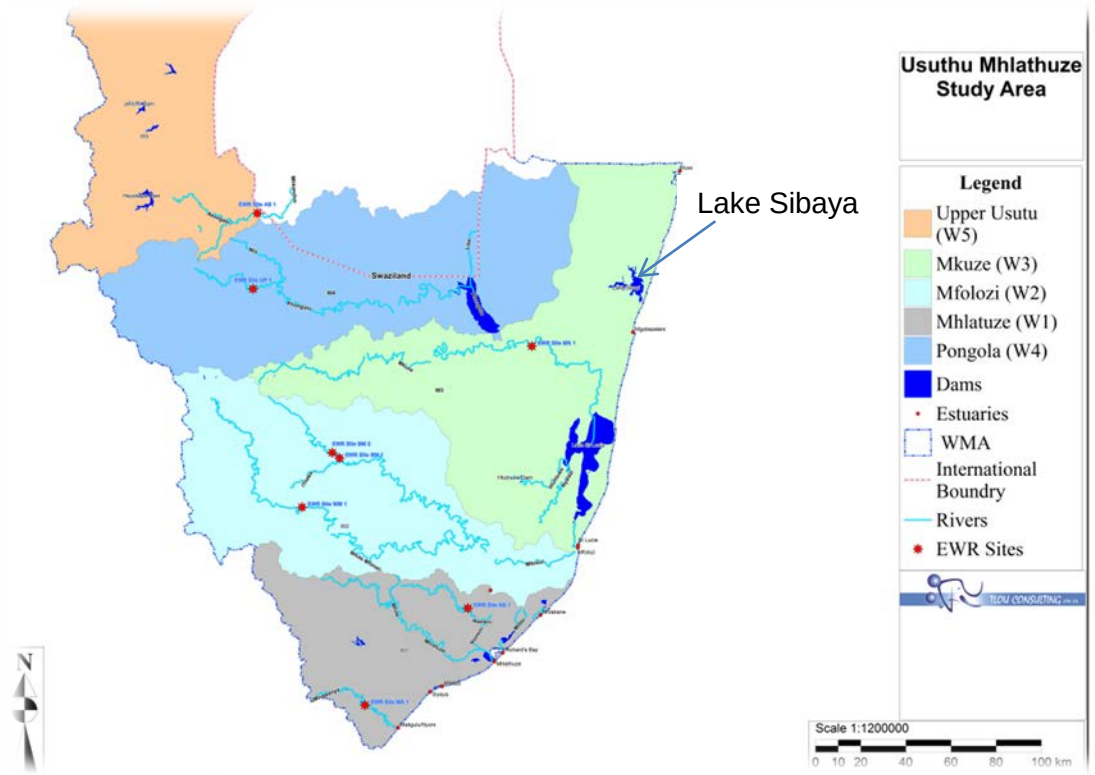

Figure 1.1 Location of Lake Sibaya in the Usuthu-Mhlatuze study area, showing the EWR river sites

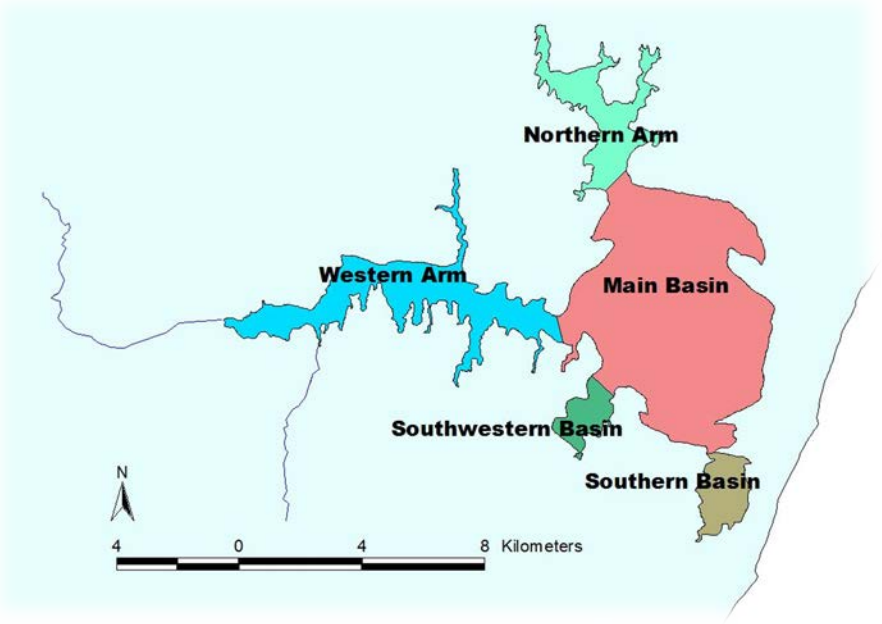

Figure 1.2 The five EWR zones of the lake

Table 1.1 Zones codes for the five EWR zones

EWR Zone	Code
Main Basin	MB
Northern Arm	NA
Western Arm	WA
Southwestern Basin	SWB
Southern Basin	SB

1.4 Specialist Team

The names and affiliations of the members of the study team for the Lake Sibaya assessment are provided in Table 1.2.

Table 1.2 Members of the study team for Lake Sibaya

Name	Affiliation	Role
Adhishri Singh	Tlou Consulting	Project Manager
Karl Reinecke	Southern Waters	EWR process co-ordinator
Alison Joubert	Southern Waters	DRIFT DSS manager
Drew Birkhead	Streamflow Solutions	Hydraulics
Susan Taljaard	CSIR	Water quality
James MacKenzie	BioRiver Solutions	Vegetation
Ricky Taylor	University of KZN	Herpetofauna, semi-aquatic mammals, molluscs and crustacean
Steven Weerts	CSIR	Ichthyofauna
Jane Turpie	Anchor Environmental	Avifauna
Toriso Tlou	Tlou consulting	Social
Jessica Hughes	Southern Waters	Report writing
Cate Brown	Southern Waters	Internal review

2 APPROACH

2.1 Introduction

As per the Inception Report, the EWR assessment for Lake Sibaya was done at an Intermediate level.

The approach used is in line with that for determining the Reserve for lakes and pans provided by Harding (1999), called the Lake Water-Level Requirement Approach (LWR; Section 2.1.1), and that was used for the determination of the Reserve requirements for Lake Nhlabane.

2.1.1 The Lake Water-Level Requirement Approach (Harding 1999)

The LWR involves the following steps applied independently for each lake (or resource unit within a lake):

- Identify the reference conditions of the resource unit;
- Discuss the present operation of the lakes for the provision of water;[1]
- Assess the present status for each of the ecological determinants of the resource unit;
- Assess the habitat integrity for the water body and the littoral / riparian zone;
- Determine the ecological importance of the resource unit;
- Determine the social importance of the resource unit;
- Assess an achievable Ecological Management Class (EMC) for the water body and the littoral / riparian zone;
- Consider the future management classes either side of the EMC and list the flow related and non-flow related activities which would be required to meet these classes;
- Prioritise and list the objectives required to attain the EMC. Recommend the water levels required to achieve the EMC and motivate these levels based on ecological grounds backed up by hydrological records where available;
- Specify the degree of confidence in the recommendations and identify further work required to increase the confidence.

The LWR steps are a combination of those followed for EcoClassification and those to evaluate the ecological and social consequences of lake-water level scenarios of change.

The steps of the EcoClassification process, listed below and provided in Volume 1 (Section 1.2), are summarised in Section 3:

- Data availability.
- Ecological Importance and Sensitivity (EIS).
- Reference conditions.

[1] A description of domestic water use is provided in the social specialist report, Volume 3: Section 9

- Baseline ecological condition, including:
    - individual component EcoClassification;
    - cause and sources;
    - trends; and
    - EcoStatus.
- Recommende['d Ecological category (REC) for each specialist component and EcoStatus.
- Alternative Ecological categories (AEC) for each specialist component and EcoStatus.
- Confidence in the results.

The LWR does not, however, stipulate the methodologies to be used in evaluating scenarios of lake-water level changes. Therefore, this study elected to use the DRIFT approach (as per the Inception Report, Brown *et al*. 2013) and the results are reported on in Volume 2: EWR assessment report.

3 ECOCLASSIFICATION, ECOLOGICAL SENSITIVITY AND IMPORTANCE, AND THE RECOMMENDED AND ALTERNATIVE ECOLOGICAL CATEGORIES

This section summarises the outcome of the discipline-specific EcoClassification (Present Ecological Status (PES)) and Ecological Importance and Sensitivity assessments (EIS), which are provided in Volume 1: EcoClassification report.

3.1 Present Ecological Status and Ecological Importance and Sensitivity

The PES and EIS of each of the EWR zones are provided in Table 3.1. Most zones of the lake were evaluated as Category B/C.

Table 3.1 PES of each of the EWR zones

Zone	Code	PES	EIS
Main Basin	MB	B/C	High
Northern Arm	NA	B/C	High
Western Arm	WA	B/C	High
Southwestern Basin	SWB	B/C	High
Southern Basin	SB	C	High
Whole lake	WL	B/C	High

Trends for each discipline at each EWR zone are indicated in Table 3.2.

Table 3.2 Trends in PES for each EWR zone

Code	WQ	Vegetation	Molluscs/ Crustaceans	Fish	Herpetofauna/ Mammals	Birds[2]
MB	Absent	Alien species stable, indigenous species negative	Negative/ absent	Negative	Negative	Negative for decreasers, positive for increasers
NA	Negative					
WA						
SWB						
SB						

MB=Main Basin; NA = Northern Arm; WA = Western Arm; SWB = Southwestern Basin; SB = Southern Basin

[2] Birds were assessed at the level of the Whole Lake and the same trends were extrapolated to the EWR zones.

The decline in condition from natural was attributed to a number of reasons relating to a combination of changes in water level, water quality, the presence of alien species and vegetation cover. Specifically, these included

- contamination from DDT in muddy extremities of the lake;
- nutrient enrichment in shallow waters;
- altered plant species composition in the aquatic zone and shoreline vegetation;
- reduced non-woody cover on the shore;
- invasion of marginal vegetation by an alien mollusc *Tarebia* that displaces other indigenous molluscs, notably *Melanoides s*p.;
- altered crustacean habitat due to the presence of an invasive aquatic weed *Myriophyllum;*
- lake water level reductions reducing the availability of shallow water habitat preferred by fish for feeding and breeding; and
- reduced numbers of crocodiles and hippos from poaching and harvesting of crocodile eggs.

3.2 Recommended and alternative ecological categories

The recommended and alternative ecological categories for each of the Sibaya EWR zones are provided in Table 3.3. These are based solely on ecological considerations and are reported upon in Volume 2: EWR Assessment Report.

In accordance with the requirements of the National Water Resource Classification System (NWRCS), EWRs are normally determined for (at minimum) the REC and two AECs, one class higher and one class lower.

Table 3.3 The recommended and alternative ecological categories (EC) for each of the EWR zones

Zone	Code	PES	REC	AEC1	AEC2
Main Basin	MB	B/C	B	B/C	B/C
Northern Arm	NA	B/C	C	C	B/C
Western Arm	WA	B/C	B/C	C	B/C
Southwestern Basin	SWB	B/C	C	C	B/C
Southern Basin	SB	C	C	C	C
Whole lake	WL	B/C	B/C	C	B/C

4 DRIFT INDICATORS AND ASSESSMENT FRAMEWORK

For the Lake Sibaya EWR assessment, DRIFT made use of a series of hydraulic, ecosystem and social indicators to capture the response of the lake ecosystem to changes in lake level, and the effects of those responses on the people who use the lake. These are detailed in the Specialist Reports (Volume 3: Specialist Reports). This section lists the indicators used.

4.1 Hydraulic and other external indicators

The 23 hydraulic indicators calculated for use in the DRIFT DSS are provided in Table 4.1 along with one other external indicator for accessibility.

Table 4.1 Hydraulic and other external indicators calculated for the Baseline and scenarios

Indicator	Units
Mean annual water level	metres
Volume	Mm^3
Area	km^2
Perimeter	km
Area exposed below 20.39 (beach)	km^2
Area 0 to 7 m deep	metres
Area between 0.65 below and 0.3 above	km^2
Area of beach between 0.6 and 3.8 above	km^2
Area of beach between 4.8 and 8.8 above	km^2
Vertical Distance from water level to fixed (masl) tree-line	Metres above sea level
Area deeper than 7 m	km^2
Area 1 to 1.8 m deep	km^2
Area 2 to 5 m deep	km^2
Area 1.5 to 2 m deep	km^2
Area 1 to 1.5 m deep	km^2
Area 0.5 to 1 m deep	km^2
Area 0 to 0.5 m deep	km^2
Area 0 to 0.3 m deep	km^2
Horizontal Distance to tree line	metres
Max Depth	metres
Volume up to 2 m	Mm^3
Volume deeper than 2 m	Mm^3
Rate of change in water level (annual)	metres per annum
Accessibility/Use	Index 1-5.

4.2 Ecosystem and social indicators

The ecosystem indicators used in this assessment are listed in Table 4.2.

Table 4.2 Ecosystem indicators used in the DRIFT DSS. (Note: I = increaser, D = decreaser)

Discipline	Indicators	Disciplines	Indicators
Water quality	Conductivity	Herpetofauna and semi-aquatic mammals	Frogs
	Dissolved oxygen		Hippos
	Vol where DIN c. 0.23mg/l		Crocodiles
	Vol where DIN c. 0.07mg/l		Crocs juvenile
	Vol where DIP c. 0.02mg/l	Birds	Little Grebe
	Vol where DIP c. 0.04mg/l		Cormorants
Vegetation	Free floating vegetation		Darters
	Submerged, rooted vegetation		Wading birds (I)
	Emergent macrophytes		Wading birds (D)
	Non-woody 'beach' macrophytes		Waterfowl (I)
	Woody 'lake dependent' vegetation		Waterfowl (D)
	Swamp forest		Waders (I)
	Wetlands, Pans connection		Waders (D)
Macro-invertebrates	*Bulinus globosus* (hosts bilharzia)		Gulls & terns (I)
	Tarebia		Freshwater terns (D)
	Melanoides		Kingfishers & birds of prey
	Pulmonates		
	Caridina (shrimp)		
	Potamonautes (crab)		
	Hymenosoma (crab)		
Fish	Mozambique tilapia (*Oreochromis mossambicus*)		
	Sharptooth catfish (*Clarias gariepinus*)		
	Climbing Perch (*Ctenopoma multispine*)		
	Top minnow and Barb (Cypriniodontidae and Cyprinid)		
	Pelagic fish		
	Other cichlids		
	Gobies		
	Number of species		
	Fishery biomass		

5 ECOSPECS AND MONITORING

5.1 Introduction

EcoSpecs and monitoring recommendations are provided for:

- Water quality (Section 5.2);
- Vegetation (Section 5.3);
- Macrocrustacea and molluscs (Section 5.4);
- Herpetofauna and semi-aquatic mammals (Section 5.5);
- Ichthyofauna (Section 5.6); and
- Avifauna (Section 5.7).

5.2 Water quality EcoSpecs

The Ecological Specifications (EcoSpecs) for water quality in Lake Sibaya are presented in Table 5.1.

Table 5.1 EcoSpecs for water quality in Lake Sibaya (DWAF 1996a and b)

Parameter	Ecological specifications	Threshold of Potential Concern
EC	EC < 95mS/m	EC > 100 mS/m (for 2 consecutive samples)
Average DO	6.5 > DO mg/l (at depths < 25 masl) 4.5 > DO mg/l (at depths > 25 masl)	DO < 6 mg/l (at depths < 25 masl) DO < 4 mg/l (at depths > 25 masl)
Average turbidity	Average turbidity < 4.5 NTU	Average turbidity >5 NTU in any survey
Average DIN Average DIP	DIN < 0.095 mg/l DIP < 0.018 mg/l	DIN> 0.1 mg/l (for 2 consecutive samples) DIP >0.02 mg/l (for 2 consecutive samples)
Sediment organic content	No data to set this with: can be specified following analysis of the first few consecutive samples collected.	No data to set this with: can be specified following analysis of the first few consecutive samples collected.
Toxic substances DDT in sediment	DDT < 3.8 µg/g dry weight	DDT > 3.9 µg/g dry weight

5.2.1 Water quality monitoring programme

Proposed sampling stations are presented in Figure 5.1 and the programme in Table 5.2.

Figure 5.1 Proposed water quality sampling stations and paths between points as potential tracts for benthic transects (Section 5.4.1)

Table 5.2 Monitoring programme for water quality in Lake Sibaya

Parameter to be measured	Frequency	Location
Routine water quality parameters as per the DWS national water quality monitoring programmes. Collect and store samples as prescribed by DWS.	Monthly.	Southern arm (W7R1) and proposed new station in Main Basin (DWS monitoring programme)
EC, Temperature, DO and Turbidity At each station measure in situ profiles using a boat (i.e. lowering a cable with multi-probes into the water column and recording at least at 0.5 m intervals). Instrument: Calibrated in situ multiprobe system (e.g. manufactured by YSI or HydroLab).	Every 3 years.	Proposed monitoring stations (see Figure 5.1).
DIN (NO3-N, NO2-N and NH3-N) and DIP (PO4-P) Collect and store surface, mid-water and bottom water samples as per specifications provided by an accredited laboratory at each station from a boat. (Note: these nutrient samples must be collected at the same time as the in situ measurements above for interpretation purposes). Submit to accredited laboratory for analysis.	Every 3 years.	Proposed monitoring stations (see Figure 5.1).

Sediment organic content, particle size distribution and DDT concentration. Collect and store sediment grab samples as per specifications provided by an accredited laboratory at each station from a boat. Submit to accredited laboratory for analysis.	Once-off (baseline) and then very 3-6 years.	Proposed monitoring stations (see Figure 5.1).

5.3 Vegetation EcoSpecs

Ecological specifications (EcoSpecs, Table 5.3) were compiled for all lake-dependent vegetation zones (see vegetation indicators Table 4.2) based on field observations at demarcated EWR sites.

Table 5.3 EcoSpecs for vegetation at Lake Sibaya

Parameter	Ecological specifications	Threshold of Potential Concern
Ecostatus score (%)	MB > 66% NA > 81% WA > 66 SWB > 81 SB > 46	MB < 62% NA < 77% WA < 62 SWB < 77 SB < 42
Alien plant areal cover (%)	Floating macrophytes (*Azolla filiculoides, Pistia stratioides)*	
	None present at MB, NA, WA, SWB and SB	Cover > 5% at MB, NA, WA, SWB and SB
	Submerged macrophytes (*Myriophyllum spicatum)*	
	MB < 20% NA< 40% WA < 50% SWB < 40% SB < 5%	MB > 25% NA > 50% WA > 55% SWB > 50% SB > 10%
	Emergent macrophytes	
	None present at MB NA < 5% WA < 5% SWB <5% None present at SB	MB > 5% NA > 10% WA > 10% SWB >10% SB > 5%
	Shore “beach” macrophytes (*Casuarina equisetefolia)*	
	Cover < 5% at MB, NA, WA, SWB and SB	Cover > 10% at MB, NA, WA, SWB and SB
	Woody lake-dependent vegetation	
	Cover < 5% at MB, NA, WA, SWB and SB	Cover > 10% at MB, NA, WA, SWB and SB
Woody areal cover (%)	Emergent macrophytes	
	No woody species present at MB, NA, WA, SWB and SB	Woody species are present at MB, NA, WA, SWB and SB
	Shore “beach”macrophytes (*Acacia karoo)*	
	Cover < 5% at MB, NA, WA, SWB and SB	Cover > 10% at MB, NA, WA, SWB and SB
	Woody lake-dependent vegetation	

Parameter	Ecological specifications	Threshold of Potential Concern
	MB > 70% NA > 60% WA >50% SWB > 60% SB > 70%	MB < 60% NA < 50% WA <40% SWB < 50% SB < 60%
Non-woody areal cover (%)	Submerged macrophytes	
	MB > 30% NA > 70% WA >75% SWB > 80% SB > 30%	MB < 30% NA < 70% WA <75% SWB < 80% SB < 30%
	Emergent macrophytes	
	MB > 40% NA > 90% WA >90% SWB > 90% SB > 15%	MB < 30% NA < 80% WA < 80% SWB < 80% SB < 10%
	Shore “beach” macrophytes	
	MB > 50% NA > 85% WA >75% SWB > 70% SB > 45%	MB < 50% NA < 85% WA <75% SWB < 70% SB < 45%
Species composition (#)	Submerged macrophytes	
	MB ≥ 4 species NA ≥ 6 species WA ≥ 6 species SWB ≥ 5 species SB ≥ 5 species	MB ≤ 3 species NA ≤ 5 species WA ≤ 5 species SWB ≤ 4 species SB ≤ 4 species
	Emergent macrophytes	
	MB ≥ 4 species NA ≥ 12 species WA ≥ 12 species SWB ≥ 11 species SB ≥ 10 species	MB ≤ 3 species NA ≤ 10 species WA ≤ 10 species SWB ≤ 9 species SB ≤ 8 species
	Shore “beach” macrophytes	
	MB ≥ 5 species NA ≥ 6 species WA ≥ 6 species SWB ≥ 6 species SB ≥ 5 species	MB ≤ 4 species NA ≤ 5 species WA ≤ 5 species SWB ≤ 5 species SB ≤ 4 species

5.3.1 Vegetation monitoring programme

VEGRAI is a simplistic tool to determine the ecological status of a riparian area (Kleynhans *et al.*, 2007). The VEGRAI model itself is not useful for monitoring changes in vegetation characteristics but the data collected during a VEGRAI assessment are and this is what is proposed below, along with additional activities that include the capture and analysis of fixed-point photographs (Table 5.3). VEGRAI may be undertaken as a simplistic level 3, which focusses upon impacts to community structure and riparian ecological integrity, or as a more detailed level 4 assessment, which includes identification of species in lateral zones and quantification of shrub and tree recruitment.

Table 5.4. Proposed monitoring protocol for lake-dependent vegetation

Monitoring Activity	Frequency and Timing	Output	EcoSpecs monitored
Undertake VEGRAI Level 4 assessment.	Every 3 years in summer.	Ecostatus score and ecological category.	Ecological condition.
Capture fixed-point photographs.	Every 3 years in summer.	Photographic data, qualitative and quantitative assessment of vegetation structure and abundance.	Increases or decreases in woody and non-woody vegetation.
Analyse data from VEGRAI Level 4 assessment.	Every 3 years in summer.	Detailed zone descriptions, species lists and areal cover data.	Invasion by alien plant species, indigenous woody and non-woody cover and species composition.

Capture fixed-point photographs

Fixed-point photographs should be taken at various locations and recorded with GPS co-ordinates or maps that will facilitate accurate repetition with each field visit. These should be used to assess change in vegetation structure and abundance. Fixed point photographs should be analysed qualitatively and quantitatively. Qualitative statements consist of the viewer's assessment of woody and non-woody vegetation cover and abundance in terms of whether there is more or less vegetation at each site (considering all available photographs at each site), and whether existing vegetation had increased in size or extent (see Table 5.5). A simple "Yes" or "No" with a note completes the assessment. Subsequent photographs should be repeated as accurately as possible in order to improve the relevance of comparisons (see Elzinga et al. (1998) for a detailed methodology of the effective use of fixed point photography in vegetation monitoring).

Table 5.5 Format of qualitative assessment of fixed point photographs for woody and non-woody vegetation

Zone	Fixed photo reference	Vegetation component to assess	General increase	General decrease	No discernible difference	Mixed response within the photograph
		Are there more or fewer woody individuals? Count the numbers of woody individuals, irrespective of size or structure or species.				
		Are they bigger or smaller than previous year? Compare the size of individual trees that occur in before/after photos.				
		Is there more or less non-woody vegetation?				

For the quantitative assessment, photographs from different time frames should be aligned as closely as possible and overlaid with equal-sized grids[3]. Focus should be given to key fixed landmarks (such as banks, hills, fixed structures) to align ensure optimal overlap of photographs. Each grid is then assessed and counted to determine if any part of the grid contains woody vegetation (any component of the plant, e.g. Figure 5.2), or non-woody vegetation. The number of grids containing woody (or non-woody) vegetation is then expressed as a proportion of the total number of grids and averaged from all photographs taken per zone. The example in Figure 5.2 shows how woody vegetation (Willow and Poplar in this case) at the site increased by 46% from 2005 to 2013. Photographs from 2005 (A and B) were compared to comparable photographs from 2013 (C and D). Each was overlaid with the same grid, and only grids containing woody vegetation were counted (coloured orange in B and D for illustration).

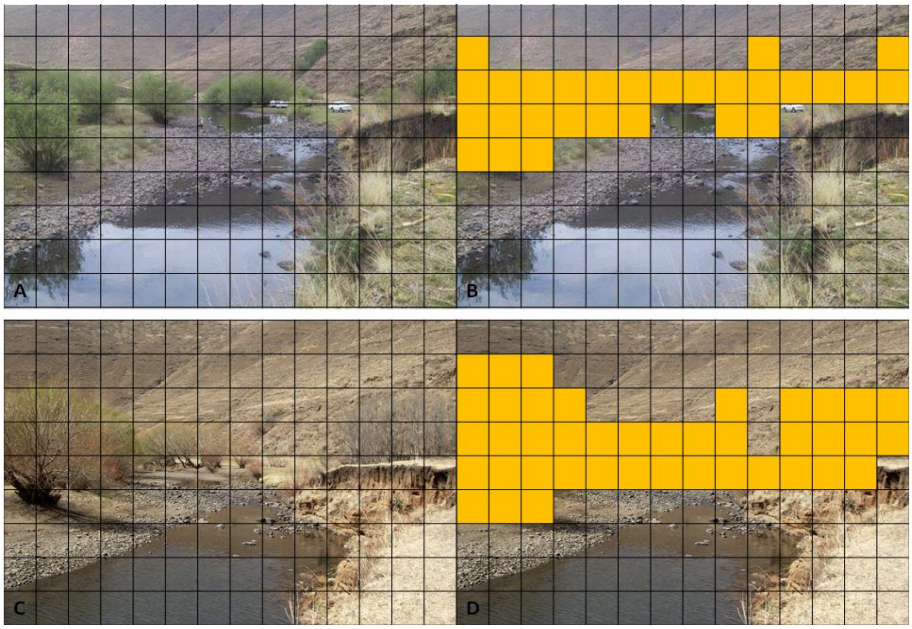

Figure 5.2 Example of qualitative assessments of fixed point photographs

Such quantitative assessments present problems, such as errors of parallax and scaling differences between different sets of photos of the same area. Nonetheless the analysis provides useful visual evidence of the changes to woody (or non-woody) vegetation structure and abundance in a given area. In general fixed point photographs cover a large area and are quick to capture.

Analyse VEGRAI level 4 data

A VEGRAI level 4 (Kleynhans *et al*., 2007) assessment should be undertaken by a suitably trained vegetation specialist to determine Ecostatus. These data include detailed

[3] Elaborate alignment procedures are outlined in Elzinga et al. (1998) and these can be used for important or long term sites.

descriptions of vegetation within each zone, species lists and areal coverage (%) for different vegetation components (see Table 5.6 for woody vegetation components and Table 5.7 for non-woody components).

Table 5.6 Example showing estimates of woody component % aerial cover

Vegetation zones	Woody phreatophyte	Woody terrestrial	Non-woody (incl. reeds)	Perennial alien	Open (alluvium)	Open (bedrock)
Submerged macrophytes.	0	0	100	0	0	0
Emergent macrophytes.	0	0	100	0	0	0
Shore "beach" macrophytes.	5	0	75	0	20	0
Woody lake-dependent vegetation.	45	0	35	0	20	0

Table 5.7 Example showing estimates of non-woody component % aerial cover

Vegetation zone	Reeds	Rushes	Sedges	Large-leaved macrophytes	Open areas	Grasses	Low woody (≤50 cm)	Aquatic	Alien veg
Submerged macrophytes.	5	10	10	0	0	0	0	20	55
Emergent macrophytes.	5	40	35	5	0	5	0	5	5
Shore "beach" macrophytes.	0	0	35	10	20	30	5	0	0
Woody lake-dependent vegetation.	0	0	5	10	30	25	30	0	0

5.4 Macrocrustacea and mollusc EcoSpecs

EcoSpecs for macrocrustacea and molluscs are provided in Table 5.8 below.

Table 5.8 EcoSpecs for crustaceans and molluscs (Appleton 1977, Hart 1979)

Parameter	Ecological specification	Threshold of Potential Concern
Alien species richness.	≤ 2 alien species present.	> 3 alien species present.
Benthic abundance of *Tarebia granifera* (Ind./m2; Ind. = number of individuals).	Ind./m2 < 3000 at 0-7m depth Ind./m2 < 80 at depths > 7m.	Ind./m2 > 4000 at 0-7m depth. Ind./m2 > 100 at depths > 7m.

Parameter	Ecological specification	Threshold of Potential Concern
Benthic abundance of *Melanoides tuberculatus* (Ind./m2; Ind. = number of individuals).	1000 < Ind./m2 < 2000.	500> # /m2.
Littoral abundance of pulmonate snails (Ind./kg; Ind. = number of individuals).	5 < Ind./kg < 25 at 0-0.5m depth.	Ind./kg < 2 at 0-0.5m depth.
Decapod crustacean species richness.	# species = 3.	# species < 3.
Molluscan species richness.	10 < # species < 14.	# species < 8.

5.4.1 Macrocrustacea and mollusc monitoring programme

The molluscs and macro-crustaceans are good indicators of the overall state of the lake. They are sensitive to disruptions by invasive species, to increased primary production levels and to changes in water quality. The objective of the sampling programme is to detect changes in species composition, abundance and distribution. Samples of the benthic, littoral and aquatic vegetation should be collected along five fixed transects, one in each EWR zone from shoreline to deep water (Table 5.9), every three years.

Table 5.9 Description of sampling sites and intensity for sampling

Basin	Transect. Length (m)	Maximum depth (mamsl)	Coordinates of starting point on shoreline*	Coordinates of the end point**
Main Basin	1000	35	-27.3605°; 32.7173°	-27.3615°; 32.7058°
Northern Arm	500	25	-27.2992°; 32.6678°	-27.2983°; 32.6730°
Western Arm	300	15	-27.3394°; 32.6023°	-27.3426°; 32.6024°
Southwestern Basin	400	10	-27.3835°; 32.6578°	-27.3856°; 32.6612°
Southern Basin	650	15	-27.4076°; 32.7115°	-27.4075°; 32.7047°

* As the water level rises or falls – so the starting point will move – to always start at the margin of the water.

** To coincide with water quality sampling locations (Figure 5.1).

Benthic fauna (in the lake sediments)

Benthic samples should be collected at three points along each transect in the following depth classes; 0 to 3.5 m, 3.5 to 7 m, 7 to 10 m, and a fourth sample at a depth of 10 to 15 m where present (Table 5.9). Sampling can either be done by diving with SCUBA (if it can be done safely given the potential presence of crocodiles) or sampling can be done with a Van Veen© grab sampler from the safety of the boat. GPS coordinates must be recorded at each sampling point. The transects have been aligned to coincide with the water quality sampling points (Figure 5.1) so that water quality data about Electrical Conductivity, pH, Dissolved Oxygen and temperature and sediment particle size and sediment organic matter content may be cross-referenced for interpretation.

If diving, the benthic samples should be collected in a steel quadrat, 0.5 m x 0.5 m, and 0.1 m in height (i.e. a tray with no bottom). The sediment can be suctioned from within the

quadrat using an airlift (Figure 5.3) and passed through a 4 mm sieve to capture the larger benthic fauna. The contents of the sieve can be stored in a labelled plastic bag and frozen for later analysis (or pickled in 96% alcohol in a sample jar). The samples may then be processed in the laboratory first by hand-picking out the organisms and counting the numbers of individuals per species, sub-sampling where large numbers of organisms have been captured. These data may be reduced to number of individuals/m^2 by dividing by the sample area (0.25 m^2).

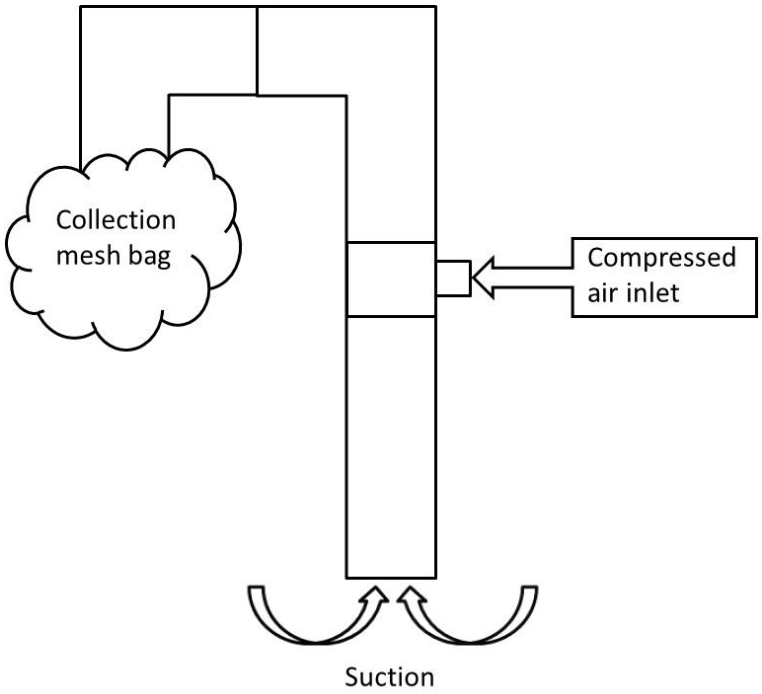

Figure 5.3 Airlift for collecting benthic sample from within the quadrat (New 1998, Loke *et al*. 2010)

Littoral fauna (at the shoreline)

Samples of the littoral fauna must be collected from submerged, emergent or floating vegetation at the starting point of each transect (Table 5.9). At each point, the net should be pushed firmly or underneath the vegetation and then jerked upwards several times to dislodge any snails. If bilharzia is known to occur, protective rubber gloves and boots should be worn. Collect 20 scoop samples with a standard scoop net (1.3m handle length, frame 320mm x 300mm x 60mm, with a 4 mm mesh). Place the contents of the net in a shallow basin and hand-pick the molluscs from the sample. Count these and preserve by freezing in a 'zip-loc' plastic bag (or 96% alcohol if necessary in a sample jar). This provides an index of abundance for the littoral margin, and a frequency of occurrence. Collect the vegetation sampled and weigh the wet mass of the vegetation by placing it into a hessian (orange) bag and attaching it to fish scale.

Table 5.10 Monitoring programme for macrocrustacea and molluscs

Parameter to be measured	Frequency	Location
Benthic fauna.	Once every 3 years in summer.	5 transects (Table 5.9).
Littoral fauna.	Once every 3 years in summer.	At the starting points of each transect.

5.5 Herpetofauna and semi-aquatic mammals EcoSpecs

EcoSpecs for herpetofauna and semi-aquatic mammals are provided in Table 5.11 below.

Table 5.11 EcoSpecs for frogs, hippos and crocodiles

Parameter	Ecological specification	Threshold of Potential Concern
Frog species richness	12 < # species to < 15	# species < 10
Abundance of hippos	50 < # hippopotami < 120	# hippopotami < 45
Abundance of crocodiles	50 < # crocodiles < 100	# crocodiles counted < 25*
# of crocodile nests	> 10 nests per year	< 5 nests found in one year

* Assuming that only half the actual number of crocodiles are counted during a census

5.5.1 Herpetofauna and semi-aquatic mammals monitoring programme

In order to collect the data required to assess whether the ecological specifications are being met or whether thresholds of potential concern have been surpassed it is necessary to quantify frog species richness, the abundance of hippos and crocodiles as well as the location and abundance of crocodile nests. The methods to do this are described below.

Frog species richness

Frog calls should be recorded at one location per EWR zone where there is lush and abundant marginal vegetation. Calls may be recorded with a digital voice recorder between December and January when air temperatures are below 25^{o}C. Recordings should be made for a period of five minutes per hour from sunset to mid-night. The digital recordings should then be downloaded into a computer and converted to sonograms that may be analysed automatically for the purposes of identifying different species with 'Raven Lite' software developed and available from the Cornell University Lab of Ornithology (http://www.birds.cornell.edu/brp/raven/RavenOverview.html).

Hippo abundance

An aerial survey to count hippos should be undertaken every year between May and June from a fixed-wing aircraft flying at an altitude of approximately 300 feet over the lake between 09:00 and 12:00 in the morning. The count should only be done in calm weather. The aircraft should fly 200-300 m inside the periphery of the lake margin and circle pods of hippo

to enable a full count to be made of different groups. The location of the pod should be recorded into a GPS and special note should be made of the number of juveniles.

Crocodile abundance

An aerial survey to count crocodiles should be undertaken every year between June and July from a fixed-wing aircraft flying at an altitude of approximately 300 feet over the lake between 10:00 and 13:00 in the morning. The count should only be done in calm weather. The aircraft should fly 200-300 m inside the periphery of the lake margin. The location of a crocodile should be recorded into a GPS and an estimate made of its length. Special attention should be paid to areas with marginal vegetation as well as the banks of the lake where crocodiles may be basking.

Crocodile nest abundance

Crocodile nests should be counted each year from January into the first week of February. The full length of the lake perimeter should be walked on foot to find the nests, which are identified as scrapes the length of the crocodile mother (an impression of the mother crocodile in the sand), beneath which the eggs are buried. There are usually two access paths, visible as crocodile spoor approaching to, and leaving, the nesting site. Often as one approaches a nest, the mother crocodile can be seen slipping quietly into the nearby water.

Once a nest is located it should be examined to determine whether it is intact or not. The presence of egg shells at the nest surface and a hole in the nest indicate whether the nest may have been predated upon or excavated. Half eaten eggs normally would indicate a predator, and their absence would indicate the eggs may have been harvested, while hatched shells at the nest tend to indicate a successfully hatched brood. Nest locations should be recorded with a GPS, a short description of the surrounding habitat made (e.g., presence of plants/trees, how shaded it is and distance from water) and also whether the nest was guarded by the mother, whether the clutch hatched successfully or whether it was predated upon or excavated.

Table 5.12 Monitoring programme for frogs, hippos and crocodiles

Parameter to be measured	Frequency	Location
Frog species richness (presence based on frog calls).	Once every 3 years.	1 location with abundant marginal vegetation per EWR zone.
Abundance of hippopotami.	Annually (May-June).	Entire lake.
Abundance of crocodiles.		
Abundance of crocodile nests.	Annually (Jan-Feb).	Entire lake perimeter.

5.6 Ichthyofauna EcoSpecs

The setting of Ecological Specifications (EcoSpecs) is made difficult by the lack of quantitative fish abundances in Lake Sibaya. The approach to monitoring (see below) needs

to consider this, and an adaptive approach should be adopted whereby monitoring results are used to refine, update and change if necessary. EcoSpecs for fishes are identified below (Table 5.13).

Table 5.13 EcoSpecs for Ichthyofauna in Lake Sibaya

Parameter	Ecological specification	Threshold of Potential Concern
Fish species richness	13 < # species < 18	# species < 12
Ctenopoma multispine.	Must be present in the lake.	Not recorded in two consecutive surveys.
Oreochromis mossambicus, Tilapia sparrmanii, T. rendalli, Pseudocrenilabrus philander, Croilia mossambica, Silhouettea sibayi, Glossogobius callidus, Gilchristella aestuaria, Atherina breviceps.	Must be present in MB, NA, WA, SWB and SB.	Not recorded in one of the EWR zones during every survey.
Barbus paludinosus, B. viviparus, Aplocheilichthys katangae, A. myaposae.	Must be present in the lake.	Not recorded in two consecutive surveys.
Presence of alien fish species.	None present.	Alien species present.

5.6.1 Ichthyofauna monitoring programme

A monitoring programme to measure the EcoSpecs is provided in Table 5.14. As indicated monitoring needs to be adaptive, and modified on the basis of incoming data. High conductivities in Lake Sibaya water might affect sampling with an electroshocker, and more than one type of seine net might need to be employed (specifically a very fine meshed seine might need to be used to sample the small goby species (*Croilia mossambica* and *Silhouettea sibayi*).

Table 5.14 Monitoring programme for Ichthyofauna in Lake Sibaya

Monitoring action	Frequency	Location
Seine net sampling of shallow terrace and slope habitats.	Summer. Twice in year 1 and every 3 years thereafter.	At least 3 sites at each EWR zone, replicate hauls at each site.
Gill nets (1", 2" and 3" mesh) should be deployed in areas where seine netting is difficult for reasons of depth and/or marginal and emergent vegetation.	Summer. Twice in year 1 and every 3 years thereafter.	At least 2 sites at each EWR zone.
Electroshocking should be conducted in marginal and emergent vegetation.	Summer. Twice in year 1 and every 3 years thereafter.	At least 2 sites at each EWR zone and at peripheral, swamps/pans.

5.7 Avifauna EcoSpecs

Lower than normal lake levels over the last decade have led to significant changes in bird community composition. This has included both reductions in certain species and increases in others. While there is no evidence of any loss of species to date, it is predicted that with further decrease in lake level, loss of bird species from the system is likely. Loss of bird species can be masked to some extent if there is an influx of different species under changed conditions, and it is therefore important to understand changes in species composition and abundance.

EcoSpecs for avifauna are provided in Table 5.15 and in some instances further detail provided in Table 5.16. The raw data from which these were calculated are provided in Appendix A.

Table 5.15 EcoSpecs for Avifauna in Lake Sibaya

Parameter	Ecological specification.	Threshold of Potential Concern
Waterbird species richness.	Species richness > 30 in any one count.	Species richness < 28.
Waterbird frequency of occurrence.	White-breasted Cormorant, Reed Cormorant, African Fish-Eagle, Black-winged Stilt, Pied Kingfisher, Purple Heron, African Jacana, Little Grebe, Common Moorhen, Goliath Heron, Black Crake, Grey Heron, Little Egret, Spur-winged Goose, Yellow-billed duck, Great Egret, Common Greenshank, White-faced Duck, Blacksmith Lapwing, Squacco Heron, African Purple Swamphen, Malachite Kingfisher, Caspian Tern, Hamerkop, African Darter, African Pygmy Goose, Water Thick-knee and White-winged Tern must all be present on one of the bi-annual counts made i.e. occur more frequently than 50% of the time (Ecospec abundance values provided in Table 5.16).	Frequency of occurrence of these 30 species < 45%.
Bird biodiversity.	2.5 > Shannon Weiner index (H) > 1.9	1.8 > Shannon Weiner index > 2.6
Bird abundance.	Numbers of cormorants, darters, resident waders, birds of prey and kingfishers, African Pygmy Goose and Caspian Tern, Squacco Heron, White-faced Duck and African Jacana remain within the limits of the are retained.	Numbers of any species in these groups drop to less than 50% of their baseline average for three consecutive years (TPC values provided in Table 5.16).

Table 5.16 The most frequently encountered birds (Frequency of occurrence = F) and the average abundance (± Standard Deviation, SD). Species used in setting the Ecological Specifications for bird abundance are bolded.

Species	F	Abundance		
		Average	SD	TPC
White-breasted Cormorant	**100.0**	**242.2**	**137.4**	**< 121.1**
Reed Cormorant	**100.0**	**254.7**	**165.8**	**< 127.3**
African Fish-Eagle	**100.0**	**10.0**	**3.9**	**< 5.0**
Black-winged Stilt	**100.0**	**18.7**	**17.9**	**9.3**
Pied Kingfisher	**100.0**	**27.4**	**11.3**	**< 13.7**
Purple Heron	96.9			
African Jacana	**96.9**	**14.5**	**8.8**	**< 7.2**
Little Grebe	93.8			
Common Moorhen	90.6			
Grey Heron	87.5			
Goliath Heron	87.5			
Little Egret	87.5			
Hadeda Ibis	87.5			
Spur-winged Goose	87.5			
Egyptian Goose	87.5			
Yellow-billed Duck	81.3			
Great Egret	78.1			
Common Greenshank	78.1			
Blacksmith Lapwing	**78.1**	**6.7**	**5.5**	**3.3**
Black Crake	75.0			
African Purple Swamphen	71.9			
Malachite Kingfisher	**68.8**	**3.7**	**3.8**	**< 1.9**
Caspian Tern	**65.6**	**8.5**	**14.4**	**< 4.3**
Squacco Heron	**62.5**	**2.8**	**2.1**	**< 1.4**
Hamerkop	62.5			
White-faced Duck	**62.5**	**22.0**	**29.1**	**< 11.0**
Water Thick-knee	62.5			
African Wattled Lapwing	56.3			
African Darter	**53.1**	**8.6**	**8.6**	**< 4.3**
White-fronted Plover	**53.1**	**11.5**	**7.2**	**5.8**
Grey-headed Gull	46.9			
Saddle-billed Stork	43.8			
African Pygmy-Goose	**40.6**	**13.7**	**21.2**	**< 6.8**

5.7.1 Avifauna monitoring programme

Lake Sibaya is currently counted twice a year by KwaZulu-Natal Wildlife and the count data are submitted as part of the Co-ordinated Waterbird Count (CWAC) programme based at the

Avian Demography Unit (ADU) University of Cape Town (Appendix A). It is recommended that the current counting regime is continued. If possible, more detailed records of counts by section and the degree of coverage and counting conditions would be useful to understand changes in use of different zones of the lake over time. .

A monitoring programme for avifauna is provided in Table 5.17.

Table 5.17 Monitoring programme for avifauna in Lake Sibaya

Monitoring action	Frequency	Location
Count all adult waterbirds, by species and record any breeding activity taking place.	Bi-annual (mid-winter and mid-summer).	Cover whole lake, but provide count data separately for the five EWR zones.

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Appendix A. RAW CWAC BIRD COUNT DATA

Species	Mar-70	May-76	Dec-81	Jul-92	Jan-93	Jul-93	Aug-94	Jul-95	Jan-96	Aug-96	Feb-97	Jul-97	Jul-99	Feb-05	Jul-05	Jan-06	Jul-06	Feb-07	Jul-07	Feb-08	Jul-08	Jan-09	Jul-09	Jan-10	Jul-10	Jan-11	Aug-11	Feb-12	Jul-12	Feb-13
WATER LEVEL MASL	17.504	20.134	18.926	19.655	19.485	19.509	18.941	18.699	18.789	18.534	18.355	18.264	18.493	17.899	17.777	17.582	17.424	17.379	17.33	17.252	17.1	17.004	16.91	16.814	16.72	16.625	16.514	16.419	16.34	16.228
Little Grebe	100	26	0	117	0	57	57	97	2	139	5	87	108	78	124	5	82	57	78	8	184	5	120	9	88	0	114	26	79	5
White-breasted Cormorant	93	241	111	201	256	111	98	87	466	23	378	34	19	336	337	597	261	349	294	404	289	472	289	385	231	175	223	251	249	147
Reed Cormorant	289	51	438	324	283	208	382	340	6	25	43	145	125	605	604	385	209	283	333	33	419	119	493	192	356	27	364	372	308	24
African Darter	0	14	15	31	13	19	12	8	1	0	2	19	2	0	2	0	0	0	0	1	0	0	0	1	2	0	0	0	4	0
Grey Heron			2	1	4	2	1	3	2	0	5	2	4	16	27	9	7	3	6	0	4	11	5	8	9	14	7	9	10	4
Goliath Heron			1	4	3	4	3	3	6	1	4	5	2	10	9	8	4	0	3	1	6	1	1	2	5	1	3	6	1	0
Purple Heron	34	9	1	4	5	1	0	3	4	2	21	3	3	23	2	28	2	12	1	10	5	24	2	17	2	9	1	36	4	11
Great Egret			17	3	1	5	5	2	0	4	0	2	0	4	3	1	2	1	3	1	3	10	6	2	4	6	4	0	1	0
Little Egret			27	14	0	22	21	34	4	12	17	15	18	17	60	27	42	3	12	0	36	18	30	9	9	3	20	1	5	2
Yellow-billed Egret				0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	6	0	0	0	0	1
Squacco Heron				6	0	4	7	1	0	7	3	3	6	1	3	1	0	1	3	0	1	1	1	0	1	0	3	0	0	1
Green-backed Heron				1	2	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Black Heron				0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Dwarf Bittern				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Little Bittern				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Black-crowned Night-Heron				0	0	0	1	0	0	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
White-backed Night-Heron				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hamerkop				0	5	0	2	0	7	2	3	0	1	5	1	6	3	0	2	4	4	1	0	0	0	0	1	4	2	7
Saddle-billed Stork				0	0	0	0	0	0	0	0	0	0	2	2	0	1	2	0	2	2	2	2	3	1	1	2	0	0	2
Woolly-necked Stork				0	0	0	0	0	4	0	2	0	0	1	0	0	0	2	0	1	0	2	3	3	1	0	1	1	0	0
African Sacred Ibis				14	1	19	15	6	0	5	0	10	11	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	Mar-70	May-76	Dec-81	Jul-92	Jan-93	Jul-93	Aug-94	Jul-95	Jan-96	Aug-96	Feb-97	Jul-97	Jul-99	Feb-05	Jul-05	Jan-06	Jul-06	Feb-07	Jul-07	Feb-08	Jul-08	Jan-09	Jul-09	Jan-10	Jul-10	Jan-11	Aug-11	Feb-12	Jul-12	Feb-13
WATER LEVEL MASL	17.504	20.134	18.926	19.655	19.485	19.509	18.941	18.699	18.789	18.534	18.355	18.264	18.493	17.899	17.777	17.582	17.424	17.379	17.33	17.252	17.1	17.004	16.91	16.814	16.72	16.625	16.514	16.419	16.34	16.229
Glossy Ibis				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Hadeda Ibis	3	29		1	0	2	25	1	2	9	6	4	6	4	7	13	4	13	4	2	9	2	1	2	6	0	3	25	3	1
African Spoonbill				0	0	0	0	9	0	0	0	3	0	1	3	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Greater Flamingo				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spur-winged Goose			8	0	5	0	21	8	9	9	12	5	6	21	20	25	3	12	9	11	11	29	5	8	5	6	22	17	2	23
Egyptian Goose				2	0	2	3	3	5	2	1	3	2	25	29	14	15	24	34	53	51	70	82	12	84	70	100	171	65	43
Comb Duck				0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
African Pygmy-Goose	8	7		74	4	2	7	49	0	4	0	12	2	0	6	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0
Yellow-billed Duck			2	0	0	0	3	11	6	6	10	3	7	45	109	30	15	44	31	97	23	60	21	0	15	10	14	0	31	17
Red-billed Teal				0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2	0	15	6	6	3	0	0	26	9	21	0
White-faced Duck				1	4	5	133	28	16	24	7	56	9	16	21	37	0	29	0	8	12	2	0	16	0	2	0	0	30	0
Fulvous Duck				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
White-backed Duck				0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
African Fish-Eagle	8	13	5	13	16	12	12	13	10	7	8	9	8	14	19	9	9	10	9	9	15	17	8	7	17	8	7	7	4	5
African Marsh-Harrier				1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Osprey				0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0
Black Crake	4	17		16	5	6	1	4	1	1	2	2	1	0	4	4	1	0	1	1	1	0	2	0	6	0	5	3	0	1
African Purple Swamphen				7	0	1	0	10	1	3	4	2	1	4	0	0	3	1	2	0	9	12	7	1	3	0	4	5	1	1
Allen's Gallinule				2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Common Moorhen				1	0	1	1	7	21	13	5	3	3	6	16	10	2	2	4	4	5	2	14	7	14	3	11	5	16	1
Red-knobbed Coot				0	0	0	0	14	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Common Ringed Plover				0	0	0	0	0	4	3	1	0	0	1	0	0	0	1	0	1	0	5	0	0	0	0	0	0	0	0
Greater Sand Plover				0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	Mar-70	May-76	Dec-81	Jul-92	Jan-93	Jul-93	Aug-94	Jul-95	Jan-96	Aug-96	Feb-97	Jul-97	Jul-99	Feb-05	Jul-05	Jan-06	Jul-06	Feb-07	Jul-07	Feb-08	Jul-08	Jan-09	Jul-09	Jan-10	Jul-10	Jan-11	Aug-11	Feb-12	Jul-12	Feb-13
WATER LEVEL MASL	17.504	20.134	18.926	19.655	19.485	19.509	18.941	18.699	18.789	18.534	18.355	18.264	18.493	17.899	17.777	17.582	17.424	17.379	17.33	17.252	17.1	17.004	16.91	16.814	16.72	16.625	16.514	16.419	16.34	16.229
Curlew Sandpiper				0	0	0	0	0	0	0	0	0	0	0	0	39	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Little Stint				0	0	0	0	0	1	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Common Sandpiper			1	0	0	0	0	0	0	3	6	0	0	17	0	13	0	2	0	4	0	0	0	0	0	0	0	8	0	0
Common Greenshank			8	0	0	0	1	3	21	11	19	0	1	26	4	48	121	10	4	12	6	9	1	5	0	8	4	24	0	11
White-fronted Plover				0	0	0	0	0	0	0	0	0	0	0	0	9	8	5	8	8	21	4	16	4	20	2	26	11	4	23
Collared Pratincole				0	0	0	0	0	2	0	0	0	0	1	0	0	4	6	0	17	0	1	0	0	0	0	0	2	0	0
Ruff			4	0	0	0	0	0	0	0	0	0	0	6	0	3	0	0	0	6	0	3	0	1	0	0	0	3	0	0
African Jacana	9	46		25	8	18	19	30	13	16	12	21	4	9	23	13	7	7	17	9	20	10	14	1	13	3	11	17	15	6
Lesser Jacana				2	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Blacksmith Lapwing				0	0	0	1	1	6	2	7	5	2	3	7	4	1	3	0	3	3	6	5	5	14	15	9	26	10	9
African Wattled Lapwing				2	0	2	1	0	6	7	8	0	0	17	3	7	0	0	0	0	0	0	0	7	7	5	2	3	0	9
Pied Avocet				0	0	0	0	0	0	3	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0
Black-winged Stilt	25	0	2	11	0	10	17	40	18	2	8	15	4	58	43	33	16	2	4	7	16	15	23	13	15	1	43	67	58	7
Water Thick-knee				0	3	0	0	0	7	0	0	0	0	8	0	4	1	4	2	3	3	6	2	3	0	0	2	8	0	22
Grey-headed Gull				2	0	0	3	1	0	0	0	0	0	0	4	9	1	4	110	0	0	2	1	0	0	3	0	22	4	0
Caspian Tern			1	4	2	13	9	0	4	4	3	0	0	2	17	68	6	0	4	0	0	0	5	21	1	2	0	1	1	1
Common Tern	35	0		0	0	0	0	0	0	0	0	0	0	0	0	17	0	7	2	32	0	0	0	0	0	0	0	0	0	0
Swift Tern				0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Little Tern				1	0	0	0	0	0	0	0	0	0	69	7	48	0	22	25	117	64	0	3	0	0	0	0	0	0	0
White-winged Tern			438	0	14	1	5	0	0	0	1	0	0	88	1	0	0	52	50	1	0	22	0	0	0	0	0	0	0	0
Whiskered Tern				43	42	1	0	0	0	0	0	0	0	0	252	0	0	0	0	0	0	0	253	16	0	0	0	0	0	0
Pied Kingfisher	50	39	5	22	25	44	18	37	33	29	36	35	14	23	25	30	25	36	13	23	24	9	25	46	45	26	27	16	19	17
Giant Kingfisher				1	3	3	3	0	0	1	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	Mar-70	May-76	Dec-81	Jul-92	Jan-93	Jul-93	Aug-94	Jul-95	Jan-96	Aug-96	Feb-97	Jul-97	Jul-99	Feb-05	Jul-05	Jan-06	Jul-06	Feb-07	Jul-07	Feb-08	Jul-08	Jan-09	Jul-09	Jan-10	Jul-10	Jan-11	Aug-11	Feb-12	Jul-12	Feb-13
WATER LEVEL MASL	17.504	20.134	18.926	19.655	19.485	19.509	18.941	18.699	18.789	18.534	18.355	18.264	18.493	17.899	17.777	17.582	17.424	17.379	17.33	17.252	17.1	17.004	16.91	16.814	16.72	16.625	16.514	16.419	16.34	16.229
Malachite Kingfisher	12	12		4	0	3	0	1	0	10	12	3	0	2	3	0	2	1	0	1	0	2	1	2	1	0	2	2	1	2
African Pied Wagtail				0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0
Cape Wagtail				0	0	0	0	0	0	0	0	0	0	0	3	0	0	3	0	0	3	0	0	0	0	0	9	0	2	0
Unidentified Waders			21	0	0	0	0	0	23	0	0	0	0	7	0	53	0	35	1	9	0	98	1	5	0	20	4	142	32	11
Unidentified Terns				0	0	53	96	64	67	78	108	44	12	84	0	0	186	151	7	81	75	12	0	90	204	526	264	116	84	0
Unidentified Ducks				0	0	0	0	0	0	0	0	0	0	23	0	0	8	6	0	0	1	26	0	5	0	0	8	72	29	0
Wood Sandpiper			1																											