Preliminary Reserve Determination for the Verlorenvlei (Intermediate), Jakkals (Rapid) and Wadrift (Rapid) Estuaries

November 2021 Field Trip

Contents

1. Scope of Work

The CSIR, NMU and DFFE were approached by BlueScience (Pty) Ltd (Pty) Ltd to conduct an Ecological Water Requirement Study on the Verlorenvlei, Jakkalsvlei and Wadrift estuaries. The study aims to determine the Ecological Water Requirements of these estuaries and evaluate the impact of the future water resources plans on these systems as part of the Berg-Olifants Water Management Area (WMA9) reserve study.

The study on the Verlorenvlei will be on an Intermediate level and Jakkelsvlei and Wadrift on a Rapid level.

The Ecological Freshwater requirement studies on the estuaries will follow the methods as described in DWAF (2008): Resource Directed Measures for Protection of Water Resources: Methodologies for the determination of ecological water requirements for estuaries (Version 2).

As part of the study a once-off reconnaissance level field visits was planned to the Jakkalsvlei and Wadrift estuaries (in spring/summer) in accordance with the data requirements specified in the EWR methods for estuaries (DWAF 2008), while two field surveys (1 detailed and 1 limited) are planned to Verlorenvlei Estuary.

This report summarises the provisional findings of the November 2021 field visit.

2. Field team

The Estuary field team consisted of team members from CSIR, NMU and DFFE. Given the complexity of the study, the field team was enlarged to bring in more expertise and increase data collection efforts.

Table 1: Estuary Team Members

STAFF	AFFILIATION	ROLE
Dr L van Niekerk	CSIR	Estuaries Component leader Estuarine hydrodynamics and physical processes
Dr S Taljaard (not present at field)	CSIR	Estuarine water quality
Dr Daniel Lemley	Nelson Mandela University	Estuarine microalgae & water quality
Prof J Adams	Nelson Mandela University	Estuarine macrophytes & microalgae
Ms Jabulile Nhleko	Department of Environment, Forestry and Fisheries	Estuarine Invertebrates & fish
Dr Stephen J Lamberth	Department of Environment, Forestry and Fisheries	Estuarine Fish & Invertebrates
Dr Gavin Rishworth	Nelson Mandela University	Estuarine Birds & Invertebrates

STAFF	AFFILIATION	ROLE
Dr Taryn Riddin	Nelson Mandela University	Estuarine macrophytes & mapping
Kanakana Mushanganyisi	Department of Environment, Forestry and Fisheries	Assistant Invertebrates
Sivuyisiwe Mbede	Department of Environment, Forestry and Fisheries	Intern fish
Langelihle Nkanyiso Sosibo	Department of Environment, Forestry and Fisheries	Intern fish

3. Estuaries Field Survey

A reconnaissance level field visit was undertaken to Jakkals and Wadrift estuaries on 8th November 2021 following the data requirements in the EWR methods. The survey of the Verlorenvlei was conducted on the 9th and 10th November 2021.

The CSIR (Dr Lara van Niekerk) led the fieldwork and focused on collecting data on the water quality and physical processes.

The Nelson Mandela University was represented by Prof Janine Adams (water quality, macrophytes, microalgae), Dr Taryn Riddin (macrophytes), Dr Daniel Lemley (microalgae and water quality) and Dr Gavin Rishworth (birds) (Figure 1).

The Department of Forestry, Fisheries and the Environment (DFFE) led the sampling of the invertebrates (Ms Jabulile Nhleko) and fish (Dr Stephen Lamberth), supported by three research assistance/interns (Mr Kanakana Mushanganyisi, Mr Sivuyisiwe Mbede, Ms Langelihle Nkanyiso Sosibo) all with a back ground in estuarine ecology.

Figure 1: Nelson Mandela University team. From Left Dr Gavin Rishworth, Dr Daniel Lemley, Dr Taryn Riddin, Dr Lara van Niekerk (CSIR) and Prof Janine Adams.

Figure 2: CSIR, NMU and DFFE team members visiting the culturally significant Elands Bay Caves after a successful field trip.

During the field surveys water and sediment samples were collected, ground-truthing for habitat maps was done, grab samples of invertebrates were taken and fish netted, along with bird counts. Each section will be discussed separately below.

Mouth conditions

As a result of low inflow the mouths of Jakkalsvlai, Wadrift and Verlorenvlei were closed. Traces of overwash was observed at Wadrift and Jakkalsvlei.

Verlorenvlei Sediment samples

During the field visit, it became apparent that the drought and over-abstraction of water from Verlorenvlei, and its associated catchment, has resulted in an unprecedented decline in water levels in the vlei. The receding water in turn has exposed extensive areas of organic sulfide soils/peats along the lake margins in the vicinity of Vleikraal which have previously been submerged for long periods of time.

Natural sulfate reduction processes in aquatic sediments can, where sufficient organic matter and iron minerals exist, result in an accumulation of sulfide minerals such as pyrite, FeS_2. Pyrite is quite stable under waterlogged conditions, however, upon exposure to air it can oxidise to produce sulfuric acid and dissolved ferrous (Fe^{2+}) iron. The ferrous ion can subsequently be oxidised to ferric ion (Fe^{+3}) which can hydrolyse and precipitate as solid ferric iron oxide ($Fe(OH)_3$) or at low pH (<4) oxidise further pyrite.

Thus pyrite (FeS_2) in organic-rich sediments oxidised and can generate high concentrations of acidity. Upon rewetting of the exposed sediments, by rainfall or lake refill, surface water acidification (pH 3-2) have been recorded in similar lake systems in Australia (Mosley et al 2014). This holds the potential to dissolve/mobilised metals (Al, As, Co, Cr, Cu, Fe, Mn, Ni, Zn) under these acidic conditions, which can greatly exceed recommended human health and aquatic ecosystem guidelines.

Figure 3: Imagery of sulfate reduction processes occurring at Velorenvlei

Sediment samples and water column samples were collected at 4 sites at VleiKraal on 9 November to verify ions and send for analysis to Element lab (Somerset west). See lab report.

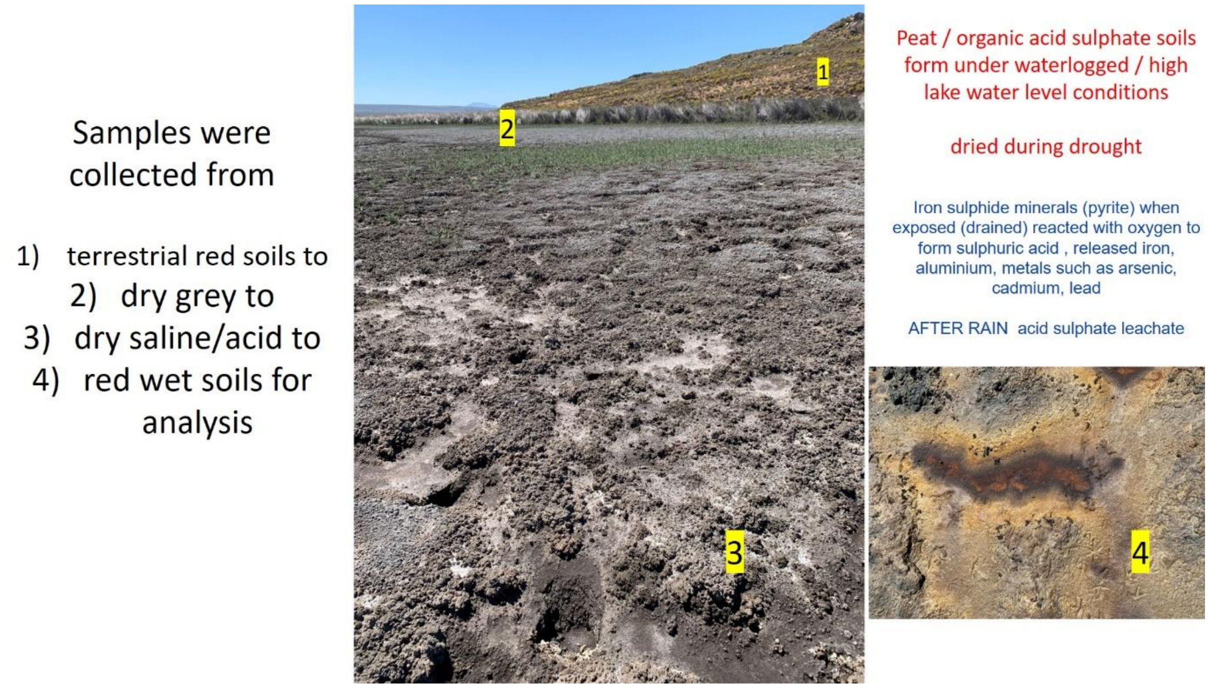

Figure 4: Sites where sediment samples were collected at Vleikraal

After a review of published literature on this aspect, an additional seven sites (Figure 5) across a range of pH values for further metal analysis (30 November 2021). Awaiting results.

Figure 5: Sites where additional samples were collected on 30 November 2021 to determine metal concentrations in sediments and water column.

Water quality

Field surveys were conducted in the Wadrift, Jakkals, (8 November 2021) and Verlorenvlei (9-10 November 2021) estuaries.

Sampling stations were selected to encapsulate spatial variability along the length of each estuary, i.e., mouth to upper reaches. However, sampling stations were limited by water availability. For example, only a single station was sampled in the Wadrift Estuary due to the middle and upper reaches being dry. The selected stations are presented in Figure 6.

At each sampling station, physico-chemical measurements were recorded using a YSI ProDSS multiparameter meter. These included salinity, water temperature (°C), dissolved oxygen (mg l^{-1}), pH, and turbidity (NTU). Where possible (> 0.5 m depth), measurements were recorded at specified depth intervals to the bottom-waters to capture any vertical gradients. Given the absence of any vertical salinity density gradients (i.e., haloclines), surface water samples were collected for inorganic nutrient analyses (orthophosphate, ammonium, and total oxidised nitrogen) at each site. Samples were filtered in the field through glass-fibre Munktell MGF filters (0.7 µm pore size) and placed into acid-washed polyethylene bottles before being frozen. Orthophosphate (PO_4^{3-}), ammonium (NH_4^+), and total oxidised nitrogen (NO_x = NO_3^- and NO_2^-) concentrations will be determined using standard spectrophotometric methods (Bate and Heelas, 1975; Parsons et al., 1984).

Table 2: In situ water quality observations for Wadrift, Jakkelsvlei and Verlorenvlei

Date	Estuary Name	Station No.	Estuarine Zone	Coordinates	Coordinates	Mouth State	Time Sampled	Depth	Salinity	Conductivity (mS/cm)	Temperature (°C)	pH	NTU	DO (mg/l)	DO (%)
08 11 2021	Wadrift	1	Lower	18 19 43.63 E	32 12 12.10 S	Closed	09h40	0	81.34	110.05	18.00	9.19	25.84	2.91	110.1
	Jakkals	1	Lower	18 18 52.52 E	32 5 6.13 S	Closed	13h40	0	31.67	48.47	22.30	8.39	3.98	7.02	96.0
								1.3	32.21	49.21	21.00	8.25	31.52	5.04	69.0
		2	Middle	18 19 8.77 E	32 5 17.43 S		14h10	0	33.68	51.21	24.10	8.49	18.00	8.98	128.6
09 11 2021	Verlorenvlei	1	Lower (Inlet below bridge)	18 19 56.84 E	32 19 0.40 S	Closed	08h45	0	140.71	170.25	19.20	8.53	2.59	2.58	65.2
								0.5	140.82	170.43	19.20	8.55	3.45	2.06	57.5
		2		18 20 18.78 E	32 18 55.76 S		09h30	0	147.48	176.34	20.40	8.72	4.68	3.98	105.1
		3	Middle (Main Basin)	18 23 41.93 E	32 19 18.70 S		13h25	0	5.36	9.52	21.60	3.23	1.85	8.86	103.7
		4		18 24 46.30 E	32 19 53.18 S		12h00	0	4.90	8.75	19.90	3.40	1.50	9.65	107.0
								0.5	4.90	8.76	19.90	3.40	1.50	9.70	109.6
								1.3	4.90	8.76	19.90	3.40	1.56	9.72	110.0
		5		18 26 19.00 E	32 21 13.02 S		13h00	0	4.71	8.44	20.40	3.41	1.12	9.22	105.1
								0.5	4.77	8.53	19.40	3.40	1.58	9.76	108.4
								1.2	4.79	8.57	19.30	3.38	1.64	9.86	110.0
10 11 2021		6	Upper	18 28 23.30 E	32 23 55.03 S		09h00	0	1.35	2.61	17.80	7.35	0.77	7.55	80.3
		7	River / Wetland	18 32 30.96 E	32 28 19.59 S		09h50	0	1.21	2.35	16.10	7.31	0.52	6.86	70.2

The only water observed at Wadrift was on the seaward side of the railway bridge and had a salinity of 81 (seawater = 35) (Table 2). No surface water could be found at any of the other preselected sites. Only two sites could be accessed in the lower parts of Jakkalsvlei with salinity of 32 (similar to seawater). Due to very low water levels the lower inlet channel at Verlorenvlei was disconnected and hyper saline at 140 to 147, while the main vlei had a salinity of about 5 and the upper estuary and river a salinity of about 1.3.

A key concern of the field study was the extremely low pH observed in the main water body (Figure 7) of Verlorenvei ranging between 2.68 and 3.4. In contrast the lower estuary had a pH of 8.53 – 8.7 (result of concentrated seawater) and the upper vlei a pH of 7.3. These measurements were verified by an independent laboratory, Element, in Somerset West.

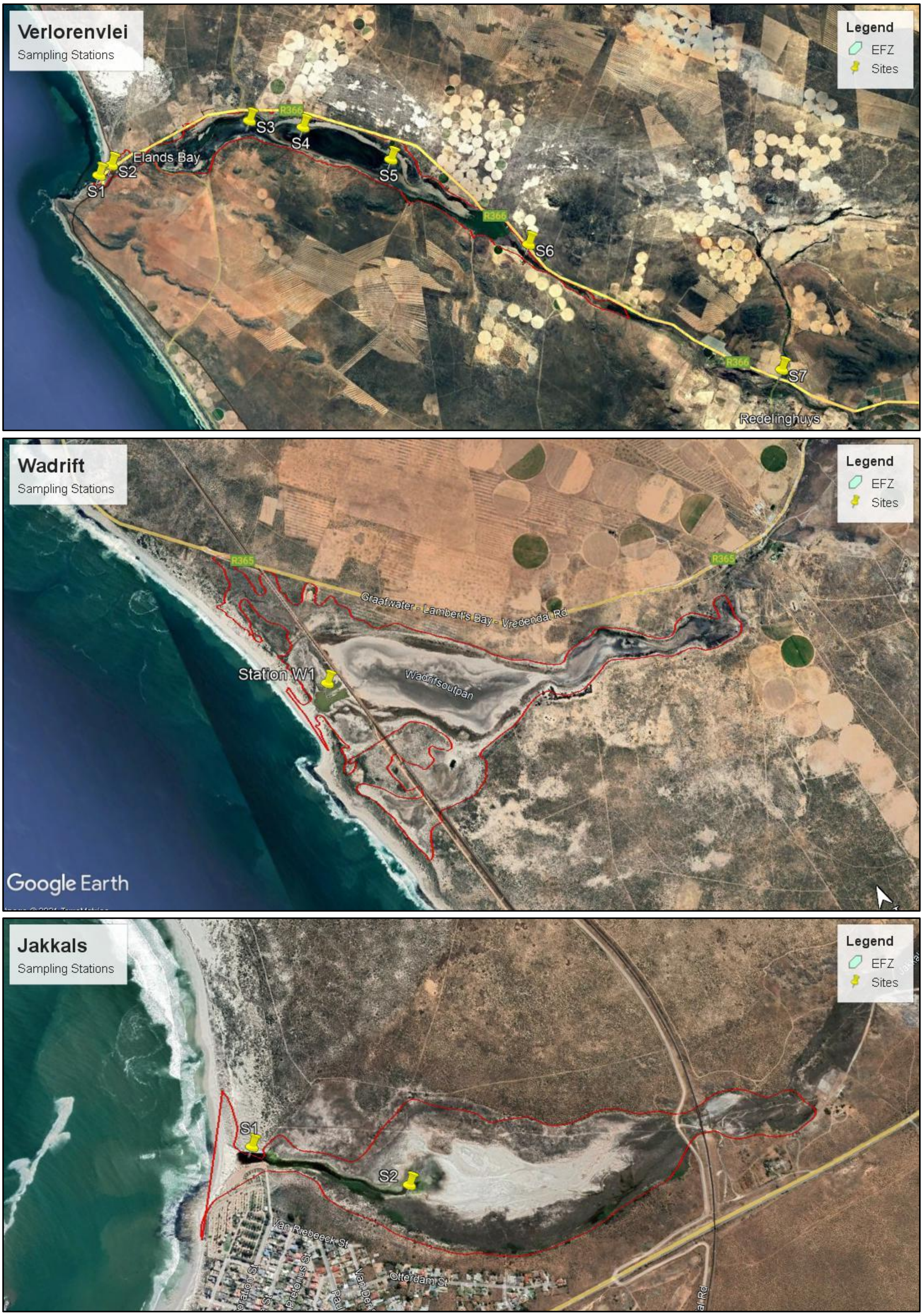

Figure 6: Water quality and microalgal sampling stations in the Verlorenvlei, Wadrift, and Jakkals estuaries.

Figure 7: Verorenvlei pH values (9 November 2021)

Additional sediment samples were taken for analysis from the mouth area, main vlei and upper reaches for further analysis.

Microalgae

Water samples for phytoplankton analyses were collected concomitantly with those for inorganic nutrient analyses (Figure 8). Water samples for phytoplankton biomass, measured as chlorophyll-a concentration (expressed as mg Chl-*a* l^{-1}), were collected by filtering triplicate samples of a known volume (i.e., 250 ml) through 0.7 µm pore-sized glass-fibre filters (Munktell© MGF). The filters were then placed in aluminium foil and frozen prior to analysis. Once in the laboratory, chlorophyll-*a* will be determined as per the method described by Nusch (1980). For the purposes of phytoplankton identification and enumeration, surface water samples were fixed with 25% glutaraldehyde solution (Sigma-Aldrich R Chemicals G5882) to a final concentration of 1% (by volume). Once in the laboratory, 25 ml of each fixed sample will be placed into 26.5 mm diameter Utermöhl chambers and allowed to settle for 24 h before identification and enumeration (cells ml^{-1}; as per Snow et al., 2000) of phytoplankton classes/species using an inverted Leica DMIL phase contrast microscope at a magnification of 630X.

Benthic microalgal communities were sampled along the adjacent shoreline at each of the sampling stations. However, benthic samples were not collected at Site 3, 6 and 7 in Verlorenvlei due to extensive reed cover. This was to ensure that epipsammic and epipelic diatoms were the focus, as previous studies (e.g., Lemley et al., 2017) have indicated that extensively vegetated sediments may skew biomass and benthic diatom community indices through favouring the growth of certain species and/or introducing epiphytic species. Three replicate sediment samples (two cores per replicate) were collected from the subtidal zone (0.3 to 0.5 m depth) using a Perspex twin-corer with an internal diameter of 20 mm for the determination of microphytobenthic (MPB) biomass (expressed as mg Chla m^{-2}). These samples were placed into acid-washed polypropylene specimen containers and frozen prior to analysis. The determination of MPB biomass will follow a similar procedure to that used for phytoplankton biomass. Finally, samples for benthic diatom community analyses were collected from surface sediments (top few millimetres) in the subtidal zone at each site and living epipelic/epipsammic diatoms were harvested using the cover slip method (Bate et al., 2013).

Figure 8: Water samples being filtered for microalgal biomass and nutrient measurements

Macrophytes

Field surveying was conducted at the Wadrift and Jakkals estuaries on Monday 8th November and on the Verlorenvlei on Tuesday and Wednesday, 9th and 10th November 2021. Preliminary present day habitat maps were produced prior to the field trip and verification was done over these three days (Figure 9).

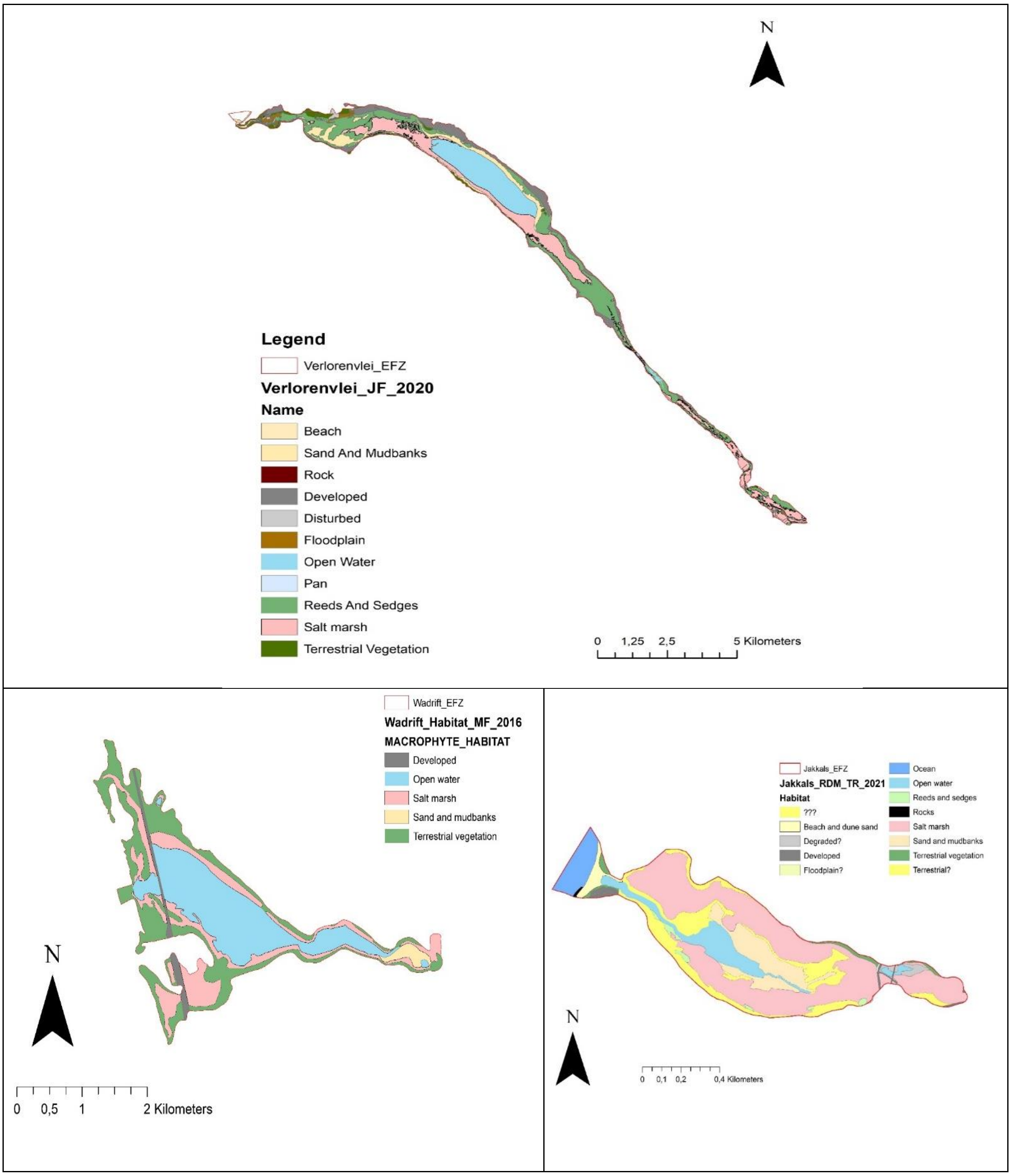

Figure 9: Preliminary habitat maps of A) Verlorenvlei, B) Wadrift and C) Jakkals estuaries.

Over 700 geotagged photos were taken and exported to a Google Earth *.kml file using GeoSetter, using date as the identifier. This allows for the assessment of changes over time, both in the past as well as for future research (Figure 10). Geotagged field notes were also taken to refine the preliminary map.

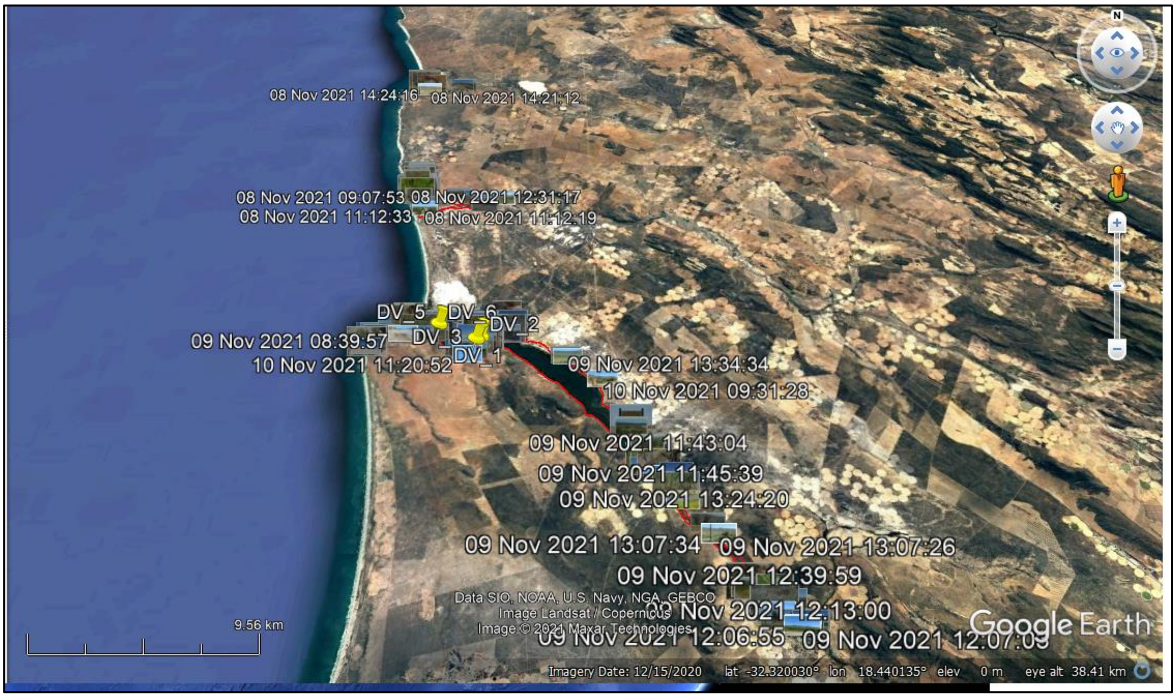

Figure 10: Geotagged photos to refine present habitat map.

Specimens of unknown plant species were collected and pressed for later identification. Many of the geotagged photos will be uploaded onto the iNaturalist platform to serve as historical evidence of species locality and extent.

Two sites that were assessed in July 2013 as part of a Master Thesis were revisited to visually assess changes over time (Figure 11).

Figure 11: Change of habitat from 2013 to 2021. Image source left: Dr Dimitri Veldkornet.

During the field trip Nelson Mandela University and CSIR liaised with Felicity Strange from Friends of Verlorenvlei (Table 3). The NGO is very active in the conservation of the Verlorenvlei and has a wealth of historical knowledge of the natural variability and local anthropogenic pressures facing the Verlorenvlei Estuary. The main ones were identified over abstraction by farming in the catchment and locally around the estuary, as well as burning (often illegal) of the wetlands. This is of major concern as burning dries out the important peatlands, as has happened in the Wadrift Estuary. The bridges and causeways over all three estuaries are also responsible for the modification and compartmentalization of the once joined water bodies.

Table 3: Timeline of changes in the Verlorenvlei Estuary.

Date	Event	Section of estuary impacted	Reference
1800 to 1850	Most of the area surrounding the estuary was developed for agriculture but progress was slow.	EFZ and catchment	Sinclair
1857	Piketberg Divisional Council took over responsibility of the area. Fishing was the main attraction for establishment.	Catchment and surrounding EFZ.	Sinclair
1946	West coast crayfish industry was established with four factories.	Increased activity in the EFZ and surrounding area.	
1960	Road bridge constructed.	Lower reaches	
1967	Sishen-Saldhana railway line and berm with gum trees planted.	Lower reaches	
Mid 1980s	Pivot irrigation main agriculture activity.	Catchment and reduced water inflow into the estuary.	EMP report
1989 to 2001	2.7 ha cleared per day for agriculture.	Catchment and reduced water inflow into the estuary.	EMP report
2005/2006	Rooibos industry begins as alternative crop production due to drought conditions.		
Easter Monday April 2005	Fire burned for 12 days from road bridge along the north bank up past Ventersklip.	EFZ	
2008	Upgrade of Sishen-Saldanah railway scoping report.		
13 May 2013	Reed fires – human induced (Grootdrif Causeway).	EFZ	
6 April to 18 June 2016	Reed fires – Bonteheuvel (no fire protocol followed). Bonteheuvel and Uithoek residue still visible on GE (13 Oct 2018).	EFZ	
8 – 16 March 2017	Reed fires Uithoek (no fire protocol followed). Bonteheuvel and Uithoek residue still visible on GE (13 Oct 2018).	EFZ	
Jan 2018	South bank fire induced by human, wind direction pushes fire towards heritage settlement, new water pipeline had to be built in Feb 2018. Effects of fire still visible in 28 Oct 2018 GE.	EFZ	
2018	Dust and sand smothering by 30 to 50 cm depending on topography.	EFZ	
1 Feb 2020	Triple lightning strike on the peninsula next to Koopmandrif induced fire. Surface fire out by 4th Feb. Peat fire continued to burn underground	EFZ	
23 April 2020	Peat fire finally extinguished.	EFZ	

Using the above timeline of changes plus the draft habitat map it is possible to identify the major habitats and functional groups in each estuary, along with their drivers (Table 4 and 5).

Table 4: Macrophyte habitats and functional groups recorded in the Verlorenvlei Estuary (species in italics). Areas are draft pending final habitat map production.

Habitat type	Distribution	Draft Area ha (2021)
Open surface water area	Serves as a possible habitat for phytoplankton. Important wading area providing feeding, nesting and resting facilities for a variety of birds.	419
Intertidal sand and mudflats	Limited intertidal zone occurs in Zone 1 in the lower reaches when the mouth is open. This provides habitat for microphytobenthos colonisation. Natural variability in lake level does lead to exposed sand banks. These can become colonised by saline grasses and other ecotone species.	0 (196)
Macroalgae	Macroalgae occurs in the lower reaches of the estuary.	TBC
Rocks	These are limited to the mouth region.	0.2
Floating macrophytes	Floating macrophytes occur in the upper reaches of the estuary where the water salinity is close to 0.	TBC
Submerged macrophytes	Floating macrophytes mainly occur in the upper reaches of the estuary where water salinity is close to 0. They often form across the full width of the water column.	TBC
Reeds and sedges	Extensive forming important peatlands. Important bird watching, Important wading area providing feeding, nesting and resting facilities.	684
Salt marsh	Includes ephemeral pans represented by Cape Estuarine salt marsh. These form in the lower to middle reaches of the estuary under low water level and the area therefore fluctuates over time.	373
Floodplain	Forms ecotone of salt marsh and terrestrial species depending on ambient water level.	215
Terrestrial vegetation	Lambert's Bay Strandveld, Saldanah Flats Strandveld, Leipodltville Sand Fynbos, pockets of Graafwater Sand Fynbos. These house many critically endangered faunal species (mole species) and due to its geographical position at the karroid/fynbos interface, the region supports a high floral biodiversity.	110
Degraded habitat	Cattle and sheep grazing in floodplain area, numerous foot paths dissect habitat and the burning of reeds have all led to degraded habitat mainly in the lower to middle reaches.	19
Developed	Road and railways bridges/causeways, pedestrian footpaths.	248
TOTAL		2264.2

Table 5: Description of factors influencing macrophytes in the Verlorenvlei Estuary.

Variable	Grouping
Mouth conditions	The estuary is perched and movement between the estuary and the sea takes places during high river inflow (floods) or overwash during sea storm events. The latter causes input of saline water into the lower reaches, which during the hot summer month, becomes hypersaline.
Retention times of water masses	Calm water results in extensive beds of submerged macrophytes and the proliferation of reeds and sedges.
Flow velocities (e.g. tidal velocities or river inflow velocities)	Strong flows prevent the establishment of submerged macrophytes. These are however extensive in the upper reaches of the estuary where river inflow is the main driver and not tidal influence.
Total volume and/or estimated volume of different salinity ranges	Salinity gradient results in a diversity of macrophyte habitats in the lower reaches. Despite high salinity in the water column, groundwater seepage of freshwater supports large stands of reeds and sedges.
Water level fluctuations	The biggest threat to the Verlorenvlei is overabstraction reducing water level, which together with drought conditions, can destablisise peat swamps. These make them more susceptible to burning and further drying out of below ground layers. Stable water levels can also cause an expansion of macrophytes such as reeds and sedges. High water level favours reeds and sedges and aquatic plants whereas low water level favours the establishment of salt marsh and ecotone species.
Wave action	The edges of the have distinct zones of emergent macrophytes, which act as a wave barrier for submerged macrophytes that grow in the shelter of these plants.
Floods	Floods would increase turbidity resulting in some loss of submerged macrophytes.
Salinity	A diversity of macrophytes is distributed along the salinity gradient; these are important indicators of changes in salinity. Groundwater inflow and seepage results in lower salinity in the root zone. Each species has a specific salinity tolerance range; particularly the submerged macrophytes, *Stuckenia pectinata* = <15, *Ceratophyllum demersum* = < 5 psu.
Turbidity	High turbidity can reduce light available to submerged macrophytes decreasing growth and cover abundance.
Dissolved oxygen	The extensive submerged and emergent macrophyte stands influence in situ oxygen concentrations particularly in the littoral zone.
Nutrients	Decreased water quality could see the proliferation of aquatic weeds such as *Azolla pinnata* subsp. *africana* (water fern) and water lettuce, *Pistia stratiotes* would proliferate.
Sediment characteristics (including sedimentation)	Sediment input, either from the catchment or through exposed surfaces following vegetation removal by fires, increases the proliferation of reeds.
Groundwater seepage	Groundwater input will be particularly important for the vegetation in large sandy areas of the Verlorenvlei. Seepage shorelines where reeds and sedges occur will be sensitive to changes in groundwater input.

Figure 12: Water and sediment sample collection.

Invertebrates

Field sampling of invertebrates was conducted in the Wadrift, Jakkalsvlei and Verlorenvlei estuaries from the 8th to 10th November 2021. Sites were selected randomly according to the length and width of estuary and accessibility (Figure 13).

Physico-chemical parameters were measured at each site using a YSI EXO1 multiprobe (Figure 14). Parameters measured include temperature, salinity, turbidity, dissolved oxygen and pH.

For sites where the depth was greater than 0.5m, bottom and surface measurements were taken. Five replicates (benthic invertebrates) were collected per site using a 250cm^2 Van Veen grab and sieved through a 500 µm mesh sieve (Figure 15).

In the lab, samples will be sorted and identified to lowest taxonomic level using a dissecting microscope.

Figure 13: Benthic invertebrate and associated physico-chemical parameter sites

Figure 14: Kanakana Mushanganyisi measuring physic-chemical parameters using a YSI

Figure 15: Kanakana Mushanganyisi and Jabulile Nhleko sampling benthic invertebrates.

Table 6: Invertebrate sites physico-chemical parameter recorded in the Wadrift, Jakkalsvlei and Verlorenvlei

Date	Estuary Name	Site	Longitude	Latitude	Time	Depth	Sal	Temp	pH	NTU	DO %	Diss mg/l
08-Nov-21	Wagdrift	1	18 19 48.81 E	32 12 10.56 S	07:50	S	90,49	18,24	8,87	35,68	67,4	3,61
		2	18 19 48.49 E	32 12 12.05 S	08:04	S	91,17	18,3	9,06	54,1	102,2	5,51
		3	18 19 46.72 E	32 12 11.97 S	08:19	S	92,07	19,4	9,11	2,9	96,1	4,83
		4	18 19 47.17 E	32 12 14.36 S	08:52	S	91,77	18,88	9,13	54,25	97	5,11
		5	18 19 43.97 E	32 12 14.18 S	09:11	S	91,9	19,58	9,07	34,6	71,2	3,21
		6	18 19 43.48 E	32 12 14.77 S	09:16	S	91,49	19,65	9,12	80,75	72,7	3,88
		7	18 19 44.81 E	32 12 10.93 S	09:45	S	91,13	21,49	9,32	36,85	148,6	8,02
	Jakkalsvlei	1	18 19 48.81 E	32 12 10.56 S	07:50	S	90,49	18,24	8,87	35,68	67,4	3,61
		2	18 19 48.49 E	32 12 12.05 S	08:04	S	91,17	18,3	9,06	54,1	102,2	5,51
		3	18 19 46.72 E	32 12 11.97 S	08:19	S	92,07	19,4	9,11	2,9	96,1	4,83
		4	18 19 47.17 E	32 12 14.36 S	08:52	S	91,77	18,88	9,13	54,25	97	5,11
		5	18 19 43.97 E	32 12 14.18 S	09:11	S	91,9	19,58	9,07	34,6	71,2	3,21
		6	18 19 43.48 E	32 12 14.77 S	09:16	S	91,49	19,65	9,12	80,75	72,7	3,88
		7	18 19 44.81 E	32 12 10.93 S	09:45	S	91,13	21,49	9,32	36,85	148,6	8,02
09-Nov-21	Verlorenvlei	1	18 24 36.59 E	32 20 2.39 S	10:14	B	5,49	19,52	3,11	1,93	108,7	9,77
						S	5,65	20,35	3,1	1,36	110	9,5
		2	18 24 45.66 E	32 19 53.13 S	10:39	B	5,51	19,4	3,11	1,92	109,6	9,79
						S	5,37	19,79	3,12	1,78	110,6	9,72
		3	18 24 53.46 E	32 19 36.93 S	11:08	B	5,49	21,59	3,1	2,68	107,3	9,21
						S	5,48	21,49	3,1	2,88	108,2	9,26
		4	18 24 4.22 E	32 19 38.64 S	13:13	B	5,68	22,07	3,01	1,28	112,4	9,51
		5	18 24 7.42 E	32 19 36.09 S	13:38	B	6,02	21,36	2,98	13,47	109,1	9,33
						S	6,25	21,29	2,99	1,45	110,2	9,42
		6	18 23 39.79 E	32 19 29.97 S	14:01	B	6,01	21,59	2,9	4,06	105,4	8,97
						S	6,02	21,57	2,89	1,92	104,7	8,97
		7	18 24 12.23 E	32 19 16.58 S	12:37	B	6,47	22,86	2,81	3,58	113,2	9,42
10-Nov-21		8	18 25 30.12 E	32 20 44.41 S	10:01	B	5,42	21,09	3,18	1,97	107,1	9,24
						S	5,39	21,4	3,19	1,66	109,1	9,35
		9	18 25 39.10 E	32 20 36.01 S	10:20	B	5,43	19,65	3,19	1,66	110,6	9,82
						S	5,41	21,37	3,19	2	112,1	9,58
		10	18 25 57.67 E	32 20 20.27 S	10:40	B	5,39	21,07	3,17	2,74	107,2	9,29
						S	5,38	20,98	3,16	2,17	109,7	9,48
		11	18 26 15.77 E	32 21 21.69 S	09:36	B	5,32	20,16	3,11	1,86	107,2	9,45
						S	5,28	20,82	3,09	1,35	107,1	9,26
		12	18 26 28.67 E	32 21 14.40 S	09:07	B	5,33	19,81	3,16	3,59	113,2	10
						S	5,27	20,21	3,05	1,21	100,8	8,5
		13	18 26 33.20 E	32 21 12.01 S	08:41	B	5,32	19,54	3,1	1,62	104,5	9,3
						S	5,2	19,94	3,05	1,4	99	8,65
		14	18 28 11.01 E	32 23 39.69 S	12:54	B	1,55	24,2	6,11	3,94	115,8	9,83
		15	18 19 56.88 E	32 19 1.39 S	13:45	B	159,35	24,53	8,34	2,94	104,8	3,52

Hypersaline conditions were observed in Jakkalsvlei, Wadrift and at a site closer to the mouth in the Verlorenvlei estuaries. Soft sediments made it difficult to sample desired sites in the Wadrift because of accessibility (team sunk in the sediment).

In the Verlorenvlei, pH values recorded were less than 4 in most of the sites sampled. Benthic samples have not yet been processed but brine shrimp, chironomids and gastropods were observed in Wadrift and Jakkalsvlei estuaries.

No life was observed in the main water body of the Verlorenvlei but water boatmen were present at Site 14 (Grootdrift) and brine shrimp at Site 15 near the mouth.

Fish

No fish were observed at Wadrift due to hypersalinity (>90). Consequently, no nets were deployed.

Nets were deployed at two sites in Jakkelsvlei (Figure 16). However, netting was unsuccessful due to extensive macroalgal and macrophyte growth. Approximately 50 large flathead mullet *Mugil cephalus* and southern mullet *Chelon richardsonii* were observed at Site 2, but were able to escape the nets. Based on their approximate size, these fish had recruited into the estuary 4-5 years ago. Some smaller mullet of 1-2 years of age were evidence of more recent recruitment.

Nets were deployed at six sites in Verlorenvlei. However, no fish were observed in the main water body of the lower part of Verlorenvlei (due to hypersalinity (>140) or in the main vlei due to low pH (~3). Small-bodied fish Cape galaxias *Galaxias zebratus* (species complex) were observed at Grootdrift, but due to extensive submerged vegetation growth could not be netted.

Figure 16: DFFE team netting for fish in Jakkalsvlei mouth.

Birds

Counts were made of all waterbirds as defined by those species listed on the annual Coordinated Waterbird Count (CWAC) surveys (available publicly at: https://cwac.birdmap.africa/index.php), and incidental observations were made of non-waterbird avifauna. At Wadrift and Jakkalsvlei estuaries, avifaunal counts took place on the morning of 8 November 2021 and the afternoon of the same day, respectively, by Gavin Rishworth (Figure 17; hereafter the "observer") who led these surveys.

Figure 17: Gavin Rishworth collecting bird data at Verlorenvlei Estuary.

At all sites he was the first team member to approach any particular area, so as to get an accurate estimate of the waterbird assemblage prior to any birds taking flight. Given the extent of the waterbody within the lower reaches of these estuaries (Figure 18) a full survey of all waterbirds was possible on foot. These were counted with the aid of a combination of binoculars (Nikon 8x42 Monarch) and a tripod-mounted spotting scope (Celestron 12-36x60 Landscout).

Each area was delineated based on the possible size for identification observable through the binoculars/scope of small waders and the observer would then move beyond this area to the next adjacent patch of the estuary using spatial reference point to not double-count individual birds. A full estimate of the larger species (e.g., flamingos, avocets, coots) was made from a single vantage point within the estuary while smaller waders were counted in sectional areas as described above. Whenever waterbird identification was in doubt, field notes were taken of key features or geo-referenced photographs taken for post-hoc verification of bird identity.

At Verlorenvlei Estuary, point location bird surveys were conducted on 9-10 November 2021. These were conducted within the full extent of the lower reaches, which consisted of interspersed hypersaline waterbodies. This survey was conducted using the same methods as above. Within the mid to upper reaches, point surveys were conducted at representative locations within the extent of the estuary, simultaneously with site verification visits by the macrophyte team. This comprised the quantification of all birds visible, and where possible audible, from a fixed point within the estuary coinciding with the approximate monitoring locations from the water quality team (Redinlinghuys –

S7, roadside between S6-S7, Grootdrif – S6, main vlei – S4-S5, Vleiveld – S3, mouth and lower reaches – S1-S2: complete survey mentioned above). Unlike at Wadrift and Jakkalsvlei, it was not possible to survey the entire extent of the estuary from a single vantage point. Therefore, the point estimates are likely a better indication of qualitative rather than quantitative observations. This will be compared during the analysis stage of this report. Consultation was also made with all other team members following the day's sampling completion based on site observations during their components (e.g., water quality, fish, invertebrates), since the team was split up while sampling at Verlorenvlei. These records were verified using identification guides where possible and added to the field notes and observations.

All waterbird data observed during November 2021 will be compared to historical datasets from these areas and published records (e.g., CWAC surveys: see the preliminary comparison in Table 7) to provide a more complete estimate of long-term trends rather than single temporal estimates (e.g., the temporal absence of some waterbird species in November 2021 might be a seasonal occurrence, and these nuances will be critically examined: see Table 7).

Where differences occur in terms of monitoring locations (e.g., Verlorenvlei CWAC data focusses on the main water body: vlei), in terms of the EWR study, conclusions will be drawn from a combination of abundance estimates linked to both water quality parameters and trends, as well as available habitat data which other members of this team will generate. For example, the low pH recorded in the main Verlorenvlei vlei, combined with a paucity of invertebrate and fish abundance, was extrapolated for this region given the absence of avifauna such as flamingos, pelicans and cormorants. Additionally, dense reed bed encroachment (sensu Verlorenvlei: Figure 18F) or lack of surface water (sense mid to uppoer reaches of Wadrift: Figure 18B) precludes benthivorous intertidal waders. These preliminary observations will be refined and expanded in future reports based on habitat and environmental historical records and predicted trends.

A total of 19, 23 and 28 waterbird species were observed at the Wadrift, Jakkalsvlei and Verlorenvlei estuaries during the November 2021 survey (see Table 7).

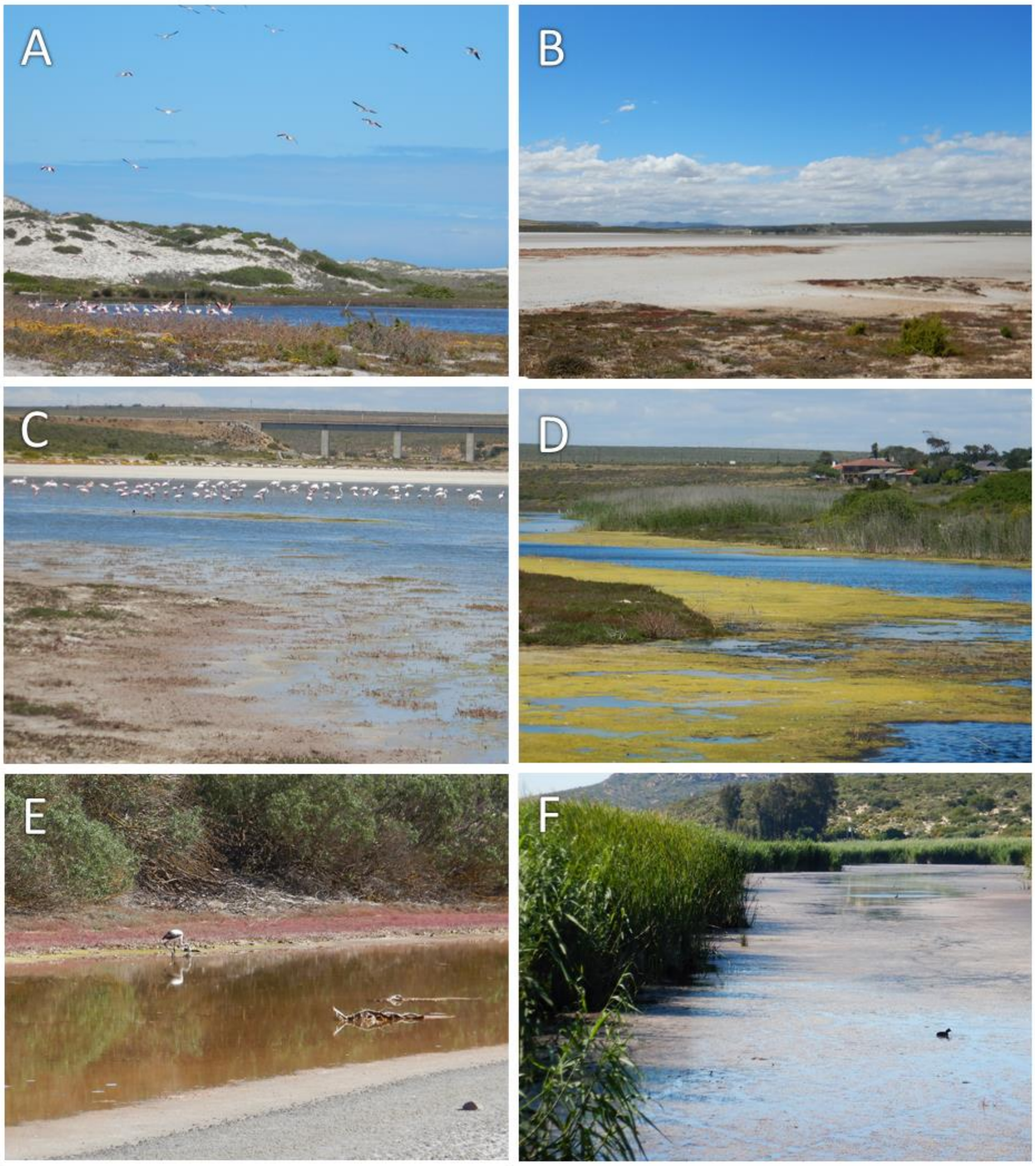

Figure 18: The mouths of the Wadrift, Jakkalsvlei and Verlorenvlei estuaries were closed and this, combined with low preceding annual runoff or groundwater flow meant that water levels in the estuaries were low. West of the railway line at Wadrift Estuary, a large water body was present (A; see habitat map figure) which was the primary site surveyed by members of this team during November 2021. This region supported the highest abundance of waterbird species at the estuary, including charismatic hypersaline planktivores such as greater and lesser flamingos. East of the railway line (B), the extensive pan surface area was dry. At Jakkalsvlei Estuary the lower reaches of the estuary supported a similar waterbird community including benthivorous waders and planktivores to that observed at Wadrift (C), with an exception being a waterfowl assemblage associated with the freshwater-indicate fringing reed beds (D). In contrast, the lower reaches of the Verlorenvlei Estuary were strongly hypersaline and apart from a few lone waders and one lonely greater flamingo juvenile (E), waterbird abundance and diversity at the time of sampling was apparently low. Similarly at the main vlei region (not shown), surface dive and pursuit foragers (e.g. grebes, cormorants) were missing, as were previously observed planktivourous waders. Further up the estuary, extensive reed beds supported high abundances of herbivorous waterfowl, especially noticeable in region were fringing reed beds surrounded shallow water bodies (F).

Table 7: **Preliminary summary of waterbird counts associated with the Jakkalsvlei, Verlorenvlei and Wadrift estuaries, comparing the mean abundance recorded at each site by the Coordinated Waterbird Count (CWAC) surveys that have taken place annually in winter and summer since 1997, 1992 and 1998, respectively (available publicly at: https://cwac.birdmap.africa/index.php), with count and presence-absence data for comparable waterbird species identified at the three estuaries during the 8-10 November 2021 field site visits (Nov-21). The full extent of available water habitat was surveyed in Nov-21 for Jakkalsvlei and Wadrift estuaries, while portions of representative habitats (point-counts) were surveyed for Verlorenvlei Estuary. As such, the following symbols compare the bird observations recorded in Nov-21 to those of the CWAC dataset: recorded abundance higher (↑) or lower (↓) in Nov-21 that mean CWAC abundance data; waterbird species observed in both CWAC and Nov-21 surveys (✓), only in the Nov-21 survey (y), not observed in the Nov-21 survey (x; cannot be recorded as absent because representative point counts were conducted, not a full available habitat survey) or absent in the Nov-21 survey (✕; full available water habitat survey).**

		Mean n (CWAC dataset)			Nov-21 survey comparisons		
Common name	**Scientific name**	*Jakkals.*	*Verloren.*	*Wadrift*	*Jakkals.*	*Verloren.*	*Wadrift*
Avocet, Pied	*Recurvirostra avosetta*	7	206	116	↑	x	↓
Coot, Red-knobbed	*Fulica cristata*	126	416	225	↓	✓	✕
Cormorant, Cape	*Phalacrocorax capensis*	4	56		✕	x	
Cormorant, Crowned	*Microcarbo coronatus*		1			x	
Cormorant, Reed	*Microcarbo africanus*	3	36	8	✕	✓	✕
Cormorant, White-breasted	*Phalacrocorax lucidus*	8	139	4	✕	x	✕
Crake, Black	*Zapornia flavirostra*		2			x	
Crane, Blue	*Grus paradisea*			3			↑
Curlew, Eurasian	*Numenius arquata*	1			✕		
Darter, African	*Anhinga rufa*	4	85	2	✕	x	✕
Duck, Domestic	*Anas platyrhynchos*	1	3		✕	x	
Duck, Fulvous Whistling	*Dendrocygna bicolor*	13	19		✕	x	
Duck, Maccoa	*Oxyura maccoa*	13	2	26	✕	x	✕
Duck, Unidentified	*N/A N/A*		42	63		x	✕
Duck, White-backed	*Thalassornis leuconotus*		2			x	
Duck, White-faced Whistling	*Dendrocygna viduata*		6			x	
Duck, Yellow-billed	*Anas undulata*	14	73	112	✕	✓	✕
Eagle, African Fish	*Haliaeetus vocifer*	1	3	1	✕	x	✕
Egret, Great	*Ardea alba*		2			x	
Egret, Intermediate	*Ardea intermedia*		1			✓	
Egret, Little	*Egretta garzetta*	2	12	6	✕	x	✕
Flamingo, Greater	*Phoenicopterus roseus*	149	294	332	↑	✓	↓
Flamingo, Lesser	*Phoeniconaias minor*	35	615	432	↑	x	↓
Goose, Egyptian	*Alopochen aegyptiaca*	19	597	77	✕	✓	✕
Goose, Spur-winged	*Plectropterus gambensis*	6	40	9	✕	x	✕
Grebe, Black-necked	*Podiceps nigricollis*	30	6	61	↓	x	✕
Grebe, Great Crested	*Podiceps cristatus*	5	45	3	✕	x	✕
Grebe, Little	*Tachybaptus ruficollis*	26	36	32	✕	✓	✕
Greenshank, Common	*Tringa nebularia*	2	7	2	✕	x	✕

Common name	Scientific name	Mean n (CWAC dataset)			Nov-21 survey comparisons		
		Jakkals.	*Verloren.*	*Wadrift*	*Jakkals.*	*Verloren.*	*Wadrift*
Gull, Grey-headed	*Chroicocephalus cirrocephalus*	3	3	3	✕	x	✕
Gull, Hartlaub's	*Chroicocephalus hartlaubii*	59	48	144	↓	x	✕
Gull, Kelp	*Larus dominicanus*	216	40	6	↓	x	✕
Hamerkop, Hamerkop	*Scopus umbretta*		1			✓	
Harrier, African Marsh	*Circus ranivorus*		3	2		✓	✕
Heron, Black	*Egretta ardesiaca*		2			✓	
Heron, Black-crowned Night	*Nycticorax nycticorax*		5	1		x	✕
Heron, Black-headed	*Ardea melanocephala*	2	2	2	✕	✓	✕
Heron, Goliath	*Ardea goliath*		4			x	
Heron, Grey	*Ardea cinerea*	2	15	2	✕	✓	✕
Heron, Purple	*Ardea purpurea*		3			✓	
Heron, Striated	*Butorides striata*		14			x	
Hybrid Mallard, Hybrid Mallard	*Anas hybrid*		2			x	
Ibis, African Sacred	*Threskiornis aethiopicus*	8	13	4	↓	x	✕
Ibis, Glossy	*Plegadis falcinellus*	18	20	10	↓	✓	✕
Ibis, Hadada	*Bostrychia hagedash*	2	3	4	✕	✓	✕
Kingfisher, Giant	*Megaceryle maxima*		2			✓	
Kingfisher, Malachite	*Corythornis cristatus*		2			x	
Kingfisher, Pied	*Ceryle rudis*	2	8		✕	✓	
Lapwing, Blacksmith	*Vanellus armatus*	7	37	8	↓	✓	↓
Mallard, Mallard	*Anas platyrhynchos*	1	1	4	✕	x	✕
Moorhen, Common	*Gallinula chloropus*	1	14	2	↑	✓	✕
Oystercatcher, African	*Haematopus moquini*	9	4	5	✕	x	✕
Pelican, Great White	*Pelecanus onocrotalus*		133	9		x	✕
Plover, Chestnut-banded	*Charadrius pallidus*	2	1	19	✕	x	↑
Plover, Common Ringed	*Charadrius hiaticula*	4	5	18	↓	✓	↑
Plover, Grey	*Pluvialis squatarola*	1	34		✕	x	y
Plover, Kittlitz's	*Charadrius pecuarius*	10	15	50	↑	x	↓
Plover, Three-banded	*Charadrius tricollaris*	5	11	7	↓	✓	↑
Plover, White-fronted	*Charadrius marginatus*	8	2	25	↑	✓	↓
Pochard, Southern	*Netta erythrophthalma*	7	8	29	✕	x	✕
Ruff, Ruff	*Calidris pugnax*	22	57	95	✕	x	✕
Sanderling, Sanderling	*Calidris alba*	23		38	✕		↓
Sandpiper, Common	*Actitis hypoleucos*	11	39	3	↑	x	↑
Sandpiper, Curlew	*Calidris ferruginea*	12	188	180	✕	x	✕
Sandpiper, Marsh	*Tringa stagnatilis*	8	5	44	✕	x	✕
Sandpiper, Wood	*Tringa glareola*	6	2	5	✕	x	✕
Shelduck, South African	*Tadorna cana*	16	130	97	↓	✓	✕
Shoveler, Cape	*Spatula smithii*	62	62	113	✕	x	↓
Snipe, African	*Gallinago nigripennis*		3	1		x	✕
Spoonbill, African	*Platalea alba*	1	34		✕	✓	
Stilt, Black-winged	*Himantopus himantopus*	19	55	70	↑	✓	✕

Common name	Scientific name	Mean n (CWAC dataset)			Nov-21 survey comparisons		
		Jakkals.	*Verloren.*	*Wadrift*	*Jakkals.*	*Verloren.*	*Wadrift*
Stint, Little	*Calidris minuta*	22	174	175	↑	x	↓
Stork, Yellow-billed	*Mycteria ibis*		1			x	
Swamphen, African	*Porphyrio madagascariensis*		5			✓	
Swan, Black	*Cygnus atratus*		1			x	
Teal, Blue-billed	*Spatula hottentota*		13	2		x	✕
Teal, Cape	*Anas capensis*	28	53	131	↓	x	✕
Teal, Eurasian	*Anas crecca*	26		250	✕		✕
Teal, Red-billed	*Anas erythrorhyncha*	47	24	62	✕	x	✕
Tern, Caspian	*Hydroprogne caspia*	2	11	27	✕	x	✕
Tern, Common	*Sterna hirundo*	1229	5	1825	✕	x	✕
Tern, Greater Crested	*Thalasseus bergii*	85	10	288	↑	x	✕
Tern, Sandwich	*Thalasseus sandvicensis*	30	5	39	✕	x	✕
Tern, Unidentified	*N/A N/A*	156	44	1	✕	x	✕
Tern, Whiskered	*Chlidonias hybrida*	4	4		✕	x	
Tern, White-winged	*Chlidonias leucopterus*	295	26	22	✕	x	↓
Thick-knee, Water	*Burhinus vermiculatus*	2	3		↑	x	y
Wader, Unidentified	*N/A N/A*	62	191	367	✕	✓	↓
Wagtail, Cape	*Motacilla capensis*	4	3		↓	✓	y

4. Appendix A

Qualitative and quantitative XRD

The material was prepared for XRD analysis using a back loading preparation method. Diffractograms were obtained using a Malvern Panalytical Aeris diffractometer with PIXcel detector and fixed slits with Fe filtered Co-Kα radiation. The phases were identified using X'Pert Highscore plus software The relative phase amounts (weight %) were estimated using the Rietveld method.

	Quartz	Muscovite	Kaolinite	Gypsum	Jarosite	Halite	Pyrite	Halite	Calcite	Aragonite
S1	97.1	0	0	0	0	0	0	1.9	0.8	0.2
ST5	100.0	0	0	0	0	0	0	0	0	0
ST7	69.0	16.7	14.3	0	0	0	0	0	0	0
ST8	97.7	1.7	0.6	0	0	0	0	0	0	0
Vleikraal Red terrestrial J2	100.0	0	0	0	0	0	0	0	0	0
Vleikraal Salime Sediment J3	73.1	15.2	7.4	0.8	0	0	3.4	0	0	0
Vleikraal Grey Sediment J4	59.1	14.6	3.9	15.1	2.8	4.5	0	0	0	0
Vleikraal Lake Sediment J5	89.4	4.1	1.4	0.8	3.7	0.6	0	0	0	0

Element Materials Technology

Client Name: Nelson Mandela University
Reference: Verlorenvlei EWR
Location: Verlorenvlei
Contact: Janine Adams
EMT Job No: 21/956

Report : Solid

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

Please see attached notes for all abbreviations and acronyms

EMT Sample No.	6	7	8	9	10	11	12	13			LOD/LOR	Units	Method No.
Sample ID	S1 (Lower Mouth)	St5 (Middle Vlei)	St7 (Upper Grootdrift)	St8 (River Redelingshuis)	Vleikraal red terestrial J2	Vleikraal felicity lake sediment J5	Vleikraal grey sediment J4	Vleikraal saline sediment J3					
Depth													
COC No / misc													
Containers	B	B	B	B	B	B	B	B					
Sample Date	<>	<>	<>	10/11/2021	10/11/2021	10/11/2021	10/11/2021	10/11/2021					
Sample Type	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil					
Batch Number	1	1	1	1	1	1	1	1					
Date of Receipt	12/11/2021	12/11/2021	12/11/2021	12/11/2021	12/11/2021	12/11/2021	12/11/2021	12/11/2021					
Fluoride	<6.0$_{AD}$	<0.3	0.8$_{AA}$	<0.3	<0.3	0.5	35.6$_{AG}$	<0.3			<0.3	mg/kg	SA_TM27/SA_PM20
Chloride ^{SA}	22231$_{AD}$	636$_{AB}$	781$_{AA}$	109	7	8356$_{AG}$	27908$_{AG}$	1780$_{AF}$			<2	mg/kg	SA_TM27/SA_PM20
Sulphate as SO4 (2:1 Ext) ^{SA}	3106$_{AD}$	516$_{AB}$	167$_{AA}$	86	4	11306$_{AG}$	96083$_{AG}$	19307$_{AF}$			<3	mg/kg	SA_TM27/SA_PM20
Nitrite as N ^{SA}	<0.2	<0.2	<0.4$_{AA}$	<0.2	<0.2	<0.2	<0.2	<0.2			<0.2	mg/kg	SA_TM27/SA_PM20
Nitrate as N ^{SA}	<50.0$_{AD}$	<2.5	<5.0$_{AA}$	<2.5	<2.5	<2.5	<250.0$_{AG}$	<2.5			<2.5	mg/kg	SA_TM27/SA_PM20
Electrical Conductivity @25C (5:1 ext)	11710	467	809	278	<100	10960	45300	6480			<100	uS/cm	SA_TM28/SA_PM58
pH ^{SA}	7.00	3.64	6.01	6.20	6.71	3.15	2.65	2.84			<2.00	pH units	SA_TM19/SA_PM11

Element Materials Technology

Client Name: Nelson Mandela University
Reference: Verlorenvlei EWR
Location: Verlorenvlei
Contact: Janine Adams
EMT Job No: 21/956

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

Please see attached notes for all abbreviations and acronyms

EMT Sample No.	1	2	3	4	5								
Sample ID	S1 (Lower Mouth)	St5 (Middle Vlei)	St7 (Upper Grootdrift)	St8 (River Redelingshuis)	Vleikraal (Felicity) (Shallow small basin)								
Depth													
COC No / misc													
Containers	P	P	P	P	P								
Sample Date	10/11/2021	10/11/2021	10/11/2021	10/11/2021	11/11/2021								
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water								
Batch Number	1	1	1	1	1						LOD/LOR	Units	Method No.
Date of Receipt	12/11/2021	12/11/2021	12/11/2021	12/11/2021	12/11/2021								
Dissolved Calcium [SA]	1650.8_{AG}	247.0_{AD}	44.7	39.8	466.4_{AF}						<0.3	mg/l	SA_TM27/SA_PM0
Dissolved Magnesium [SA]	5583.4_{AG}	256.0_{AD}	69.5	61.2	524.3_{AF}						<0.2	mg/l	SA_TM27/SA_PM0
Dissolved Potassium [SA]	1777.6_{AG}	25.3	4.1	2.2	33.0						<0.1	mg/l	SA_TM27/SA_PM0
Dissolved Sodium [SA]	51386.3_{AG}	1080.6_{AD}	366.8_{AC}	288.0_{AC}	2029.2_{AF}						<0.1	mg/l	SA_TM27/SA_PM0
Fluoride [SA]	$<30.0_{AG}$	<0.3	<0.3	<0.3	0.4						<0.3	mg/l	SA_TM27/SA_PM0
Chloride [SA]	86101.4_{AG}	2640.0_{AD}	713.6_{AC}	726.3_{AC}	3652.9_{AF}						<0.3	mg/l	SA_TM27/SA_PM0
Sulphate [SA]	13137.3_{AG}	1714.4_{AD}	69.5	56.2	3436.8_{AF}						<0.5	mg/l	SA_TM27/SA_PM0
Nitrite as N [SA]	$<0.600_{AG}$	<0.006	<0.006	<0.006	<0.006						<0.006	mg/l	SA_TM27/SA_PM0
Nitrate as N [SA]	$<5.00_{AG}$	<0.05	<0.05	<0.05	<0.05						<0.05	mg/l	SA_TM27/SA_PM0
Ortho Phosphate as P	0.049	0.052	<0.015	<0.015	0.075						<0.015	mg/l	SA_TM191/SA_PM31
Ammoniacal Nitrogen as N [SA]	$<1.50_{AF}$	22.60_{AA}	<0.03	<0.03	86.38_{AD}						<0.03	mg/l	SA_TM27/SA_PM0
Total Alkalinity as CaCO3 [SA]	296	<3	136	144	<3						<3	mg/l	SA_TM32/SA_PM0
Electrical Conductivity @25C [SA]	176500	8870	2640	2380	14890						<2	uS/cm	SA_TM28/SA_PM0
Dissolved Iron II [SA]	0.03	3.10_{AC}	0.09	0.04	113.60_{AE}						<0.03	mg/l	SA_TM48/SA_PM0
pH [SA]	8.43	3.14	7.31	7.51	2.68						<2.00	pH units	SA_TM19/SA_PM0