# REPORT 10 RALL, JL

## IFC/GEF VILANCULOS COASTAL WILDLIFE SANCTUARY PROJECT – FRESHWATER AQUATIC SYSTEMS

## MOZAMBIQUE

## OCTOBER 2002

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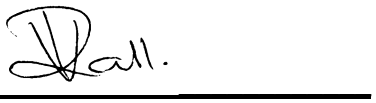

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# 1. INTRODUCTION

## BACKGROUND

East African Wildlife Properties Ltd has been charged with the responsibility of managing, the recently approved, Vilanculos Coastal Wildlife Sanctuary (VCWS) in Mozambique's Inhambane Province. As custodians of the sanctuary they are in the process of establishing a biodiversity and conservation management plan that would encompass the marine, terrestrial and freshwater ecosystems. In this endeavour they seek to apply the principle of "conservation through utilisation" by means of the sustainable and profitable commercial use of the Sanctuary's natural resources to the benefit of both the Company and of the local people residing in the Sanctuary (Environmental Impact Assessment for the Vilanculos Coastal Wildlife Sanctuary, Part I – Non Technical Summary). A team of specialists was employed to conduct a preliminary environmental assessment in order to design a strategy as principle for the conservation master plan as well as the biodiversity management plan. This document serves as the outcome of the Freshwater Aquatic Ecosystem component

## TERMS OF REFERENCE

The work as delineated in the proposed terms of references (May 2002) required the following tasks

- Classification of the Freshwater Aquatic System
    - Broad scale physical classification of the freshwater systems associated with the VCWS based on surface waters – general hydrological regime, size and general water chemistry i.e. pH, EC, DO.
    - Broad scale biological characterization (fish & macro-invertebrates) of the described freshwater systems associated with the VCWS.

- Conservation importance of the freshwater aquatic system associated with the area
    - Naturalness – A qualitative assessment of the deviation from a perceived natural state in terms of abstraction, exotics, erosion, flow regulation, pollution and land use.
    - Diversity – General qualitative macro-habitat descriptions and rapid sampling of fish and macro-invertebrates (identification of macro-invertebrates only to family level)
    - Rarity – Presence of habitats or species within VWCS.
    - Extent – Presence of habitats or species within VWCS.
    - Sensitivity – Perceived vulnerability and viability of habitats or species

- Identification of threats
    - Threats to the Freshwater aquatic systems & Hydrology (FASH)
    - Information gaps & research needs
    - Threats & limitations that may affect management actions

- Development of management plan
    - General description of the FASH
    - General description of the ecological attributes of the FASH

- Description of the threats
- Define management/ conservation objective for FASH
- Define management goals (milestones to measure performance and set endpoints to ensure achievement of the objective) for FASH

**OBJECTIVE**

The objective for the FASH component of the work were to conduct:
"*An assessment of the aquatic freshwater systems, within the VCWS area, to identify conservation needs and priorities*."

**ASSUMPTIONS AND LIMITATIONS**

The VWCS project is regarded as a preliminary assessment of the study area to set the basis for the development of a management framework. In this light the focus of the FASH survey was to identify aquatic ecological attributes rather than to present a detailed classification of the aquatic biota and habitat types associated with the VCWS. Issues such as the incidence of waterborne diseases were therefore not discussed but is regarded as a very important component of any management plan proposed for the study area.
The information is presented as principles for the way forward and is intended to highlight red flag issues and to focus efforts on relevant work and research needs.
The major limitation to the work is regarded as the lack of seasonality in the overall sampling strategy. The survey was conducted at the end of the dry period and is therefore regarded as limited in scope, and the results should be treated as part of an adaptive management strategy that could change as more data become available.
Another major limitation was the lack of aerial photographs for the study area. It was therefore not possible to delineate the extent of the different freshwater types associated with the study area and the approach was limited to known and accessible freshwater bodies.

**DESCRIPTION OF THE DEVELOPMENT**

The development plans propose to isolate a 70km stretch of coastline and two adjacent islands into a reserve, which will contain 50 private residences and a lodge. The area includes a marine reserve concession up to the 20m contours. Game; including elephant, buffalo, hippo, eland and waterbuck; will be introduced. The local people will own the game and will benefit from this. The development group will be responsible for protecting the area against poaching and pollution and will further provide patrolling of the region and an intensive assessment is planned to set up a conservation management framework. An additional area, Phase II, might also be added to the sanctuary.

**APPROACH**

The overall approach to the Freshwater Aquatic Systems (FAS) study was implemented as a hierarchical sequence of dependant tasks intended to highlight important FAS attributes that should be considered as part of the design of the Biodiversity Management Plan (BMP) & the Conservation Master Plan (CMP).
The study was initiated with a literature survey to gather available information regarding freshwater ecosystems for the study area. A field survey was conducted to gather baseline data to assist with the development of a classification framework for the freshwater aquatic system as

well as the identification of relevant ecological attributes that would enable the design of a conservation and biodiversity management plan for the freshwater ecosystem.

## 2. STUDY AREA

The Vilanculos Coastal Wildlife Sanctuary is situated on the San Sebastian peninsula, in the Inhambane Province just south of Vilanculos on the Mozambique Coast. The peninsula is roughly halfway between Maputo and Beira. The reserve area is approximately 22 000ha and with the inclusion of the marine concession, approximately 30 000ha.

The area consists of a variety of habitat types including woodlands, wetlands and savannah. Aquatic habitats include wetlands, pans, freshwater lakes, tidal mudflats, salt marshes, mangroves and estuaries. Exact demarcation of these habitats was not possible since aerial photographs were not available for the study area during the course of the field survey and it was not possible to implement a systematic survey that would ensure inclusion of all different freshwater types of the study area. The sites were therefore selected to represent as many of the known types of freshwater bodies present in the study area (Appendix 2 represents a map of the study area). Table one presents the coordinates of the different sampling sites.

**Table 1**: Sites visited during the field visit

| **Site** | **Co-ordinates** | |
|---|---|---|
| Xilowane Swamp | S: 22º15'20.3" | E: 35º30'31.9" |
| Nhahotsane Pan | S: 22º11'53.3" | E: 35º28'18.1" |
| Njone Lake | S: 22º11'09.9" | E: 35º28'11.2" |
| Tirweni Pan | S: 22º07'45.5" | E: 35º27'15.4" |
| Switsangweni Pan | S: 22º07'51.6" | E: 35º27'20.6" |
| Jacana Pan | S: 22º07'40.6" | E: 35º26'55.0" |
| Mukwe pan | S: 22º07'55.3" | E: 35º27'14.9" |
| Manhale Lake | E: 35º26'48.9" | S: 22º16'55.7" |
| Madaca'munhu Marsh | E: 35º29'34.7" | S: 22º08'47.9" |
| Jane Marsh | E: 35º29'51.0" | S: 22º21'11.0" |
| Msasa Marsh | E: 35º26'43.4" | S: 22º08'10.5" |
| Mazolo Marsh | E: 35º27'12.2" | S: 22º08'57.2" |
| Marapi Marsh | E: 35º26'23.7" | S: 22º09'30.4" |

## 3. DATA COLLECTION AND INTERPRETATION METHODS

This study was based on a review of available data on aquatic ecosystems and a field visit during the dry season, September 2002. The field visit was used to collect broad scale baseline data on water quality, aquatic invertebrates and fish.

### 3.1 CLASSIFICATION OF FRESHWATER BODIES

Freshwater bodies were classified based on major identifiable differences. Although certain of these characteristics, used in the classification of the water bodies were artificial, these are intended to facilitate decision-making regarding the implementation of future research and or management actions. The classification system was based on characteristics such as type, size, hydraulic types, as well as presence of biotopes.

## 3.2 HYDROLOGY

### 3.2.1 Rainfall

The rainfall data was made available by Theron Theunissen and was obtained from the "Instituto Nacional de Meteorologia." The data represents the nearby town of Vilanculos and covers the period 1987 – 2001.

### 3.2.2 Water Quality

*In situ* water quality data was collected from most sites during the field visit. Temperature (ºC), conductivity/TDS (ppm) and turbidity (cm secci) were measured in the field with lightweight, compact field equipment. A water sample was also collected for Laboratory analysis from Mukwe Pan (reticulation pan). Locations of the collection sites are presented in Table 1.

## 3.3 AQUATIC INVERTEBRATES

The aquatic invertebrates of the study area have been poorly studied. In order to implement an approach that would allow an evaluation of the aquatic macro-invertebrate fauna, the same sampling exercise as used for the South African Scoring System (SASS5) was adopted to sample the diverse habitat types. SASS is a rapid method developed as a tool to assess the condition of flowing water in South African Rivers. Since the study area do not present many areas with flowing waters only the sampling protocol of SASS was used to standardize collection effort. The number of taxa collected from the different biotopes associated with the freshwater bodies was used to indicate the general diversity of these waters. The sampling protocol were standardised to four biotopes that included fringing or emergent vegetation, aquatic vegetation, open waters and bottom sediments. Sampling was conducted with a 1mm mesh size net mounted on a $30cm^2$ frame.

The number of taxa collected at each site was converted to a percentage of the total number of taxa collected during the survey. This percentage diversity score was used as an indication of the invertebrate diversity at each site. Sites with a high diversity were generally regarded as of a higher conservation importance than sites with low diversities. Sites supporting rare and/or sensitive taxa (in terms of total diversity for the survey) were also warranted a high conservation importance, even if the site's overall biodiversity was low.

## 3.4 FISH

Fish were collected using standard sampling strategies, which included electro fishing; both small and large seine nets as well as gill nets. Different sampling strategies were used at the different sampling sites depending on the nature of the habitats present as well as the suitability of the sampling equipment for that habitat type. Each of the different methods is known to display some bias either amongst size classes or different species. The approach was therefore to use as many of the different strategies at each site as possible to minimize the likelihood of bias.

- Electro fishing: Is an efficient method, being quick and requiring little manpower. When used properly, fish experience minimal negative effects and it can be used in a wide variety of habitats including both shallow and deep waters as well as flowing and standing waters. The efficacy of this method depends on the conductivity of the water, temperature, species and fish size. Two electro fishing units were used, i.e. a portable

battery operated unit (DC, 1A 350V pulsating) as well as a fixed generator driven unit (DC 600V 5A pulsating)

- Seine & gill netting: Netting, on the other hand, is not affected by conductivity or temperature and can be applied for different species as well as size classes. The method can also be implemented in much deeper water bodies where shocking would be impractical. This method does require experience and knowledge of fish habitats and behaviour. Two seine nets were used (15m x 9mm stretched mesh & 50m x 9mm stretched mesh) as well as a fleet of 10, 10m multifilament gill nets, ranging from 22mm to 150mm stretched mesh sizes.
- Fish poisons: Fish poisons such as Rotenone are used extensively specifically during baseline studies and abundance assessments. Due to the lack of available information regarding the presence of likely rare or sensitive species it was however decided not to use fish poisons during this survey.

Sampling effort for the different sampling methods was standardised for each depth and cover type present within the study area. These standardised methods are presented in Table 2.

**Table 2**: Standardised sampling methods for different depth and cover classes.

| | **Slow shallow** | **Slow deep** |
|---|---|---|
| **Overhanging vegetation** | Shock<br>Seine, small | Seine, small<br>Gill net |
| **Undercut banks** | Shock | Gill net |
| **Aquatic macrophytes** | Shock<br>Seine, small | Seine, small<br>Gill net |
| **Open water** | Seine, large | Seine, Large<br>Gill net |

Captured fish were identified and measured before being released. Reference samples were retained for identification purposes and will be lodged at the South African Institute of Aquatic Biodiversity.

### 3.5 HABITAT INTEGRITY ASSESSMENT (HIA)

The ecological integrity of an aquatic system is defined as its ability to support and maintain a balanced, integrated composition of physico-chemical and habitat characteristics, as well as biotic components on a temporal and spatial scale that are comparable to the natural characteristics of ecosystems in the region (Karr & Dudley, 1981). In order to describe possible deviations from the natural conditions expected for the freshwater aquatic systems associated with VCWS, an approach based on the Kleynhans' (1996) approach was adopted to assess the

habitat integrity status. The HIA measures specific criteria on a qualitative basis, based on the estimated level of impact affecting the site, to give an indication of the impact category of a site. The HIA approach followed was based on impacts, as were identified during the field visit, that would ensure that the integrity assessment was relevant to actual impacts affecting the aquatic habitat template for the different freshwater bodies present in the sanctuary. The threats identified during the field survey are described in Table 3.

Table 3. Threats to the freshwater aquatic system associated with the VCWS

| **CRITERION** | **DESCRIPTION** |
|---|---|
| **Aquatic Zone Criterion** | |
| Water abstraction | Abstraction for consumptive purposes |
| Infilling | Sediment infilling as a result of erosion |
| Resource exploitation | Exploitation of biotic resources |
| Water quality modification | Washing and/or salt loading |
| Inundation | Inundation from flooding |
| Exotic macrophytes | Presence of exotic macrophytes |
| Exotic aquatic fauna | Presence of exotic fauna |
| **Riparian Zone Criterion** | |
| Indigenous vegetation removal | Removal of vegetation associated with the riparian zone |
| Exotic vegetation encroachment | Encroachment of exotics in riparian zone |
| Erosion | Erosion affecting run-off and sediment load into the water body |
| Villages | Presence of villages in the catchment |
| Roads/Paths | Presence of roads or paths in the catchment |
| Burning | Affects of burning in the catchment |
| Cropping | Extent of cropping affecting the catchment |
| Excavation | Excavation activities within the catchment |
| Trampling | Trampling as a result of anthropogenic activities |
| Mining | Salt mining |

Impacts were weighted using a weight matrix and cross comparison. Impact levels were evaluated as a deviation from a perceived natural condition to enable a qualitative assessment of the integrity of a site. Sites were classed from no discernable impairment (zero) to critical impairment (25) (Kleynhans, 1996). A Score summary is provided in Table 4

Table 4: Summary of scoring for impact criteria

| Criteria score | | |
|---|---|---|
| **Description** | **Score** | **Impact category** |
| No discernable Impact, or the factor is located in such a way that it has no discernable impact on habitat quality diversity, size and variability | 0 | **None** |
| The modification is limited to few localities and the impact on habitat quality, diversity, variability and size is very small | 1-5 | **Small** |
| The modification is present at a small number of localities and the impact on habitat quality, diversity, variability and size is also limited | 6-10 | **Moderate** |
| The modification is generally present with a clearly detrimental impact on habitat quality, diversity, large areas are however not influenced | 11-15 | **Large** |
| The modification is frequently present and the habitat quality, diversity, variability of almost the whole section are affected. Only small areas not affected | 16-20 | **Serious** |
| The modification is present overall with a high intensity, the habitat quality, diversity, variability in almost the whole of the defined section are detrimentally influenced | 21-25 | **Critical** |

For the purposes of this survey, the Habitat Integrity Approach was applied with the intention to present an indication of habitat quality rather than impact level, in order to facilitate decision-making regarding the conservation importance of the different water bodies as well as the need to implement restoration plans. Once the scores were weighted, the weighted score for each criterion at each site was calculated by the following equation (Kleynhans, 1999):

$$WS = (SR) \times (25)/CW$$

Where
WS = Weighted Score
SR = Severity Rating = Impact Score given in the field
25 is the maximum possible severity rating in this case
CW = Criteria Weight Percentage

The weighted scores for all the criteria at a particular site were then summed to produce a score indicating what percentage of that site is impacted. This score is subtracted from 100 to give an indication of what percentage of the site is not impacted. This percentage is categorised into impact classes in Table 5.

Table 5: Classification of site impact classes (Kleynhans, 1999).

| Score (%) of Total | Class | Description |
|---|---|---|
| 90-100 | A | Unmodified, natural |
| 80-90 | B | Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the basic ecosystem functions are essentially unchanged. |
| 60-79 | C | Moderately modified. A loss and change of natural habitat and biota has occurred, but the basic ecosystem functions are still predominantly unchanged. |
| 40-59 | D | Largely unmodified. A large loss of natural habitat, biota and basic ecosystem functions has occurred. |
| 20-39 | E | The loss of natural habitat, biota and basic ecosystem functions is extensive. |
| 0-19 | F | Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances, basic ecosystem functions have been destroyed and the changes are irreversible. |

# 4. RESULTS AND DISCUSSION

## CLASSIFICATION OF AQUATIC SYSTEMS

The classification of the freshwater aquatic systems is based on a single survey at the end of the dry season. This presents a major limitation to the overall survey, since it was not possible to assess the level of connectivity between the different (currently isolated) water bodies.

The current delineation between pans and lakes is regarded as an artificial one since it is based only on size. This delineation is however regarded as important and is related to the perceived sensitivity of the water body to impairment. Smaller water bodies generally have a lower resistance to change than larger systems. This difference in resistance (ability to withstand change) and resilience (ability to recover from change) between small and large systems necessitates a division between small and large systems for management purposes.

### Pans

Pans are regarded as water bodies without in- or outflow (endorheic) that are fed through rainwater run-off or recharged by groundwater. Pans are generally smaller than approximately 20ha, deeper than 1m and could dry up on a seasonal basis. Pans on the sanctuary are divided into vegetated pans e.g. Nhahotsane Pan, Switsangweni Pan, Jacana Pan and non vegetated pans i.e. Tirweni Pan.

### Lakes

Lakes are not necessarily closed water bodies and are much larger, typically larger than 30 ha and deeper than 3m. Lakes are generally permanent and are maintained through run-off, groundwater recharge or surface water inflows.

### Freshwater Marshes

The freshwater marshes (Jane Marsh & Xilowane Marsh) on the sanctuary are open systems and drains into the ocean or estuary. These marshes are densely vegetated and supports only small areas of non-vegetated open water. The marshes are maintained through rainwater and/or groundwater recharge.

### Ecotone Marshes

Ecotone marshes are the transitional areas between the freshwater and marine environments. These are highly fragile ecosystems since the maintenance of these systems depends on a delicate balance between the influx of both fresh and salt water and any alteration to this balance can have far reaching implications on the functioning of the marsh. Such impacts are still evident from the destruction that resulted from the 2000 floods.

The Ecotone marshes are divided into marshes that are maintained by inflow of surface freshwater e.g. Xilowane Ecotone marsh, and marshes that are maintained by freshwater seepage e.g Msasa Ecotone marsh, Mazolo Ecotone marsh, Madaca'munhu Ecotone marsh, Airstrip Ecotone marsh and Marapi Ecotone marsh.

## HYDROLOGY

### Rainfall

The rainfall in the VCWS will be seasonal with summer rainfall and the winters relatively dry. The Mean Annual Precipitation (MAP) is likely to be in the range 750 mm to 800 mm. The coast of Mozambique is subject to the occasional cyclone activity, which could cause extreme rainfall conditions to occur.

### General hydrological description

The VCWS is situated in sand dune systems along the coast to the north of Maputo. The system consists of a series of lakes swamps and pans set in the coastal dunes. There are no major river systems passing through or feeding the current extent of the VCWS area. The water generated in the VCWS is by direct rainfall or the tidal influx from the sea in certain areas.

The system of lakes and pans is essentially driven by the groundwater system under the dunes. The dune sands have relatively high hydraulic conductivities and therefore high infiltration rates. The rainfall intensities associated with typical storms in the area would infiltrate into the dunes down to the water table causing the water table level to fluctuate. In intense storm events or storms of long duration, the water table will rise to the surface and the sands will become saturated. The rainfall would then flow over the surface to the water bodies. In general however the water would flow subsurface to maintain the surface water bodies (Figure 1).

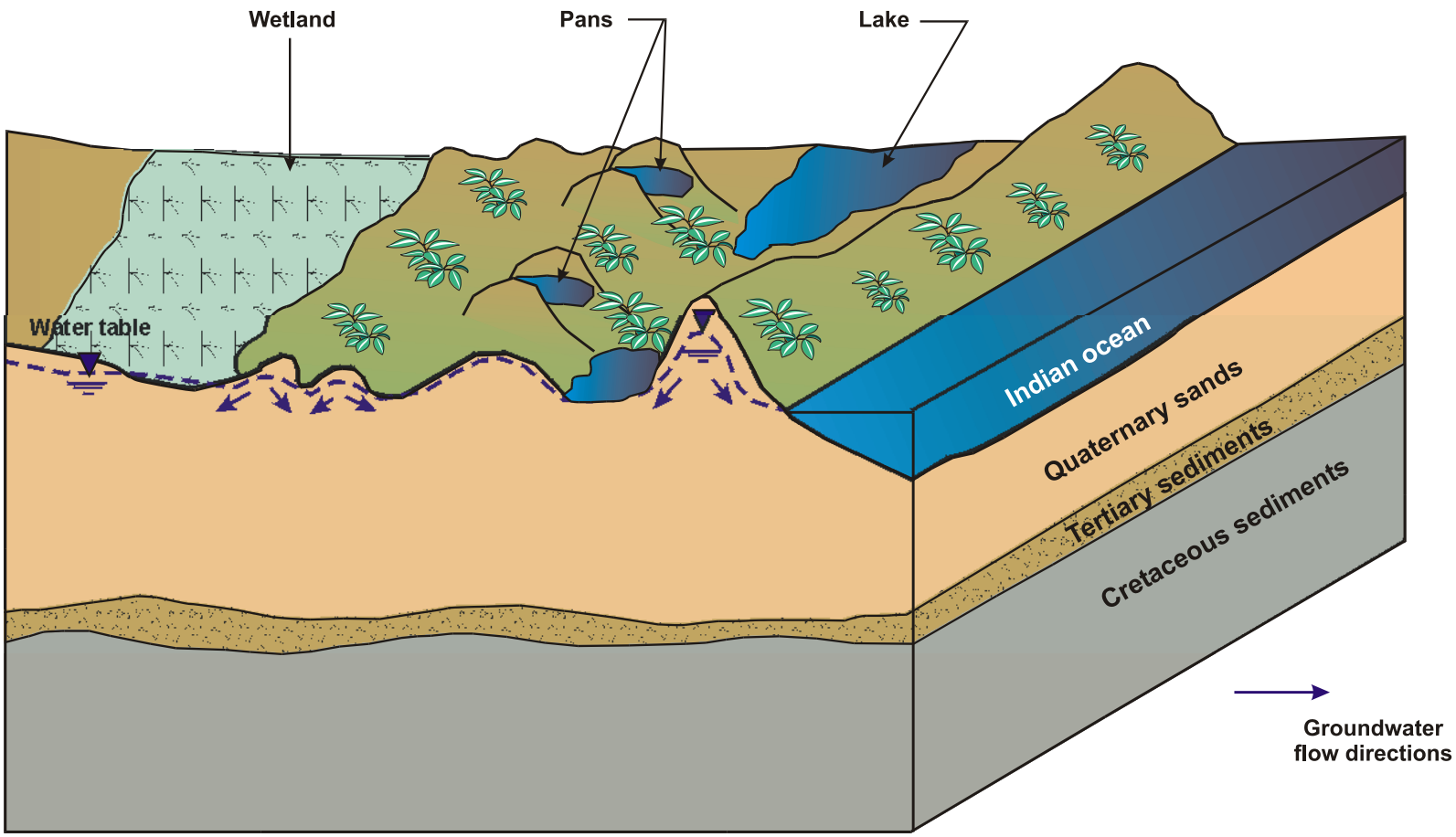


**Figure 1 : Schematic of ground and surface water interaction**

The nature of the subsurface flow would depend on the topography, geology of the dunes and hydraulic conductivities of the particular basin. The subsurface flow could reach the water bodies in the following ways: -

- Subsurface flow all the way to the body;
- The subsurface flow could daylight in the form of a spring or seepage area which would then flow over the surface to the water body;
- Within a particular catchment, the local conditions could vary such that the water bodies could be fed by both mechanisms.

The groundwater catchments could be quite different from the surface water catchments. The groundwater surface in the dunes would define the water bodies that are linked. The individual basins or catchment areas could therefore be linked through the groundwater. One water body could flow into another. A series of boreholes, topographical survey (contour plan of the area) and hydrographic survey of the lakes/pans would enable the groundwater catchments and flow directions to be defined.

**Water Quality**

*In situ* water quality measurements were made on site and are presented in Table 6. Water quality has a direct effect on aquatic biota and is also important in defining the specific characteristics of a site.

**Table 6**: *In situ* water quality.

| Site | Date | Time | Temp(°C) | TDS(ppm) | Turbidity(mm) |
|---|---|---|---|---|---|
| Xilowane Marsh | 29/08/02 | 10:31 | 27 | 310 | |
| Nhahotsane Pan | 30/08/02 | 13:10 | 28.5 | 240 | 2170 |
| Njone Lake | 31/08/02 | 15:35 | 28.5 | 990 | 690 |
| Tirweni Pan | 1/9/2002 | 9:04 | 26 | 260 | 210 |
| Switsangweni Pan | 1/9/2002 | 10:32 | 28 | 190 | 750 |
| Jacana Pan | 1/9/2002 | 15:14 | 29 | 420 | 570 |
| Mukwe Lake | 2/9/2002 | 12:38 | 29 | 230 | 1350 |
| Manhale Lake | 5/9/2002 | 13:33 | | 670 | 570 |
| Madaca'munhu Ecotone | 4/9/2002 | 15:06 | | ADL | |
| Jane Marsh | 10/9/2002 | 11:08 | 26.3 | 200 | 750 |
| Msasa Ecotone | 3/9/2002 | 10:12 | | 1990 | |
| Mazola Ecotone | 4/9/2002 | 11:00 | | ADL | |
| Marapi Ecotone | 3/9/2002 | 14:15 | | ADL | |

ADL = Above detection limit

Although water quality parameters were generally of high standard, and no major pollution sources were identifiable, TDS and Turbidity ranges are worth mentioning. The total dissolved salt load ranged between 190 mg/l to 990mg/l for the inland freshwater systems and were much higher for the Ecotone marshes ranging from 1990mg/l up to 33000mg/l. Turbidity also varied from as high as 2170mm to only 210mm secci direct measurement. The cause for the difference in salt loading in Njone Lake is at this stage not clear. Table 7 gives the results for the sample from Mukwe Pan that was taken for laboratory analysis.

**Table 7: Water quality results from Mukwe Pan**

| Analysis Results | mg/l |
|---|---|
| ***Total Dissolved Solids*** | **188** |
| ***Chlorides as Cl*** | **63** |
| ***Total Alkalinity as $CaCO_3$*** | **20** |
| ***Fluoride as F*** | **<0.01** |
| ***Sulphate as $SO_4$*** | **1.3** |
| ***Calcium as Ca*** | **2.44** |
| ***Magnesium as Mg*** | **2.80** |
| ***Sodium as Na*** | **17.9** |
| ***Iron as Fe*** | **<0.01** |
| ***Manganese as Mn*** | **<0.01** |
| ***Conductivity at 25° C in mS/m*** | **27.7** |
| ***pH-Value at 25 ° C*** | **7.08** |
| ***Boron as B*** | **0.06** |
| ***Aluminium as Al*** | **<0.01** |
| ***Total Coliform Bacteria per 100ml*** | **110** |
| ***Faecal Coliform per 100 ml*** | **60** |
| ***Heterotrophic Plate Count per 1,0ml*** | **339** |

**AQUATIC INVERTEBRATES**

Due to time constraints aquatic macro-invertebrates were only collected from the pans and lakes visited during the study and not from the Ecotone marshes. A total of 37 aquatic macro-invertebrate taxa were sampled at nine sites during the survey and are presented in Appendix 1.

Some invertebrate taxa that could be regarded as sensitive to water quality impairment were collected (seed shrimp, pale burrower etc.) from all sites. Of specific importance are the seed shrimps collected from Mukwe Lake. Seed shrimps usually occur under conditions with elevated salt concentrations. The site at which they occurred had a fairly low TDS of 230. Freshwater sponges, another taxa sensitive to water quality impairment, were also collected from Xilowane Pan and Lake Mukwe.

### Diversity of taxa

The number of taxa and % diversity for each site are represented in Table 8.

Diversity of the macro-invertebrate fauna associated with the freshwater system is generally low. The reason for this is ascribed to the lack of any flowing/rocky biotopes known to support high diversities.

The diversity assessment focussed on the truly freshwater systems and no macro-invertebrate collections were made from the Ecotone Marshes.

**Table 8:** The number of taxa collected, the % of taxa collected and the diversity score for each site.

| Site | No# of taxa | % Total taxa | Diversity score |
|---|---|---|---|
| Nhahotsane pan | 15 | 40.54 | Medium |
| Xilowane marsh | 33 | 89.19 | High |
| Njone lake | 16 | 43.24 | Medium |
| Tirweni pan | 9 | 24.32 | Low |
| Manhale lake | 13 | 35.14 | Medium |
| Jane marsh | 17 | 45.95 | Medium |
| Switsangweni pan | 10 | 27.03 | Low |
| Jacana swamp | 12 | 32.43 | Low |
| Mukwe lake | 18 | 48.65 | Medium |
| TOTAL | 37 | 100.00 | |

0 – 33% = Low diversity
34 – 66% = Medium diversity
67 – 100% = High diversity

The variation in the diversities of Invertebrate Taxa amongst different freshwater bodies can probably be related to intrinsic biotope diversities.

**Taxa of conservation importance**

A freshwater sponge was collected from Mukwe Lake. Freshwater sponges are known to be highly sensitive to water quality alterations and are therefore regarded as good indicator organisms. An Ostracod was also collected from Mukwe and awaits identification.

**FISH**

Very low fish diversities were collected from the different sites. The collected species represented mostly generalist and widespread species. This low diversity is ascribed to the absence of any river system that feeds the area. The dominant species sampled was *Oreochromis mossambicus.* This species was collected from all the different freshwater types visited during the field survey and was, except for the marshes (Freshwater & Ecotone) and Njone Lake, the only species collected from the endorheic pans. Other species collected during the survey included *Barbus paludinosus, Clarias gariepinus, Awaous cf aeneofuscus* and a Gobiidae species from Njone Lake that is awaiting identification. Mud skippers (*Periopthalmus koelreuteri)* were sampled from most of the Ecotone marshes.

**Fish resource utilization**

Length frequency distributions were drawn up for four of the sites where local people are known to harvest the freshwater fish resource. At all these sites sufficient numbers of *Oreochromis mossambicus* were caught to allow a brief evaluation of resource utilization. Figures 2 – 5 presents the length frequencies of *O. mossambicus* for the different water bodies.

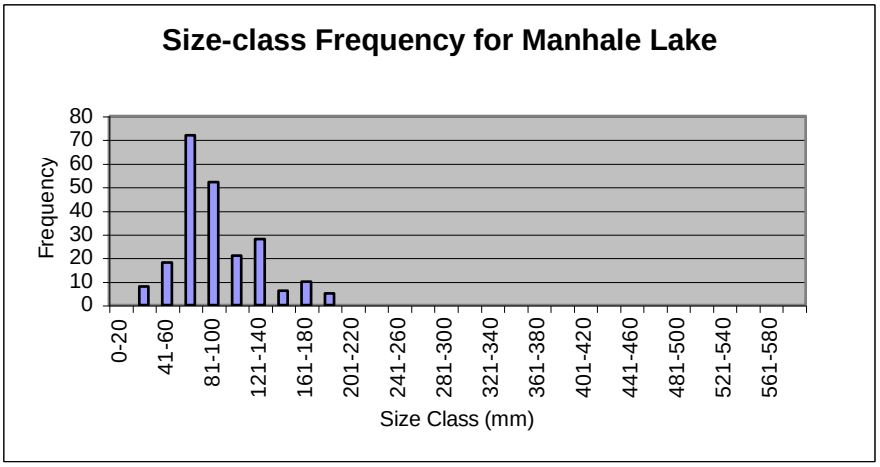


Figure 2: Size-class Frequency of *Oreochromis mossambicus* sampled in Manhale Lake

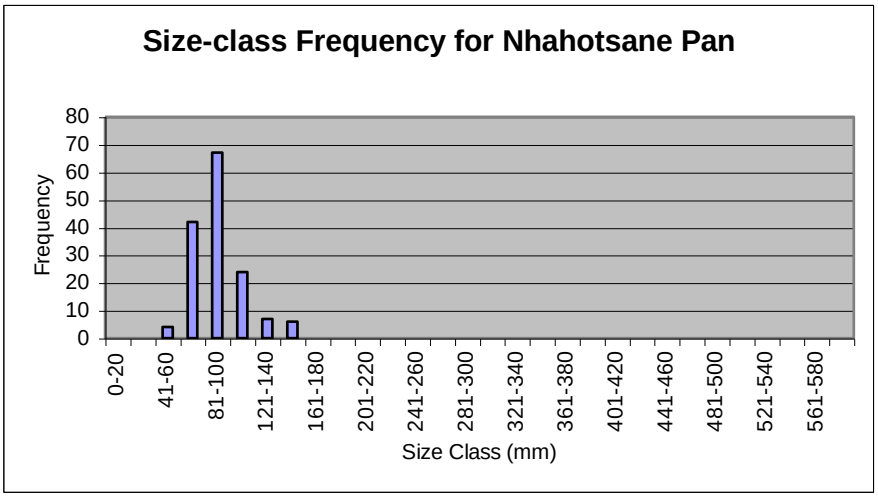


Figure 3: Size-class Frequency of *Oreochromis mossambicus* sampled in Nhahotsane Pan

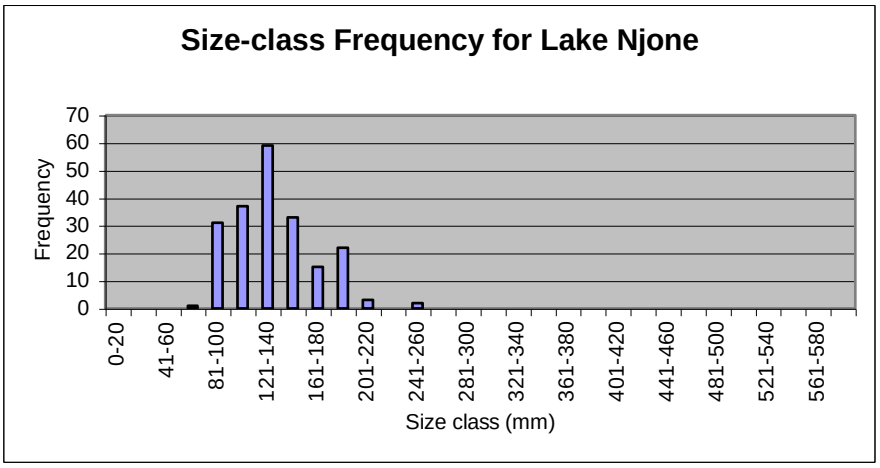


Figure 4: Size-class Frequency of *Oreochromis mossambicus* sampled in Lake Njone

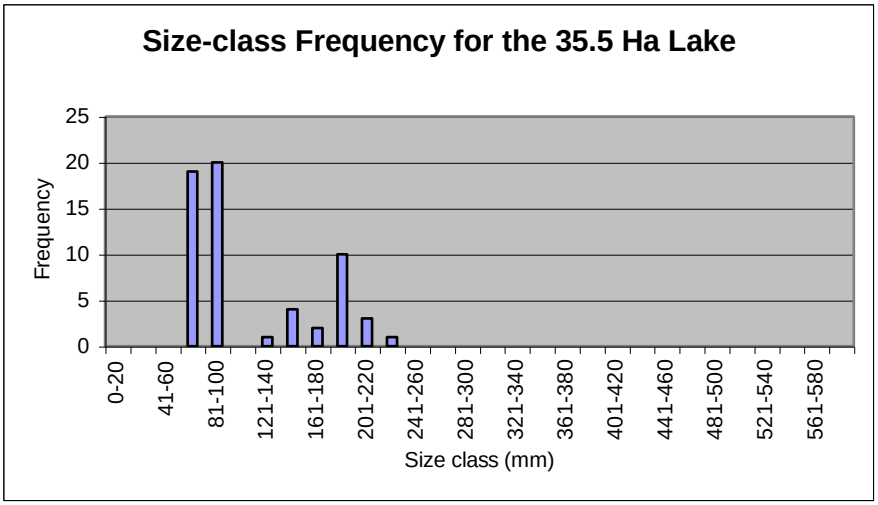

Figure 5: Size-class Frequency of *Oreochromis mossambicus* sampled in Lake Mukwe

From the length frequency distributions it is evident that the populations associated with the different lakes cannot necessarily be regarded as over exploited since different size classes were generally represented in the collected samples. Possible indications of over exploitation can however be inferred from the lack of large individuals from the lakes known to be the best fishing areas in the sanctuary (discussed with local fishermen). The length frequency distribution for Mukwe Lake is also of concern since some pressure must be the cause for the non-typical length frequency distribution recorded from the Lake. This is however more likely related to intrinsic habitat conditions or ecological pressures in the lake rather than fishing pressure, since the lake is not regarded as a good fishing area (overgrown with aquatic macrophytes). The length frequency distributions were described from the once off survey in the lakes and pans, and should therefore not be regarded as representative of the actual population structure in the lakes and pans but as an indication of overexploitation as well as the general status of these populations.

**Issues of conservation importance**

Three issues are of specific conservation importance:

- The likely presence of the Burrowing Goby *Croilia mossambica* within the Ecotone marshes, typically Msasa marsh which is fed by surface freshwater.
- The Gobiidae species collected from Njone Lake.
- The variation in colour patterns of *Oreochromis mossambicus* from Mukwe Lake indicating isolation from other populations on the sanctuary as well as from mainland populations.

## HABITAT INTEGRITY ASSESSMENT

Aquatic ecosystems are very sensitive to physical and chemical changes (Maitland & Morgan, 1997), since they represent that component of the ecosystem where catchment level impacts ultimately culminate. In order to assess the Integrity of the sites an evaluation exercise was implemented to ensure a fair evaluation of impairment levels associated with the VCWS.

The site integrity scores are summarised in Table 9 along with the associated impact classes

**Table 9:** Site Integrity Score Summary

| Site | Score | Class |
|---|---|---|
| Airstrip | 87.08 | B |
| Xilowane | 95.36 | A |
| Madaca'munhu | 93.21 | A |
| Manhale | 87.52 | B |
| Msasa | 94.10 | A |
| Mazolo | 94.28 | A |
| Mukwe | 96.04 | A |
| Marapi | 96.35 | A |
| Jacana | 97.90 | A |
| Switsangweni | 98.04 | A |
| Njone | 89.77 | B |
| Tirweni | 92.23 | A |
| Nhahotsane | 94.90 | A |

From this assessment it is evident that the habitat integrity of the different freshwater systems associated with the VCWS are generally of an exceptionally high status. The impairment levels at all these freshwater systems are still regarded as of a limited nature that can be restored since it is not affecting the overall functioning of these water bodies. The only exception to this is the impacts on the Airstrip Ecotone that could result from the excavation associated with the landing strip. Although the excavation of the drainage line into the salt marsh has not yet resulted in the onset of erosion it represents a nick point in the drainage line that could threaten the functioning of the whole marsh by erosion.

Both Manhale and Njone Lakes also indicate generally increased impairment levels. This is attributed to the importance of these lakes as fishing areas and the resultant high anthropogenic pressures on the lakes.

An overlay of the site percentage scores for each site is presented in Figure 6 with a bar graph giving the summed habitat integrity scores before they were weighted.

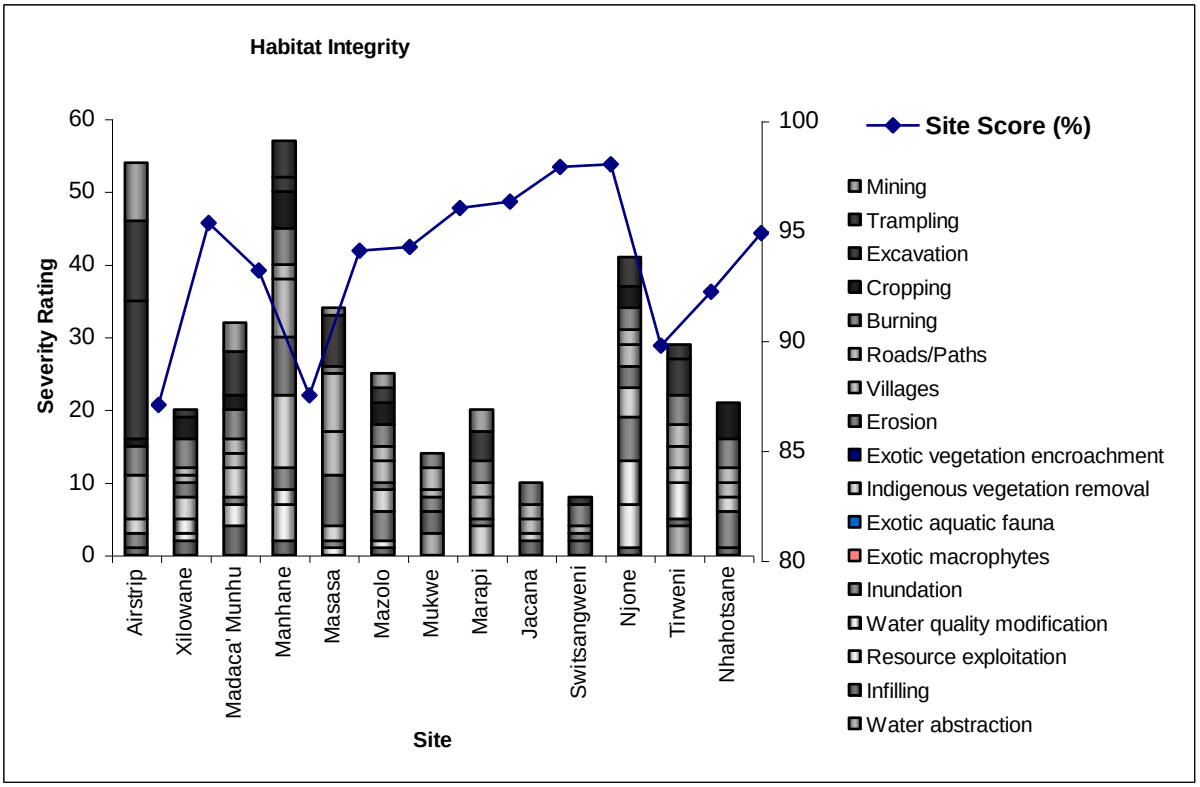


**Figure 6:** Overlay of Integrity score over Summed severity ratings for each site.

## 5. MANAGEMENT STRATEGY

### IDENTIFICATION OF IMPORTANT ECOLOGICAL ATTRIBUTES

The overall intention of the work was to identify conservation needs and priorities. The basis for this identification followed an approach of identifying the important ecological issues relevant to VCWS. The principal criteria for the selection of such ecological issues are regarded as (Maitland & Morgan, 1997):

- Naturalness: Most freshwater habitats have been influenced by man to some extent and are no longer in an unimpacted or natural state. Sites in the least impacted condition are therefore of higher conservation value. The naturalness of the different freshwater bodies is presented as the integrity of the sites as determined under sections 3.5 & 4.5.
- Habitat diversity: Habitat diversity can give an indication of the potential of a site. A site with greater habitat diversity is generally able to support greater species diversity and is therefore regarded as of higher conservation importance than sites with lower diversity.
- Species diversity: Sites that contain high species diversity are generally regarded as of higher conservation importance.
- Extent: In general, larger sites contain greater diversity, simply because they cover a larger area and are more likely to contain a greater variety of habitats. Large sites are also more resistant to changes. It was not possible to do an evaluation of the extent of the different water bodies, since aerial photographs of the area were not available that would allowed for the quantification of the area of the different water bodies.

- Rarity or uniqueness: Species or habitats that are rare or occur outside of their normal distribution at a particular site are of high conservation priority. Unique sites are therefore regarded as important.
- Fragility (viability): Some species have very specific requirements and are vulnerable to changes in their environment. Sites supporting sensitive organisms are therefore regarded as of a higher conservation importance than sites supporting generalist, non-sensitive species.
- Representativeness: The full range of variation in a region should be protected. In other words, all species should be represented in a protected area. The conservation approach should therefore be to include all different habitat types present in the sanctuary within the protected area.

The outcome of the evaluation based on these criteria is presented under Table 10.
From this table it is evident that several of the freshwater components associated with the sanctuary are of significant conservation importance. The threats identified under section 3.5 are used as the basis to decide on prioritising conservation actions required for the different water bodies.
Each of the different freshwater bodies sampled during the field survey are described separately.

**Manhale Lake**

Manhale Lake hosts a significant fisheries resource to the local people around the Lake. The impacts affecting the lake are as a result of this, the highest of all the lakes and pans. Since this lake represents a large system, the fragility of the lake is however regarded as much lower than, for example, that of the Ecotone marshes. The urgency of conservation and restorative actions are therefore regarded as of a lower priority than addressing those impacts threatening Msasa marsh. The impacts threatening Manhale includes cropping, burning, erosion, resource utilisation, villages as well as indigenous vegetation removal. The integrity of Manhale is listed as of a Class B integrity (Largely natural with few modifications - a small change in natural habitats and biota may have taken place but the basic ecosystem functions are essentially unchanged). Due to the high importance of the Manhale fisheries as a resource to the local people, implementation of a socio-economic evaluation to assess the importance of the resource, versus the status of the resource, is of utmost importance and should be implemented over the short term. Such a program can at the same time serve a purpose as the basis for a community participation program to implement restorative actions that would curb the impacts threatening the lake e.g. burning, erosion and indigenous vegetation removal.

**Njone Lake**

Njone Lake probably represents the most unique inland system on the sanctuary. It is a turbid lake with a high salt load, which hosts a unique (within the boundaries of the sanctuary) Gobiidae species (submitted to the South African Institute for Aquatic Biodiversity (SAIAB) for identification). The lake further supports the highest habitat diversity of all the pans and lakes visited during this dry period. The lake is threatened by resource exploitation, the presence of villages, burning, water quality alteration (probably natural, cause of high salt loading not known) and inundation as a result of the 2000 floods. The lake is therefore regarded as of a Class B integrity (Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the basic ecosystem functions are essentially unchanged).

The same approach is recommended for Njone as for Manhale i.e. implement a socio-economic evaluation over the short term to assess the importance of the resource, versus the status of the resource. Expand such a program to a restoration initiative to address the threats currently affecting the lake.

**Mukwe Lake**

Water abstraction, infilling and roads are the main impacts affecting Mukwe Lake. The lake is largely overgrown with aquatic macrophytes, but supports a unique (within the boundaries of the sanctuary) Ostracod (submitted for identification). The colour patterns within the *O. mossambicus* population sampled from the lake further differs from that sampled from the other populations on the sanctuary and probably suggests a longer period of isolation from the other populations. The strategy proposed for Mukwe Lake is regarded as a medium term strategy intended to monitor the status of the lake and conduct ecological attribute research on the lake.

**Madaca'munhu Ecotone Marsh**

The Madaca'munhu Ecotone Marsh receives freshwater through underground recharge. The Ecotone is narrow and does not present open freshwater habitats for inhabitance by freshwater fauna. The marsh is threatened by Salt mining, trampling, resource utilization, indigenous vegetation removal and infilling. The strategy proposed for the marsh is regarded as a medium term one intended to monitor the status of the lake and conduct ecological attribute research on the lake.

**Airstrip Marsh**

Excavation and an airstrip have recently impacted on the Airstrip Ecotone marsh. The drainage line that naturally supported the Ecotone and the salt marsh has been excavated to facilitate storm and flood water drainage away from the airstrip. This development was implemented during the dry season and the onset of likely effects that might result from the channelisation of the drainage line, have at the time of the survey not affected the functioning of the marsh. The threat posed by the alteration of the natural drainage line to the overall functioning of the marsh, served as the cause for a Class B integrity classification for the marsh. It is recommended that mitigative actions be implemented immediately to alleviate the erosion threat posed by this development to the overall functioning of the marsh.

**Msasa Marsh**

Msasa Marsh presents a diverse habitat and probably supports a red data species (Cr*oilia mossambica).* The presence of this species could however not be verified.

Erosion, trampling and roads through the marsh have impacted on Msasa Marsh. The ecological functioning of the marsh is however still regarded as natural, but these impacts as well as erosion that resulted from the 2000 floods, needs to be addressed. The impacts threatening Msasa Marsh requires immediate action to ensure that the habitat integrity at this marsh is maintained as a Class A. It is therefore recommended that mitigative actions be implemented immediately to prevent further impacts on the marsh and alleviate the threats posed by existing impacts on the marsh' overall functioning.

**Mazolo Ecotone Marsh**

This Ecotone marsh is affected through cropping, removal of indigenous vegetation, burning, the presence of villages as well as inundation. These impacts are generally localized and do not threaten the overall functioning of the marsh. Habitat integrity at Mazolo marsh is therefore regarded as representative of a Class A. The marsh supports a diverse habitat type that ranges from an extensive area covered with knee roots to open sand flats and open surface waters. The marsh is fed both through surface seepage as well as underground seepage. Although the marsh is also (like Msasa) regarded as very sensitive to perturbations it is remote and not accessible by vehicle. Future threats will therefore likely be limited to that currently affecting the marsh. The strategy proposed for the marsh is regarded as a medium term one intended to monitor the status of the marsh and to conduct ecological attribute research on the marsh. An environmental training program is also recommended to ensure that the local people understand the importance of such a marsh and to promote sustainable utilization practices.

**Marapi Ecotone Marsh**

Marapi Ecotone marsh is small in relation to the other marshes and do not support a diverse habitat. The marsh is fed through groundwater and did not support any surface freshwater. The habitat is therefore limited. Marine Pipefishes (Syngnathidae) were however collected from this site. These fishes seem to have very specific habitat requirements and were only recorded from this area. Marapi Ecotone marsh is regarded as a Class A marsh and the associated impacts only affects small areas of the marsh. These impacts include burning, mining, trampling, villages and indigenous vegetation removal. The marsh is however also fairly remote and may therefore not be threatened by additional impacts. The strategy proposed for this marsh is regarded as the same as for Mazolo marsh.

**Jane Marsh**

Jane marsh is regarded as the biggest and least impacted of the freshwater marshes associated with VCWS. The impacts associated with the marsh include resource utilization, roads, villages and indigenous vegetation removal. These impacts are however very isolated and only affects small areas within the habitat types. Both marshes provided the highest species diversities for fish recorded on the sanctuary. This higher diversity therefore ensures a higher conservation importance for the marshes. Jane marsh is also remotely situated and may therefore not be threatened by additional threats that may stem from the development. The strategy proposed for Jane Marsh is regarded as similar to that proposed for the previous two Ecotone marshes and is seen as a strategy that should be implemented over the medium term with the focus on ecological attribute research as well as for environmental education.

**Xilowane Marsh**

Xilowane marsh is affected by burning, cropping and indigenous vegetation removal. The marsh is regarded as a Class A marsh. The fish diversity was again highest for this area and therefore warrants a higher conservation importance. The threats on the marsh could increase, since the area is exposed to the new road constructed to provide access to the southern most boundary of the first phase. This freshwater marsh also supports a wide variety of habitats. The strategy proposed for the marsh is regarded as the same to that for Jane Marsh.

**Tirweni Pan**

This pan represents the only pan, visited during the survey, that does not support any aquatic vegetation. Although this pan is therefore regarded as unique, no unique taxa were collected during the field survey and its conservation importance is regarded as lower than for example Njone Lake. The pan is impacted on through excavation, burning, water quality modification (cause unknown) and water abstraction. The pan is regarded as on the border between Classes A and B, although it is still grouped in Class A. The conservation actions required is therefore regarded as the same strategy proposed for Msasa Ecotone Marsh, i.e. that mitigative actions be implemented to prevent further impacts on the marsh and alleviate the threats posed by existing impacts on the pans' overall functioning. Implementation of such actions in the immediate future is however not regarded necessary, since the pan is not regarded as a specifically sensitive pan. Mitigative actions should however be implemented over the medium term.

**Switsangweni Pan**

Switsangweni Pan is regarded as the water body with the highest integrity score of all the different freshwater bodies visited during the survey. It maintains a upper Class A, but does not support specifically sensitive or unique faunal taxa. This pan is impacted on by burning and infilling. The same conservation actions recommended for Jane Marsh is regarded as relevant to this pan and it should only be implemented over the medium term.

**Nhahotsane Pan**

Nhahotsane Pan is also regarded as a Class A pan despite the impacts affecting the pan, i.e. cropping, burning and inundation. No unique habitats or taxa were collected from the pan. The same strategy as for Njone Lake is recommended, except that rehabilitation efforts may not necessarily be required.

**Jacana Pan**

Jacana pan is after Switsangweni pan the least impacted. It is affected through burning as well as the presence of villages. This pan also represents a high integrity score and is therefore regarded as a Class A water body. The conservation strategy proposed for Jacana Pan is therefore regarded as the same to that proposed for Njone Lake except that rehabilitation efforts may not necessarily be required.

**Table 10**: Identification of Important Ecological Attributes.

| | | | Lake | | | Ecotone marsh | | | | | Marsh | | Pan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Manhale | Njone | Mukwe | Madaca'munhu | Airstrip | Msasa | Mazolo | Marapi | Jane | Xilowane | Tirweni | Switsangweni | Nhahotsane | Jacana |
| Clarity | | | Mod | Low | Mod | - | - | - | - | - | Mod | Mod | Mod | Mod | High | Mod |
| Conductivity | | | Mod | High | Low | - | - | - | - | - | Low | Low | Low | Low | Low | Mod |
| Diversity | Habitat | | Low | High | High | Low | Low | High | High | Low | High | High | Low | Mod | Mod | Low |
| | Bio | Macro-inverts | Mod | Mod | Mod | * | * | * | * | * | Mod | High | Low | Low | Mod | Low |
| | | Fish | Low | Mod | Low | Abs | Abs | Mod | Mod | Mod | High | High | Low | Low | Low | Low |
| | | Unique habitat or taxa | Abs | Pres | Pres | ? | ? | Pres? | Pres | Pres | Abs | Abs | Pres | Abs | Abs | Abs |
| | | Red data | ? | ? | ? | ? | ? | Pres? | ? | ? | ? | ? | ? | ? | ? | ? |
| Integrity (Naturalness – Table 6) | | | B | B | A | A | B | A | A | A | A | A | A | A | A | A |
| Resource use | | | High | High | Low | Low | Low | Low | Low | Low | Mod | Low | Low | Low | Low | Low |
| Fragility | | | Low | Low | Low | High | High | High | High | Mod | Low | Mod | Mod | Mod | Mod | Mod |
| Threats | | | Mod | Mod | Low | Low | High | High | Low | Low | Low | Low | Low | Low | Low | Low |
| Conservation action required | | | Short | Short | Med | Med | Imm | Imm | Med | Med | Med | Med | Med | Med | Med | Med |

- = Not applicable
* = Not sampled
? = Not known
Mod = Moderate
Abs = Absent
Pres = Present
A, B = Integrity classes, A =Pristine, B = Largely natural with few modifications
Short = Short term future 1-2 years
Med = Medium term future 2-5 years
Imm = Immediate
RED = Important issues

## PROPOSED MANAGEMENT STRATEGY

The success of any conservation strategy depends entirely on the realm within which the day-to-day running of such a strategy occurs. Any management strategy therefore has to take cognisance of all threats and pressures that could jeopardize the success of the overall conservation strategy. Any trade-offs, socio-economic versus ecological, must be justified only in accordance with the overall conservation objective. Such a conservation objective is therefore needed for the fresh water aquatic system to ensure that the conservation thrust is focussed and dedicated towards achieving a certain objective. Ascribing to such an objective will ensure accountability and will facilitate performance evaluation.

### Proposed Conservation Objective for the Freshwater Aquatic Systems

***"To design, promote and maintain a strategy that would allow the sustainable utilization of natural resources associated with the Freshwater Aquatic Ecosystem on the VCWS in such a manner that it would ensure the preservation of the physical, chemical and biological integrity of the freshwater aquatic system associated with the VCWS"***

The framework proposed for the implementation of this objective is regarded as an interactive strategy that would facilitate a process of adaptive management based on the outcome of ongoing research and monitoring. The management framework for the freshwater aquatic system is regarded as a three-legged approach where all conservation actions are supported by sound scientific evidence, generated from ongoing research, and where such actions are supported by and implemented within a locally accepted legal framework.

### Conservation Management Framework

The conservation framework is regarded as the operational component of the overall strategy and should include the following actions:

- Approval of the conservation objective
  - Convene a workshop where local, national as well as individual role players are represented. Present the conservation objective to all relevant role players and seek general approval.
- Design conservation goals that would facilitate the achievement of the objective
- Implement tasks to achieve conservation gaols which should include:
  - Impact assessments
    - Assess the significance of impacts associated with previous and new developments and design mitigative actions to ameliorate all significant negative impacts.
  - Ongoing monitoring
    Until such time that an index or indices are developed to measure the integrity of the wetlands it is recommended that a simplified approach is implemented to serve as the basis for identifying likely threats to the FAS associated with the VCWS
    - Identify sites to be incorporated in the monitoring program, these sites could be selected based on results from this survey i.e. include Msasa Ecotone marsh, Airstrip Ecotone marsh, Njone Lake and Manhale Lake,

but must be expanded to include all freshwater systems associated with the sanctuary
        - Delineate the sites and the impacts effecting the sites if these can be delineated on aerial photographs
        - Regularly visit (to represent seasonal variation) these sites and visually assess the impact levels using strategies like fixed point photography or video graphic approaches as well as visual estimates of effect levels (how much of the site is visually affected on a percentage basis) of identified impacts
        - Use these as screening techniques to prioritise & identify actions required as the basis for the rehabilitation and restoration strategy
    - Restoration and rehabilitation
        - Design and implement a restoration and rehabilitation strategy based on participatory rural appraisal (PRA) methods to ensure buy-in of the local people
    - Sustainable utilization of natural resources
        - Design and implement a management strategy, using PRA methods, that allows responsible and sustainable utilization of the natural resources associated with the Freshwater Aquatic Ecosystem in a manner that would not be detrimental to the overall integrity of the natural resources on VCWS.
- Ongoing evaluation of the conservation framework
    - Design and implement a strategy that would facilitate evaluation of:
        - performance of the company
        - performance of the restorative and mitigative actions
        - performance of the different conservation goals to achieve the conservation objective
        - identification of any limitations

**Legal Framework**

The conservation objective will have to be scrutinized at a legal and institutional level to evaluate whether existing legislature and or laws (national & communal) provides a sound basis for the protection of the freshwater aquatic system. Sectoral issues that may affect or hamper achievement of the conservation objective (use of scarce resources or introduction of exotics) needs to be identified and action plans must be designed to ameliorate such threats. The tasks associated with the legal framework is regarded as:

- Review existing institutional and legal frameworks
- Review existing laws, national & communal
- Identify Issues
- Design and implement action plans to ensure the preservation of the integrity of natural resources within a framework of sustainable utilization

**Research Framework**

The research framework is intended as the basis for the conservation strategy proposed for VCWS. Research is regarded as necessary mainly in the following two fields: Resource

utilization and Ecological attributes. Information generated from this research should serve as the basis for decision-making within the conservation framework.

***Resource Utilization***

The extent of resource utilization from the freshwater aquatic system is currently not known. The only approach that would facilitate quantification, of such utilization, is regarded as one where the socio-economic research is conducted within an ecological context. Such research should verify the following issues:

- The socio-economic importance of the resources
- The extent, type and seasonality of utilization
- Harvest strategies and post harvest preservation techniques to maximize collection efforts and reduce pressure
- The perceived ownership over the resources
- The current methods of control over natural resource utilization e.g. seasonal use
- The perceived changes to resource status
- The actual ecological status of such resources
- The identification of resources not being used

This information should then serve as the basis for the design of a future management plan. Such a plan should again be implemented using Participatory Rural Appraisal Techniques to ensure instilment of local ownership over the management plans.

***Ecological Attributes***

Research regarding ecological attributes is required in the following fields: Species assessments, Functional assessments and Integrity assessments.

<u>Species Assessments</u>

- Biodiversity
    - Identify biodiversity hotspots
    - Identify areas with unique taxa
- Distribution & abundance
    - Delineate species specific distribution ranges only for rare and sensitive species
    - Delineate boundaries of biodiversity hotspots
    - Conduct abundance assessments for rare and sensitive species
- Population dynamics
    - Assess the status of fish populations under pressure using the following indicators: population structure, recruitment, growth, survival rates, mortality rates and fishing pressure
- General ecology
    - Assess the habitat requirements of sensitive species e.g. *Croilia mossambica* & the Gobiied species from Njone
    - Conduct research on the life history of sensitive species

<u>Functional Assessments</u>

- Habitat
    - Fine tune habitat classification as designed from this survey

- Delineate important habitats based on diversity, uniqueness etc
- Describe species assemblages associated with each habitat type

- Source/ habitat interactions
  - Identify habitat building blocks and describe importance e.g. extent of freshwater input into Ecotone marshes vs influx of salt water; seasonal fluctuations of pans; importance of groundwater level to maintain water levels in the pans

Integrity Assessments/Monitoring

- Identify reference conditions
  - Identify non-impacted ecosystem types as well as impacted ones preferably over a quantifiable impact gradient
  - Characterise and compare the biological assemblages (plants or animals, associated with the wetland systems, combined to form a coherent group) using standardized techniques to present a basis for the identification of bio-criteria
- Develop bio-criteria
  - From the characterization exercise identify those metrics (biological indicator) or combination of metrics, that presents a high correlation with the impact gradient, hence representing the condition of the wetland
  - Use this information to design an index of integrity for the different wetland systems
  - Test and validate the Index on other systems in the area
  - Set as the basis for ongoing monitoring (section 5.2.2)

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**APPENDIX 1.** List of aquatic macroinvertebrates sampled in the study area.

| Organsisms | Nhahotsane | Xilowane | Njone | Tirweni | Manjale | Jane | Switsangweni | Jacana | Mukwe |
|---|---|---|---|---|---|---|---|---|---|
| **Ephemeroptera** | | | | | | | | | |
| Betidae | * | * | * | * | * | * | * | * | * |
| Caenidae | * | * | | | | * | | | |
| Polymitarcyidae | | * | * | | * | | | | |
| **Trichoptera** | | | | | | | | | |
| Hydropsyche | | | | | | | | | * |
| Ecnomidae | * | | | | | | | | |
| Leptoceridae | | | * | | | * | * | | |
| Sericostomatidae | | | * | * | | | | | * |
| **Coleoptera** | | | | | | | | | |
| Dytiscidae | | * | | | | * | * | * | * |
| Gyrinidae | | * | | | * | | | | |
| Hydaenidae | | * | | | | | * | | |
| Elmidae | | | * | | | | | | |
| Helodidae | * | * | | | | | | | |
| Hydrophilidae | | | | | | | | | |
| **Hemiptera** | | | | | | | | | |
| Naucoridae | * | * | * | * | | * | | * | * |
| Belostomatide | | * | * | | | * | | | |
| Notonectidae | * | * | * | * | | * | * | * | * |
| Gerridae | | | | | | * | | | |
| Corixidae | * | * | * | | * | | | * | * |
| Veliidae | * | | | * | | * | * | | * |
| **Odonata** | | | | | | | | | |
| Libellulidae | | * | * | * | * | | | * | * |
| Gomphidae | | * | | * | * | * | * | * | * |
| Corduliidae | | | | * | * | | | | |
| Aeshnidae | * | * | | | | * | | * | * |
| Platycnemididae | * | * | * | | | * | | | * |
| Coenagrionidae | * | | * | | * | * | * | * | * |
| Lestidae | | * | | | | | | | |
| Chlorolestidae | | | | | * | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Diptera** | | | | | | | | | | |
| Chironomidae | * | * | * | * | * | * | * | | * | |
| Simulidae | | * | | | | | | | | |
| Culicidae | * | * | | | | | | * | | |
| **Hydracarina** | | | | | | | | | | |
| Hydrachnellae | * | | * | | * | | | | * | |
| **Annelida** | | | | | | | | | | |
| Hirudinae | | * | * | | | * | * | * | * | |
| Oligochaeta | | | | | | * | | | | |
| **Mollusca** | | | | | | | | | | |
| Physidae | | * | * | | * | | | | * | |
| Lymnaeidae | * | | | | | | | | | |
| Planorbidae | | * | | | * | * | | * | | |
| **Crustacea** | | | | | | | | | | |
| Ostracoda | | | | | | | | | * | |
| **Porifera** | | | | | | | | | | |
| Porifera | | * | | | | | | | * | |
| **TOTAL TAXA** | **15** | **23** | **16** | **9** | **13** | **17** | **10** | **12** | **19** | **38** |

## APPENDIX 2. MAP OF THE STUDY AREA