# APPENDIX C

# SPECIALIST REPORT ON MACROPHYTES AND MICROALGAE

**DRAFT SPECIALIST REPORT ON THE MACROPHYTES AND MICROALGAE OF THE ORANGE RIVER ESTUARY**

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**Scope of work**

Specialist reports on the microalgae and macrophytes of the Orange River Estuary were completed as part of the rapid resource directed measures (RDM) assessment of the estuary.

The tasks were to complete a literature review, the reserve assessment templates and provide preliminary Estuarine Health Index scores for predicted changes. This specialist report provides a summary of available literature and a summary of the data requirements to improve the confidence of a reserve determination assessment for the microalgae and macrophytes.

**Importance of the Orange River Estuary**

The Orange River estuary forms part of the Orange River Mouth Transboundary Ramsar Site (ORMTRS). The site is approximately 10 km from the Ernest Oppenheimer Bridge to the river mouth and covers 2000 ha of the ORMTRS (Anon. 2002). It is a coastal wetland of international importance located at the international boundary between South Africa and Namibia. A Ramsar wetland was initially defined as one that supports appreciable numbers of globally and regionally important waterbird species.

The ORMTRS was designated a Ramsar site because it fulfilled the following criteria:

- It is an example of a rare or unusual wetland in the biogeographical region.
- It supports rare, vulnerable or endangered species.
- It supports substantial numbers of individuals from particular groups of waterfowl, indicative of wetland values, productivity or diversity.
- It regularly supports 1 % or more of the individuals in a population of one species or subspecies of waterfowl.

The Orange River estuary is characterised by a variety of habitats in the form of braided islands and channels. These create sheltered shallow water areas where birds such as herons, ducks, egrets and waders can feed and roost. In particular the extensive reed beds provide habitat for warblers and other roosting or reedbed-dwelling passerines. Fringing reeds also provide perches for the variety of kingfishers. The macrophytes also stabilize the river banks thus protecting the mouth area.

**MACROPHYTES**

**The distribution of macrophytes**

The vegetation of the lower reaches of the Orange River is described by O'Callaghan (1984), Burns (1989), Morant and O'Callaghan (1990) and Raal (1996). Subsequent reports e.g. Anon. (2002) has used the data from these reports and no recent comprehensive vegetation survey data are available. These reports state that estuarine plant communities were distributed primarily along the southern bank of the estuary, corresponding to the 2 to 2.5 kilometre limit of saltwater penetration.

The delta-type river mouth has a wide range of habitats that consists of a series of braided troughs interspersed with sandbanks, channel bars and small islands, with a tidal basin and a saltmarsh on the southern bank. Several pans occur on either bank, extensive mudbanks occur at the mouth and large areas of interfluvial marsh occur upstream of the mudflats. Several small, artificial wetlands occur on either side of the river including the Alexander Bay oxidation ponds and lucerne fields pan on the South African side and the yacht club pan on the Namibian side.

*Scirpus littoralis* (reedswamp) occurred close to the mouth in small clumps but was replaced by the dominant species *Phragmites australis* along the shallow edge habitats further upstream. Both species thrive in brackish conditions when salinity is less than 15 ppt. The submerged macrophyte *Potamogeton pectinatus* was associated with *Phragmites australis* (CSIR 1991). This plant grows best at a salinity less than 10 ppt. The submerged macrophyte *Ruppia cirrhosa* was also reported but its abundance was said to be limited because of low salinity and high turbidity of the water (CSIR 1991, Raal 1996).

The vegetation on the braided system of islands within the lower reaches of the river are ephemeral due to periodic flooding. The pioneers such as *Sporobolus virginicus* (brakgras) and *Scirpus maritimus* dominate these communities and are normally in a sub-climax state. The peripheral marshes are dominated by *Sporobolus viginicus*, but various herbs, sedges and grasses such as *Cotula coronopifolia*, *Juncus kraussii* (sharp rush), *Apium graveolens* and *Cyperus laevigatus* also occur. All these species would thrive under brackish conditions (< 15 ppt). Recent aerial photographs (2002) indicate that two large vegetated areas occur on the south bank of the main river channel. These areas are probably composed of a mosaic of brackish species as described above.

The following species formed a mosaic of salt marsh vegetation: *Cotula coronopifolia*, *Triglochin* spp., *Juncellus laevigatus*, *Sporobolus virginicus* and *Sarcocornia pillansii*. *Sarcocornia perennis* formed a salt marsh on the right bank of the river near the mouth (Morant and O'Callaghan 1990). This species usually occurs in the intertidal zone of permanently open estuaries. *Sarcocornia pillansii* was dominant in the salinized lower floodplains (Figure 1). On the south bank of the river a large area of desertified saltmarsh exists. In 1986 approximately 90 % of this saltmarsh had died. Saltmarsh communities that were still present at elevated zones were dominated by *Sarcocornia pillansii.* This species usually occurs in the supratidal saltmarsh zone of South African estuaries. It has a wide salinity tolerance range (0-70 ppt) and in the Olifants estuary survives the semi-arid conditions by utilizing saline groundwater (Bornman 2002).

After the 1998 flood, much of the bare sand on the islands and banks were colonized by exotic species, mainly *Paspalum paspaloides*, *Nicotiana* spp and *Datura stramonium* (Morant and O'Callaghan 1990). The persistence of these species is unknown. As salinity increased the brackish wetland species i.e. *Phragmites australis* and *Sporobolus virginicus* could have outcompeted these weeds.

## Anthropogenic influences

It is estimated that 90 % of the area of the salt marsh on the southern bank has been lost. This is now a barren saline desert (Figure 2) and is a major cause for concern as highlighted in Anon. (2002). Because of the threatened status of the salt marsh the wetland was placed on the Montreux Record in 1995. South Africa is now obliged, as a signatory of the Convention**,** to ensure that the ecological character of the site is restored. A sequence of events is responsible for the loss of large areas of the marsh. These include the leakage of diamond-mining process plant water into the saltmarsh (Figure 3), the effect of windblown dried slimes dam sediment on the marsh vegetation, construction of flood protection works and beach access road, and the elimination of tidal exchange into the wetland due to a dyke constructed at the river mouth (Anon. 2002). Raal (1996) also cited other impacts such as the diversion of flood channels away from much of the wetland, grazing of cattle on the floodplain and the addition of fertilizers.

Chronologically the first impacts occurred in 1929 when attempts were made to keep the mouth open. This would have prevented backflooding of the marsh area. From 1968 the operation of the PK Le Roux and other dams reduced small floods. The combination of these floods with high spring tides is thought to have played an important role in flooding the marsh area (Van Niekerk *et al*. 2003). The reduction in the recharge potential of the brackish or freshwater lens above the saline wedge due to the modified river hydrology will also have contributed to the process of marsh die-back (CSIR 1991).

In the late 1960's tidal penetration into the western extreme of the salt marsh was blocked by a rubble berm in an attempt to control the mosquito problem. This berm later formed part of the beach access road (CSIR 1991). In 1974 the first dykes or levees were constructed to increase agricultural area. The dykes cut off two flood channels that used to extend southwards into the salt marsh via the Dunvlei channel system, part of which is now used as a sewage oxidation pond for Alexander Bay.

At this point both tidal and freshwater input was reduced to the marsh. There would have been a loss of brackish communities such as reeds and sedges and an increase in halophytic plants. The sediment would have been dry and saline. The beach access road and berm would have resulted in the loss of intertidal salt marsh. An isolated coastal lake developed behind the dunes in the lower part of the salt marsh and the water in this lake became highly saline, mainly because of ongoing evaporation (CSIR 1991).

Mining operations first commenced in 1929, the process uses seawater and wastewater collects in a slimes dam that is positioned adjacent to the salt marsh. Seepages from the slimes dam would have inundated the salt marsh for extended periods causing die back. Since 1929 the marsh became progressively stressed and in 1984 the final collapse of the system started and progressed rapidly. The trigger event around which the collapse is considered to have hinged was the introduction of North Sieve process water and slimes dam dust into the marsh along its south-western perimeter (Raal 1996).

In 1995 Alexkor together with the CSIR initiated a rehabilitation programme. The road embankment at the mouth was removed to allow for regular tidal flushing of the lower reaches of the degraded saltmarsh area. Recent aerial photographs (September 2002) indicate some success of this programme, however a vegetation survey would be necessary to confirm this.

**Driving physical / chemical factors**

**Flow**

Previous studies indicated that the major mechanism for inundating the salt marshes was regular mouth closure and the related back flooding. However according to van Niekerk *et al*. (2003) mouth closure was not a regular event and an alternative mechanism for inundating the salt marshes under the Reference condition was the combined effect of high river inflows/floods (1:1 – 1:10 year floods) and high spring tides. This has also been observed in the Olifants Estuary (Bornman *et al*. 2002). However there has been a marked reduction in floods from the reference to the present condition and thus this mechanism of inundating the salt marsh does not occur. Such floods would probably have lasted for periods of a few weeks at a time (van Niekerk *et al*. 2003).

Seasonal flow has been changed from that being high in summer and low in winter to similar but reduced flow in both summer and winter. The high summer flow was probably important in maintaining reduced salinity levels when evaporation was at its highest.

Rooted submerged macrophytes are not a dominant feature of the estuary probably because of the high flows and low water retention times. Agricultural activities along the river and in the catchment result in erosion and an increase in silt load to the estuary (Anon. 1992). This may also have reduced the distribution of submerged macrophytes.

Flow velocity and the stability of the sediment influence colonisation by emergent macrophytes such as reeds and sedges. It has been said that the vegetation on the braided system of islands within the lower reaches of the river are ephemeral due to periodic flooding. Reduced flooding will result in reed encroachment. Morant and O'Callaghan (1990) report on the effect of a major flood (8000 $m^3 s^{-1}$) in 1988 on the biota of the Orange River mouth. This flood destroyed 315 ha of wetland vegetation through erosion and deposition of coarse sediment. However the flood was important in reducing salt marsh salinity and stimulating germination, seedling growth and flowering of *Sarcocornia pillansii*. Floods would also deposit rich organic mud in the mouth area and thus floods have an important nutrifying effect.

Because of continuous releases of water from the dams for the generation of electricity and for irrigation purposes water levels are also far less variable now. This probably has resulted in sandbanks being more permanently exposed and, as a consequence become vegetated (van Niekerk *et al*. 2003). Evidence of this in the main channel where two large islands of brackish vegetation occur.

**Salinity**

The vegetation of the lower part of the river are typical of a low salinity coastal wetland. Salinity is mostly less than 15 ppt and the macrophytes present in the main river channel reflect this. In the desertified salt marsh area in 1994 a layer of crystallized salt occurred on the sediment surface and this was a highly saline environment (Figure 2, pers. obs). The salt marsh plant *Sarcocornia pillansii* occurred in some of the elevated areas. This plant has a wide salinity tolerance range of 0-70 ppt (Bornman 2002). If the desertified salt marsh area was previously covered by the saltmarsh plant *Sarcocornia pillansii*, it is unlikely that tidal exchange occurred regularly in this area. *S. pillansii* is a supratidal salt marsh species and at maximum is inundated with every spring tide. Large areas of *S. pillansii* occur in the Olifants estuary, a detailed 3 year investigation (Bornman 2002) established that these plants are dependent on the saline groundwater. The salinity of the groundwater is maintained at acceptable levels (< 70 ppt) through the influence of the estuary on groundwater. Rain was found to be important in stimulating growth and germination of seedlings. There is the possibility that the salinity of the water table in the vicinity of the desertified marsh has increased over time and that this has also contributed to the demise of the salt marsh.

Since the road embankment near the mouth has been removed and tidal exchange has occurred in the desertified marsh area, one could expect salt marsh zonation typical of a saline (35 ppt) permanently open estuary in the low lying areas. To re-establish *Sarcocornia pillansii* in the elevated areas the salts would need to be flushed out. CSIR (1991) believed that prior to the cut-off of freshwater input to the marsh the area would have supported a mosaic of communities associated with freshwater and brackish conditions (e.g. reeds and sedges such as *Phragmites* and *Scirpus*). When the desertified marsh area was cut-off from the main channel an isolated coastal lake developed behind the dunes in the lower part of the salt marsh and the water in this lake became highly saline, mainly because of ongoing evaporation (CSIR 1990). If tidal exchange is not currently maintained in the marsh area it could revert back to a saline lake.

**Mouth condition**

Mouth closure did occur in August and September under reference conditions (i.e. 10% of the time for a 68 year period under drought conditions when flow was < 10 $m^3$/s.) Backflooding of the desertified saltmarsh area would then have occurred. This event would have flushed out accumulated salts and lowered groundwater salinity. The mouth no longer closes because of continuous releases of water from the dams for the generation of electricity and for irrigation purposes (van Niekerk *et al*. 2003).

An open mouth is important for the recovering saltmarsh on the south bank. Since the causeway has been removed in the vicinity of the mouth, the saltmarsh now shows signs of recovery that is dependent on regular tidal inundation.

The location of the mouth could influence the salinity of the water reaching the salt marsh on the south bank near the mouth. When the location of the mouth at the southern position, considerable amounts of seawater enter the area at spring tides, but the salinity of the water entering the salt marsh would be much lower if the mouth were located at the northern bank. The needs of the salt marsh, therefore, should be considered before the mouth is breached (van Niekerk *et al*. 2003).

**Intertidal conditions**

There is considerable tidal variation over spring tides and no tidal variation over neap tides (Huizinga 1996). The mean tidal range at the mouth of the Orange River is approximately 1.6 m and can be as much as 2.2 m during spring tides (van Niekerk *et al*. 2003). Large stands of intertidal salt marsh have been reported in the past, i.e. on the south bank. Morant and O'Callaghan (1990) found 10 ha of the intertidal salt marsh plant *Sarcocornia perennis* prior to the 1998 flood. This plant typically occurs in the intertidal zone of permanently open estuaries. A vegetation survey is needed to verify the area currently covered by intertidal salt marsh.

**Data requirements**

To assess the present status of the macrophytes recent aerial photographs and a GIS map are needed indicating the present distribution of the different plant community types. Changes in the areas covered by the different plant community types should then be calculated using the earliest available aerial photographs or orthophotomaps. Field data are needed to verify the maps. These are:

- Number of different plant habitats (plant community types)
- Area covered by each plant habitat
- Species list for each plant habitat
- Extent of anthropogenic impacts such as mining, agriculture, grazing, trampling, alien vegetation.

This is an important task as there are indications that increased tidal exchange in the lower reaches of the estuary have resulted in the recovery of salt marsh.

Permanent transects (sampling stations) need to be set up for long term monitoring of changes in plant habitats. These transects should be set up along an elevation gradient and the percentage cover of each plant species in duplicate quadrats (1 $m^2$) recorded. An earlier assessment by CSIR (1991) included transects in the lower reaches. As far as possible the same transects should be used so that historical changes can be incorporated. The transects should span across the recovering intertidal salt marsh as well as the desertified marsh.

Boreholes need to be installed along the transect so the depth to the water table and water table salinity can be monitored. This is important because if this is found to be hypersaline then mouth closure and backflooding may have little effect in creating a favourable habitat for salt marsh growth.

## MICROALGAE

### Importance

Microalgae as the primary producers in estuaries in the form of phytoplankton and benthic microalgae support many secondary consumers. For this reason they can be said to fuel the food chain. It is therefore imperative that they are included in RDM studies. Phytoplankton biomass indicates the river-estuary interface zone, this is a brackish zone in the estuary characterized by high biomass and diversity. As freshwater inflow is reduced the extent of the river-estuary interface zone changes and the flow requirements of the estuary are set based on the acceptable change.
Phytoplankton biomass indicates the nutrient status of an estuary. For example in the Mhlanga estuary that receives sewage input biomass was greater than 200 $\mu g\ l^{-1}$ indicating a eutrophic system. Species composition also indicates the nutrient and hydrodynamic status of an estuary. Dinoflagellates are common when the estuary is nutrient rich and stratified. They occur when salinity is greater than 5 ppt whereas cyanophytes (blue-green algae) are common in nutrient rich water when salinity is less than 5 ppt.

A project has recently been completed (Bate *et al*. 2003) on the benthic diatoms in South African estuaries and responses to salinity. Species composition can indicate the recent salinity regime that the estuary was exposed to. Species composition can also be used to indicate nutrient status i.e. blue-green algae are abundant under nutrient rich conditions.

### Present status

Little to no information is available on the microalgae in the Orange River Estuary. Harrison *et al*. (CSIR, unpublished data) completed a once-off survey and the data for this are shown in Table 1. The estuary was sampled on 17 January 1994. The estuary was turbid with a secchi disk depth of 5 cm. pH was between 7.7 and 7.8, temperature was between 22 and 23 $^{o}$C and salinity was 1 ppt. The estuary was clearly flowing strongly and any microalgae (phytoplankton) present in the water column must have been brought from upstream with no *in situ* estuary production due to the short residence time. The nitrate concentrations are fairly high and could indicate agricultural input. The chlorophyll-a concentrations are also high, that is if the units of mg $l^{-1}$ are correct. The interpretation of this is that agricultural inputs in the riverine sections stimulate phytoplankton growth and during high flow this is transported into the estuary. This would need to be verified from the identification of phytoplankton groups and species. Earlier reports stated that high water turbidity in the Orange River mouth precluded phytoplankton as a significant contributor to primary production. This may be true for high flow conditions but during low flow biomass could be high.

Table 1 Water column nutrient and chlorophyll-a concentrations in the Orange River Estuary (from Harrison *et al.,* CSIR, unpublished data*).*

| **Sites** | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
|---|---|---|---|---|---|---|---|---|
| **Parameter** | Top | Bottom | Top | Bottom | Top | Bottom | Top | Bottom |
| Depth (cm) | 0 | 130 | 0 | 140 | 0 | 200 | 0 | 90 |
| $NO_3$ (µg $l^{-1}$) | 1730 | 1030 | 1410 | 1070 | 1240 | 1410 | 890 | 1020 |
| $PO_4$ (µg $l^{-1}$) | 60 | 50 | 60 | 60 | 60 | 70 | 70 | 80 |
| Chl-a (mg $l^{-1}$) | | 4.2 | | 2.4 | | 2.4 | | 2.8 |

Although phytoplankton is probably unimportant because of high flows and flushing which would preclude the development of resident populations, benthic microalgal biomass could be high in quiet backwater areas. Benthic microalgae would be important primary colonizers after floods as their mucilage secretions would help stabilize newly formed sandbanks. Brown (1959) reported that the sediment at the mouth was coarse and composed of a mixture of sand and gravel. These substrata would not support high benthic microlalgal biomass. Sediment characteristics changed abruptly inside the mouth when the estuarine sediment changed to fine mud which extended at least 8 km upstream. These types of sediment are expected to support a large biomass of benthic microalgae. Usually intertidal biomass is greater than subtidal biomass.

An open mouth, the interaction between seawater and freshwater and increase in available nutrients would be important in stimulating phytoplankton growth. Phytoplankton biomass is usually highest in the river-estuary interface zone of estuaries where the water is brackish (< 15 ppt) and nutrient availability is high. The flow in the Orange River Estuary is probably too high for a river-estuary interface zone to develop for any length of time.

**Data requirements**

Field surveys are clearly needed before an assessment of the present status of the microalgae can be made with any confidence. Duplicate samples should be collected for chlorophyll-a analysis at the surface and 0.5 m depth intervals for a miniumum of 5 stations. Cells of the dominant phytoplankton species are counted and identified.

For benthic microalgae intertidal and subtidal benthic samples are collected for chlorophyll a (biomass) analysis. A minimum of 5 samples at each site should be collected. The relative abundance of the different algal groups must be determined. Physico-chemical parameters that are measured include water salinity, inorganic nutrients, light penetration, sediment particle size distribution and organic content.

For an intermediate reserve determination these measurements are usually made during a low and high flow season. For a comprehensive assessment sampling should be conducted seasonally for 2 years with river inflow being representative of a particular season.

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**FIGURES**

**Figure 1 *Sarcocornia pillansii*, the dominant salt marsh plant in saline supratidal areas.**

**Figure 2 Barren desertfied marsh on the southern bank (1994).**

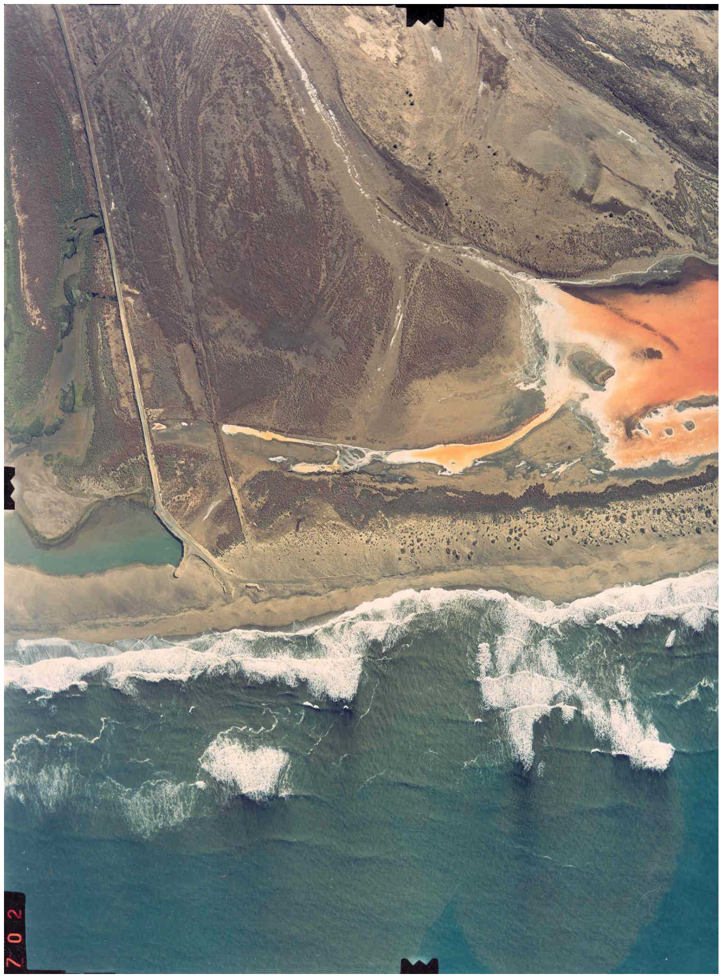


**Figure 3 Approximately 90 % of the salt marsh in the present desertified area has been lost (Photo source: CSIR, November 1986). This was as a result of leakage of diamond-mining process plant water, the effect of windblown dried slimes dam sediment, construction of flood protection works and beach access road, and the elimination of tidal exchange into the wetland due to a dyke constructed at the river mouth.**