Orange-Senqu River Basin

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

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Priority Interventions for the Management of the Orange-Senqu River Mouth

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Executive summary

Introduction

This document discusses critical issues impacting on the health of the Orange-Senqu River mouth and identifies local priority interventions recommended for the SAP implementation phase.

Study site

The Orange-Senqu River mouth is situated between the towns of Oranjemund in Namibia and Alexander Bay in South Africa. The study area extended from the mouth to the head of tidal influence at the Sir Ernest Oppenheimer Bridge, approximately 11 km upstream, and included the banks up to the 5 m contour. The total area is approximately 2, 700 ha.

Biodiversity importance

Following South Africa's accession to the Ramsar Convention, the Orange-Senqu River mouth was designated a Ramsar Site, i.e. a wetland of international importance, on 28/06/1991 (Cowan, 1995). Namibia ratified the Ramsar Convention in 1995, after which the designated area was enlarged and the Namibian part of the wetland was designated too. In September 1995 the South African Ramsar Site was placed on the Montreux Record (a list of Ramsar Sites that are in a degraded state) as a result of a belated recognition of the severely degraded state of the saltmarsh on the south bank (CSIR, 2001). The implication is that the Orange-Senqu River mouth may lose its status as a Ramsar Site unless the condition of the saltmarsh can be restored.

The Namibian section of the Orange-Senqu River mouth was recently included in the proclamation of the Sperrgebiet National Park in Namibia. However, the section in South Africa is still in the process of being formally protected through legislation. Turpie et al. (2002) ranked the Orange-Senqu as the seventh most important estuary in South Africa in terms of conservation importance. The Orange-Senqu River mouth is also one of only two estuaries on the Namibian coast, the other being the Kunene River mouth.

Estuary importance is an expression of the value of a specific estuary to maintaining ecological diversity and functioning of estuarine systems on local and wider scales. The estuary importance score takes size, the rarity of the estuary type within its biographical zone, habitat, biodiversity importance and functional importance of the estuary into account. The biodiversity importance score is in turn based on the assessment of the importance of the estuary for plants, invertebrates, fish and birds, using rarity indices. The importance scores ideally refer to the system in its natural condition. The functional importance of this estuary was also deemed to be very high, since the sediment supply from the Orange River catchment feeds the beaches to the north of the mouth. The sediment input from the river is also very important for flatfish in the near-shore environment in the vicinity of the mouth as it provides the habitat on which they depend.

Based on its present state, the overall biodiversity importance of the estuary is therefore 'high'.

Present ecological status

The health scores allocated to the various abiotic and biotic parameters for the Orange-Senqu River mouth are used to calculate the overall health score (see table below). The Orange-Senqu River mouth has an overall health score of 51 relative to the natural condition. This is mostly attributed to the following factors:

- Significant freshwater flow modification – both loss of floods and increased baseflows;
- Lack of estuary mouth closure and resulting backflooding of saltmarshes with fresher water;
- Road infrastructure in the form of the old causeway across the saltmarshes and old bridge crossings;
- Nutrient input from the catchment downstream of Noordoewer/Vioolsdrift;
- Gill netting of indigenous fish species and considerable fishing effort at the mouth on both sides of the estuary;
- Riparian infrastructure – levees preventing backflooding;
- Mining activities;
- Wastewater disposal (sewage and mining return flow); and
- Grazing and hunting.

The estuary health score for the Orange-Senqu River mouth under present conditions and the study confidence levels are provided below.

Variable	***Weight***	***Health score***	***Confidence***
Hydrology	25	44	Low/Medium
Hydrodynamics and mouth condition	25	70	Low
Water quality	25	53.2	Medium
Physical habitat alteration	25	78	Medium
Habitat health score		***61***	***Medium***
Microalgae	20	40	Low
Macrophytes	20	50	Medium
Invertebrates	20	45	High
Fish	20	50	Medium
Birds	20	23	Medium
Biotic health score		*42*	*Medium*
Estuary health score		51	
Present ecological status		D	
Overall confidence			*Medium*

The overall health score translates to a present ecological status (PES) of D, representing a 'largely modified' estuary.

Recommended ecological category

The recommended ecological category (REC) represents the level of protection assigned to an estuary. The first step is to determine the 'minimum' ecological category (EC), based on its present ecological state (PES). The relationship between the estuary health score (derived from a estuary health index), PES and minimum REC is set out below.

Estuary health score	*PES*	*Description*	*Minimum EC*
91 – 100	A	Unmodified, natural	A
76 – 90	B	Largely natural with few modifications	B
61 – 75	C	Moderately modified	C
41 – 60	D	Largely modified	D
21 – 40	E	Highly degraded	-
0 – 20	F	Extremely degraded	-

The PES sets the minimum REC. The degree to which the REC needs to be elevated above the PES depends on the level of importance and level of protection, or desired protection, of a particular estuary. The PES for the Orange-Senqu River mouth is a D. The estuary is rated as 'highly important', it is a designated Ramsar Site, a Protected Area on the Namibian side; and a desired protected area in the South African Biodiversity Plan for the 2011 National Biodiversity Assessment (Turpie et al., 2012). The REC for the estuary is therefore its Best Attainable State which is estimated as a Category C.

Recommendations

To improve the health of the Orange-Senqu River mouth the following mitigation measures are required:

- Local-level physical interventions
  - Removal of the remnant causeway that still transects the saltmarshes to improve circulation during high flow and floods events. This will also assist with increasing the water circulation into the intertidal and lower marsh areas.
  - Removal of old earth-moving equipment buried in the sand berm near the mouth of the Orange. They were buried to prevent southwards migration of the mouth, but the further south the mouth moves, the more friction the inlet channel develops; which ultimately would assist with closure under low flow conditions.
  - Controlling wind-blown dust and wastewater from mining activities to reduce smothering of saltmarshes

- Controlling the fishing effort on both the South African and Namibian side through increased compliance and law enforcement. This also requires the alignment of the fishing regulations (e.g. size and bag limits) and management boundaries on both sides of the transboundary estuary There also needs to be strict enforcement of the prohibition of gillnetting in the estuary.

- Local level supporting interventions
  - Vehicular access to the berm should comply with the South African Integrated Coastal Management Act (ICMA, 2008) and be restricted to landowners that need to access private land via the berm. Angler access to the berm should be strictly by foot.
  - Livestock grazing by domestic (and feral) cattle needs to be appropriately managed as it further degrades the saltmashes, competes with the indigenous large herbivores and detract from the tourism value of the site and compete for valuable grazing resources.
  - Illegal dog-hunting and predation by feral dogs on the floodplain and islands needs to be curtailed.
  - Alien invasive plants in the floodplain need to be controlled in order to restore the integrity of estuarine vegetation and maintain the meandering nature of the estuary channels. Large strands of alien invasive trees have been establishing themselves on the islands and flood plain in the upper reaches of the estuary after the 2010/11 floods which is in urgent need to intervention.
  - A Lidar survey[1] of the Orange River mouth shall be conducted, to assist with identifying elevated areas that obstruct tidal intrusion and drainage of flood plain after high flow events. The same data would also assist in determine the maximum water level (relative to mean sea level) at which critical infrastructure and developments will be inundated and at which artificial breaching needs to be conducted.
- Local-level institutional interventions
  - The existing dirt-road network crossing the Orange River mouth floodplain needs to be rationalised to limit impacts on estuarine habitat and provide access to the Ramsar sites in an ecological sensitive manner while enhancing tourism in the area.
  - Reviewing and developing a joint zonation scheme to manage activities within the Ramsar sites and/or protected area(s). This includes revisiting the boundaries of the

[1] Lidar (light detection and ranging) is a remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light.

site and formal protected areas, as well as the planning schemes for Alexander Bay and Oranjemund.

- As artificial breaching of an estuary mouth/inlet requires legal approval, a mouth management plan (i.e. artificial breaching protocol) needs to be proactively formalised to provide guidelines for when and how the estuary mouth may be breached (e.g. water level, position, trench size, what equipment etc).

- Longer term interventions outside of the Orange-Senqu River mouth
  - Decreasing nutrient input from the catchment downstream of Noordoewer/ Vioolsdrift, through improved agricultural practices. The effect of increased nutrient loads were very apparent in August 2013 under low flow condition.
  - Decreasing the winter baseflows sufficiently to allow for mouth closure and related backflooding of the saltmarshes with brackish water to reduce soil salinities.
- Risks
  - Inundation of developments/infrastructure (e.g. golf course) and farm land on the flood plain during the closed phase.
  - Fish recruitment failure if estuary mouth remains closed during spring and summer recruitment peak whilst acknowledging that this happed under natural conditions as well.
  - Increased aquatic macrophyte blooms under low flow conditions before mouth closure.

Abbreviations

CSIR	*Centre of Scientific and Industrial Research*
DWA	*Department of Water Affairs*
DWAF	*Department of Water Affairs and Forestry*
EC	*Ecological category*
EFR	*Environmental flow requirements*
H	*High*
L	*Low*
ICMA	*South Africa's Integrated Coastal Management Act, 2008 (Act No 24 of 2008)*
M	*Medium*
MAR	*Mean Annual Runoff*
Mm³	*Million cubic metres*
Mm³/a	*Million cubic metres per year*
NWA	*South Africa's National Water Act (Act No. 36 of 1998)*
ORASECOM	*Orange-Senqu River-Commission*
PES	*Present Ecological Status*
PSU	*Practical Salinity Units (also called parts per thousand (ppt))*
RDM	*Resource Directed Measures*
REC	*Recommended ecological category*
VL	*Very low*

1. Orange-Senqu River mouth

1.1 Estuary importance

Following South Africa's accession to the Ramsar Convention the Orange-Senqu River mouth was designated a Ramsar Site, i.e. a wetland of international importance, on 28/06/1991 (Cowan, 1995), because of (a) being one of only nine perennial coastal wetlands on the southern African west coast, (b) its supporting more than 20,000 waterbirds of about 60 species, (c) its supporting an appreciable assemblage of rare and endangered water bird species, and (d) supporting more an 1% of the world and southern African population of several species of waterbirds. Namibia ratified the Ramsar Convention in 1995, after which the designated area was enlarged and the Namibian part of the wetland was designated too. Following national bird counts in the 1970s and 80s, the estuary was recognised as being one of the most important estuaries in South Africa in terms of its waterbird populations (Turpie, 1995), and as a top priority in terms of its overall biodiversity conservation importance (Turpie et al., 2002; Turpie and Clark, 2007). It has also been designated as an Important Bird Area (Barnes and Anderson, 1998).

Since its designation as a Ramsar site, however, numbers of birds on the estuary have declined dramatically, probably due to a combination of on-site and off-site factors (Anderson et al., 2003). In September 1995 the South African Ramsar Site was placed on the Montreux Record (a list of Ramsar sites around the world that are in a degraded state) as a result of a belated recognition of the severely degraded state of the saltmarsh on the south bank (CSIR, 2004). The implication is that the Orange-Senqu River mouth may lose its status as a Ramsar Site unless the condition of the saltmarsh can be restored.

The Namibian section of the Orange-Senqu River mouth was recently included in the proclamation of the Sperrgebiet National Park in Namibia. However, the section in South Africa is still in the process of being formally protected through legislation (Louw, D et al., 2013a).

Estuarine importance is an expression of the value of a specific estuary to maintaining ecological diversity and functioning of estuarine systems on local and wider scales. The Orange-Senqu River mouth is one of only two estuaries, the other being the Kunene River Mouth, on the Namibian coast. Turpie et al. (2002) ranked the Orange-Senqu River mouth as the seventh most important estuary in South African in terms of conservation importance. The prioritisation study calculated conservation importance on the basis of size, habitat diversity, zonal type rarity and biodiversity importance. The biodiversity importance, in turn is based on the assessment of the importance of the estuary for plants, invertebrates, fish and birds, using rarity indices. Furthermore, the functional importance of the estuary was also deemed to be very high, since the sediment supply from the Orange River catchment feeds the beaches towards the north of the mouth. The sediment input from the river is also very important for flatfish in the nearshore environment in the vicinity of the Orange-Senqu River mouth as it provides the habitat they depend on.

The Orange-Senqu River mouth is deemed 'highly important' from a biodiversity perspective and therefore an important conservation area.

1.2 Characteristics of the Orange-Senqu River mouth

Study area

The Orange-Senqu River mouth, situated between the towns of Alexander Bay in the Northern Cape Province, South Africa and Oranjemund in Namibia has an area of about 2,700 ha (Louw, D et al., 2013a). The estuary comprise an (almost) permanently open river mouth, a 2 – 3 m deep tidal basin, a braided channel system (located between sand banks covered with pioneer vegetation) and a severely degraded saltmarsh on the south bank of the river mouth (Cowan, 1995). A satellite image of the estuary is shown in Figure 1.

Figure 1. Satellite image of the Orange-Senqu River mouth showing the 5 m mean sea level contour in red (Source: Google Earth).

Orange-Senqu River mouth extends from the mouth as far as the Sir Ernest Oppenheimer Bridge, approximately 11 km upstream (CSIR; 2004). Tidal variations of only a few centimetres are observed during springtide at this bridge. The geographical boundaries of the Orange-Senqu River mouth are estimated as follows (Louw, D et al., 2013a):

- Downstream boundary: The Orange-Senqu River mouth (28°37'58.91"S, 16°27'16.02"E);
- Upstream boundary: Head of tidal influence at the Sir Ernest Oppenheimer Bridge, approximately 11 km for mouth (28°33'43.63"S, 16°31'23.02"E); and
- Lateral boundaries: Five meter contour above mean sea level along the banks.

Although the flows have been drastically reduced and regulated, the estuary is still dominated by river flow. The marine water interchange is limited to the lower section of the estuary under normal flow conditions.

At times the mouth is located at the northern bank and sometimes at the southern bank. In the past the location was strongly influenced by the position where the mouth was breached (artificially or natural). The mouth breachings were alternatively undertaken on the north and south sides of the river by Namdeb and Alexcor respectively. The objective of these breachings was to protect low-lying infrastructure from being flooded.

Estuarine sediment dynamics and morphology

The Orange-Senqu River mouth usually consists of a braided channel system, with many islands in the upper estuary, which feeds into a open tidal basin area. The inlet is maintained by fluvial discharge, and additional fluvial sediment passes through the estuary and is deposited in the sea, where it is dispersed. Overall, large floods are crucial in maintaining the long-term dynamic equilibrium with respect to the sediment regime in the Orange-Senqu River mouth. During major resetting floods in the river, large volumes of sediment are flushed out from the entire estuary, removing many of the islands between the braided channels, scouring out the basin area and flushing a large part of the sand bar into the ocean. During the falling stage of the flood, fluvial sediments are again deposited throughout the estuary with large depositions in the upper estuary area. The sand bar across the mouth is rapidly rebuilt by coastal processes after the flood. Smaller river floods tend to move some of the sediment from the upper estuary towards the tidal basin through scouring of the braided channels or erosion of the islands. During periods of low river flow, tidal flows through the mouth (especially during spring flood tide) transport littoral sediment into the tidal basin area. The marine sediment is non-cohesive and much coarser than the fluvial sediment. In the offshore zone, sediments on the inner continental-shelf mudbelt are associated with the Orange-Senqu River mouth prodelta, and are dominated by laminated clay-rich sediments (Louw, D et al., 2013b).

The available information currently indicates that the depth and bed morphology over most of the estuary are relatively similar to that of the natural state. At present the braided channels in the upper estuary are deemed to be more stable, and probably slightly narrower and/or shallower, due to reduced intermediate river flows. The increased cohesion of riverine sediments and stabilisation of sand bars by vegetation in the braided channel area, means that relatively higher magnitude floods are necessary to effect significant morphological change. The reduction in large floods from the natural state to the present state, indicates that the system would originally have been reset more frequently, thus increasing overall variability in morphology, sediment processes and characteristics. The residence period and average extent of marine sediments (carried into the tidal basin during flood tides) would also originally have been less.

The sediment supply has changed significantly over the years. Bremmer et al. (1990) calculated a discharge rate of 119 million tons per year a prior to 1921. By the 1980s this was estimated to be less than 44 million tons per year (Basson et al., 2011), primarily due to dam developments.

Microalage

Microalgae, as primary producers, form the base of the food chain in estuaries. The group includes those living in the water column (phytoplankton) and those living on exposed intertidal or submerged surfaces (benthic microalgae).

Phytoplankton biomass and species composition indicates the nutrient and hydrodynamic status of an estuary. Dinoflagellates are typically abundant when the estuary is nutrient-rich and stratified. Phytoplankton chlorophyll a was lowest at the mouth of the estuary and highest upstream. Cell densities were typical of a phytoplankton bloom, supporting the chlorophyll a results. The flagellates and dinoflagellates are highest in the middle reaches of the estuary (Louw, D et al., 2013b). The highest flagellate densities are found in the deep 'old water' in the lower 3 km from the mouth, making this the most likely group to have contributed to the elevated chlorophyll a in the system. The diatoms and chlorophytes increased in density with distance from the mouth, indicating that the majority of cells were transported into the estuary in the river water (Louw, D et al., 2013b).

Benthic diatoms are known to respond to salinity and most references describe diatoms as freshwater, brackish or marine species (Bate et al., 2004). In addition, diatoms have proven to be useful indicators of trophic status, particularly in freshwater ecosystem studies (Taylor et al., 2007). The benthic diatoms in the Orange-Senqu River mouth in August 2012 were dominated by species tolerant of polluted waters (Louw, D et al., 2013b). The general community composition in the estuary indicates that the estuary was brackish or electrolyte-rich for a period of time leading up to sampling and, more importantly, the environment was eutrophic or strongly polluted.

Macrophytes

The Orange-Senqu River mouth has unique estuarine macrophyte species diversity. Steffen et al. (2010) described an ecomorphotype of *Sarcocornia pillansii* (Moss) A.J.Scott that shows unique morphology in this estuary. The Orange River ecomorphotype is characterized by corky, swelling internodes. Other estuarine macrophytes that were previously recorded in the estuary were *Bassia diffusa*, *Bolboschoenus maritimus Palla*, *Cotula coronopifolia*, *Juncus kraussii*, *Phragmites australis*, *Salicornia meyeriana*, *Sarcocornia natalensis* and *Triglochin striata*. The total habitat area was calculated as 2,700 ha (Louw, D et al., 2013b). The major habitat types were channel, sand/mud banks, reeds and sedges, submerged macrophytes, supratidal saltmarsh and intertidal saltmarsh (Figure 2).

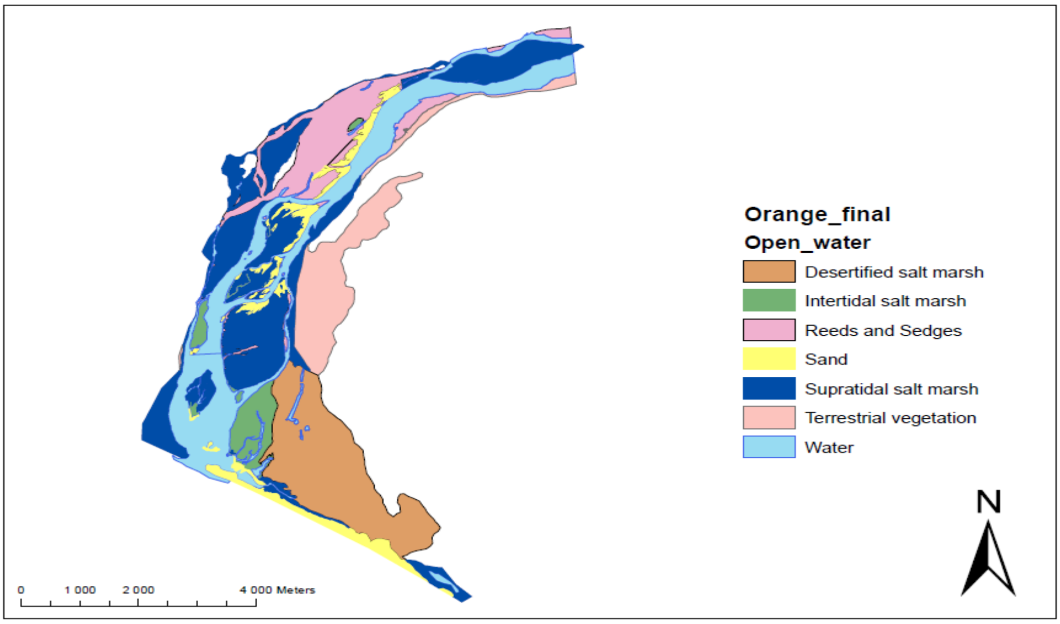

Figure 2. Vegetation map of the Orange-Senqu River mouth (2012).

The Orange-Senqu River mouth vegetation had been highly modified since 1929 because of the following events (Louw, D et al., 2013b):

- In 1929 attempts were made to keep the mouth open that would have prevented backflooding of the marsh area.
- In the late 1960's tidal penetration into the western extreme of the saltmarsh was blocked by a rubble berm in an attempt to control the mosquito problem.
- 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 saltmarsh via the Dunvlei channel system, part of which is now used as a sewage oxidation pond for Alexander Bay.
- From the mid 1970s the operation of the Gariep (1971), van der Kloof (1977) 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 (CSIR, 2004).
- Mining operations first commenced in 1929, the process uses seawater and wastewater collects in a slimes dam that is positioned adjacent to the saltmarsh. Seepages from the slimes dam would have inundated the saltmarsh for extended periods causing die back 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. Sections of the causeway at the mouth were removed to allow for regular tidal flushing of the lower reaches of the degraded saltmarsh area. Aerial photographs from 2002 indicate some success of this programme. Bornman et al. (2004) studied the success of the rehabilitation programme and found that rehabilitation of the desertified marsh can succeed only if the groundwater salinity is reduced.

This could be achieved by further linking the marsh back with the main river channel, i.e. removing sections of the causeway or the whole of it, thereby introducing less saline water and establishing favourable geohydrological conditions. Backflooding of the floodplain used to occur under natural conditions and might be useful initially in flushing the sediment and groundwater of excess salts. Floodplain saltmarsh is intolerant of standing water and proper drainage of the floodplain should be ensured before backflooding is attempted. This could be achieved in part through the removal of the causeway. The establishment of favourable physico-chemical conditions should result in the natural recolonisation of the bare areas by the dominant species *Sarcocornia pillansii*.

Invertebrates

The invertebrate fauna of the Orange-Senqu River mouth is considered to be species poor and atypical of tidal estuaries along the west coast of southern Africa (Louw, D et al., 2013b). Those few species resident in the estuary are widely tolerant of a highly variable physic-chemical environment, although populations fluctuate significantly in terms of abundance and composition both within years (variations in seasonal flow) and between years (magnitude of floods and state of the mouth including breaching (artificial or natural).

When the three main invertebrate groups are considered (zooplankton in the water column, hyperbenthos just above the substrate, and the benthos on or in the bottom sediments), abundance was maximal among species that are either resident in the benthos (polychaetes) or those that have a strong association with the substrate (mysids in the hyperbenthos). Even under present day flow conditions, tidal currents (when the mouth is open) and the associated low residence time of the water probably lead to significant export of biomass to the ocean.

Fish

A total of 33 fish species from 17 families have been captured from the Orange-Senqu River mouth (CSIR, 2004). Thirty four percent show some degree of estuarine dependence, 24 % are marine and the remaining 42 % freshwater species (Louw, D et al., 2013b).

Catches throughout the year are dominated by the partially estuarine-dependent *L. richardsonii* which compromises about 50% of the adult or large fish component and more than 90% of the juvenile component of the fish assemblage. The remaining 10% of the fish assemblage is dominated numerically by the estuary-resident *Gilchristella aestuaria* and the freshwater *Labeobarbus aeneus*, *Labeo capensis*, *Tilapia sparrmanii* and *Pseudocrenilabris philander*.

The presence of a range of size classes of *L. richardsonii* suggests that the Orange-Senqu River mouth is being utilised as a nursery for this species. Similarly, various size classes of the estuary-breeder *Gilchristella aestuaria* indicate that the estuary is supporting a viable population of this species. Catches of the other species able to breed in estuaries *Caffrogobius nudiceps*, *C. saldhana*, *Atherina breviceps*, *Clinus superciliosus* and *Syngnathus acus* were low but their presence suggests that they are using the Orange-Senqu River mouth as a nursery. Catches of juvenile obligate estuary-dependant *Mugil cephalus* and *Lichia amia* and partially dependent *P. saltatrix* indicates that the same holds true for these species. Most freshwater species were also represented by juveniles.

On the whole, the high diversity and abundance of estuarine dependant and marine species suggests that the Orange-Senqu River mouth is an extremely important estuarine nursery area and not just a freshwater conduit as previously thought (Louw, D et al., 2013b). Historically, it was likely that estuarine and freshwater fish escaped floods and high flows by either swimming upstream or moving onto the inundated floodplain and saltmarshes or even into the adjacent surf-zone. Nowadays obstructions such as the dykes and causeway have removed much of this temporary refuge and the chances of being flushed from the system are higher and may even occur at lower flows. Reduced inundation of the marginal and channel areas of the saltmarsh are also likely to have seen a reduction in habitat and numbers of benthic species such as the gobies *Caffrogobius nudiceps* and *C. saldhana* and pipefish *S. temminckii*. This is also likely to have greatly reduced the intertidal foraging area of the dominant species in the estuary, *L. richardsonii*. Higher flows in the winter months may have reduced the residence time and/or numbers of marine and estuarine dependent species entering the system whereas lower flows during the summer months may have seen fewer fish escaping cold upwelling events in the sea. Higher winter flows are also likely to have resulted in the freshwater species persisting in the estuary throughout winter whereas previously they would have moved back into the upper reaches in response to increased salinity.

The above assumptions are supported by an apparent increase in species composition and abundance over the last decade following a reduction in hydroelectric releases during winter and the partial removal of the causeway, the latter restoring much of the intertidal habitat previously lost to fish in the estuary.

Birds

An analysis of waterbird survey data (1980 – 2012) shows that the maximum number of waterbirds recorded during the 1980s was 21,512 individuals in January 1980 and between 20,563 and 26,653 individuals in December 1985 (Anderson et al. (2003). Since then there has been a significant decline in waterbird numbers a situation primarily accounted for by the decline in Cape Cormorant and Common Tern S. hirundo populations (Louw, D et al., 2013b). Without the large numbers of Cape Cormorants and Common Terns, the important number of 20,000 waterbirds, one of the criteria used for the original designation of the Orange-Senqu River mouth as a Ramsar site, cannot be attained. The maximum number of waterbirds recorded at the mouth since being listed on the Montreux Record were 9,240 in July 2000 and the maximum number of species recorded in December 1995 were 64.

Yet despite a change in fortunes, the waterbird population still comprise of close to 60 species of which 14 regularly occurring and an additional seven occasionally occurring species are Red Data listed. An analysis of the summer and winter waterbird survey data also found that significant proportions of the regional populations of South African Shelduck *Tadorna cana* and Cape Shoveller *A. smithii* and globally significant populations of Kelp Gull *L. dominicanus* and Hartlaub's Gull were present during the winter months.

Both on-site and off-site factors may be responsible for the decline in the numbers of Cape Cormorants and Common Terns are, including the following: (1) depletion of food reserves, (2) increased disturbance by humans, (3) disturbance and trampling by livestock, (4) predation and disturbance by feral dogs and cats, (5) change in the architecture of the mouth and islands with a consequent effect on roost site availability, (6) more suitable roosting sites elsewhere, (7) disease (avian cholera Pasteurella multocida) and (8) oiling (Anderson et al. (2003)).

The Orange-Senqu River mouth still met several of the standard Ramsar criteria required for designation: (1) It is an example of a rare and unusual wetland type on the arid and semi-arid coastline of western southern Africa; (2) It supports an appreciable assemblage of rare and endangered bird species, 14 of which are listed in the previous South African or draft Namibian list. (3) At times it supports more than 20,000 waterbirds (of 50-57 species); and (4) The mouth regularly supports (a) more than 1% of the world population of three species of waterbirds that are endemic to southern Africa, namely the Cape Cormorant, Hartlaub's Gull and Damara Tern, and (b) more than 1% of the southern African populations of six species of waterbirds, namely the Black-necked Grebe, Lesser Flamingo, Chestnut-banded Plover, Curlew Sandpiper, Swift Tern and Caspian Tern. A re-evaluation of the Orange River estuary in terms of the new Ramsar criteria, concluded that the Ramsar site still meets several of the criteria for which it was originally established and at least one new criterion (Anderson in Van Niekerk et al 2008).

2. Key pressures

2.1 Flow related

Water resource development, and related major dam infrastructure, in the Orange-Senqu River basin has reduced runoff to the Orange-Senqu River mouth by more than 50% (Louw, D et al., 2013a).

On a flow volume basis, preliminary analyses indicate that floods have been reduced by as much as 85% for 1 in 2 year and 74% for 1 in 5 year events respectively (i.e. 15% (1:2) and 26% (1:5) remaining). Similarly, it is estimated that 1 in 20 year floods are reduced by about 20%, while 1 in 100 year floods are reduced by about 10% from reference condition to present state (CSIR, 2004). Larger floods play an important role in resetting the habitat of the estuary. On an occurrence basis, smaller 'reference' floods occurred about 2 to 3 times more frequently than at the present state (i.e. peak flows in the order of 1 in 2 to 5 years flood now occur on average 1 in 8 to 11 years), while 'reference' 1 in 10 year floods now occur in the order of 7 times less frequently (i.e. these peak flows now occur on average 1 in 66 years) (Louw, D et al., 2013a).

In contrast, seasonal low flows (below 50 m^3/s) have significantly increased from reference conditions to the present state, with a drastic increase in the 10 to 20 m^3/s inflow range. This is the result of agricultural return flow and surplus releases for the generation of hydropower purposes. These surplus releases are currently in the process of being significantly reduced from about 320 million m^3/a, as was the case up to the 2000s, to 60 million m^3/a at present.

The result is that the Orange-Senqu River mouth has not closed since 1995 (CSIR, 2004).

2.2 Water quality

Agricultural activities in the catchment are the most significant sources of inorganic nutrients (nitrogen and phosphate) to the river, and ultimately the estuary. Although some enrichment can occur in the estuary, it is expected that riparian vegetation largely acts as a filter of inorganic nutrients.

For example, recent median monthly values for dissolved inorganic nitrogen concentrations measured in river inflow to the Orange-Senqu River mouth (1995–2011), as well as monthly median river flow, over the same period, are presented in Figure 3 (Louw, D et al., 2013b). Median dissolved inorganic nitrogen concentrations at the Sir Ernest Oppenheimer Bridge (mainly comprising nitrate - N) correlate well with median monthly flow, where highest concentrations are measured during months of high river inflow. Dissolved inorganic nitrogen concentrations were around 100 μg/ℓ, peaking at 400 μg/ℓ during high flow periods. De Villiers and Thiart (2007) estimated dissolved inorganic nitrogen concentrations in river flow from the lower Orange basin under reference condition to be <50 μg/ℓ. Higher concentration under the present state are mostly associated with runoff from agricultural land in the catchment. Both dissolved phosphate and total phosphate concentrations show a similar correlation with median monthly flow, where highest concentrations are measured during months of high river inflow, but total phosphate concentrations is much more pronounced. Results also reveal that a significant proportion of phosphate enters the estuary is in the particulate (or organic) form. Note that the Sir Ernest Oppenheimer Bridge site shows elevated levels from January to June, while at Noordoewer/ Vioolsdrift the values are remaining low. This points to agricultural sources in the lower 250 km, just above the estuary, that are causing additional enrichment during this period.

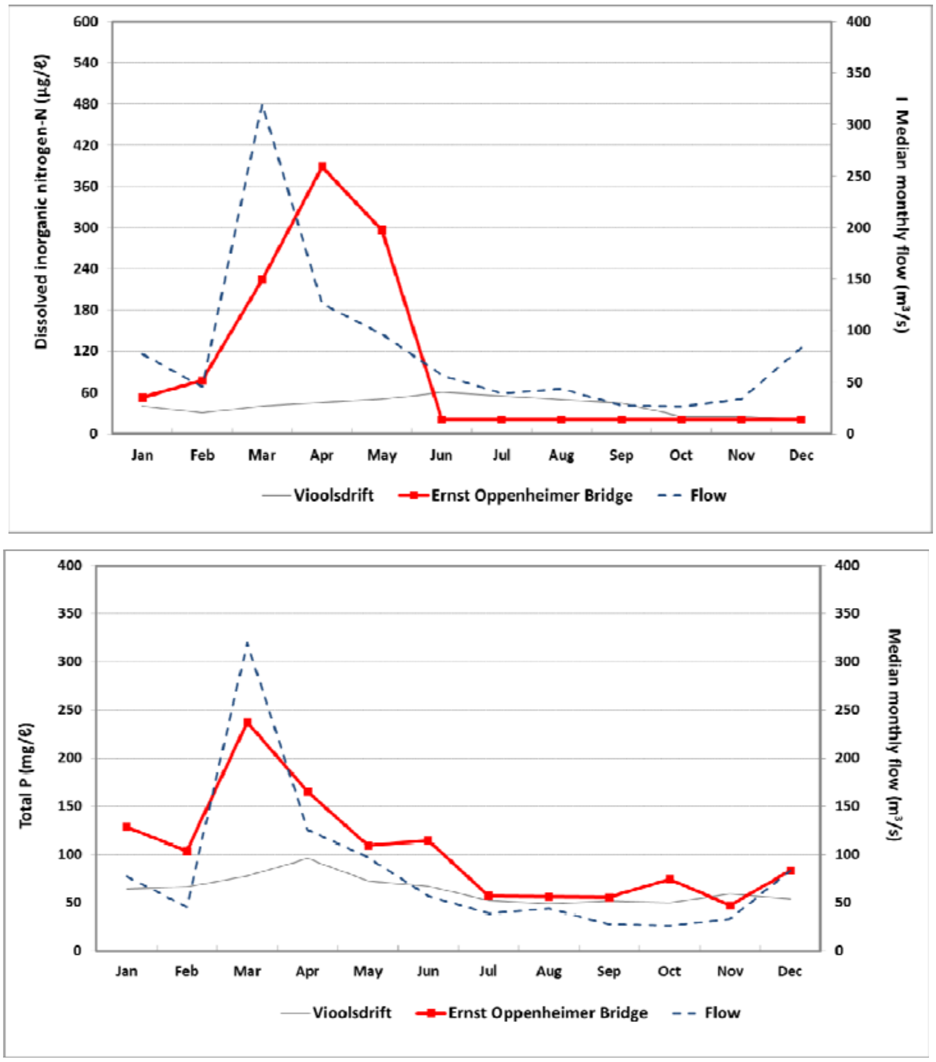

Figure 3. Monthly median dissolved organic nitrogen concentrations (above) and total phosphate concentrations (below) from 1995–2011measured at Noordoewer/Vioolsdrift (grey) and Sir Ernest Oppenheimer Bridge (red), as well as median monthly river flow measured at Noordoewer/Vioolsdrift (Source: DWA).

It has been reported on occasion, that algal blooms occur in the river upstream of the estuary. These algal blooms can make their way downstream, resulting in river water entering the estuary being almost anoxic.

Wastewater discharges from the mining activities at Alexander Bay also tend to modify interstitial/groundwater salinity levels in the adjacent saltmarsh area.

There is no information on the toxic inputs from mining operations, the adjacent towns, other developments or agriculture practices. This will have to be confirmed through measurements.

2.3 Exploitation of living resources

Fishing

Legal gillnetting and seining in South Africa ceased in 1998 with the Marine Living Resources Act (No. 18 of 1998) and the South African government policy to phase out all netting in estuaries countrywide. Unfortunately, there is still significant fishing effort in the form of illegal gill netting and recreational angling at the mouth region and adjacent surf-zone has increased. The latter arose from a redistribution of effort that occurred after Namibian authorities implemented more stringent catch control measures including bag limits specifically aimed at anglers leaving the country's borders. Comparable catches and limited fisheries control saw an increase in angling effort on the Alexander Bay side. Local compliance enforcement on the Namibian side is also hampered by the demarcation of the formal protected area only up to the high water mark (i.e. the park does not include the estuary open water area).

There has also been a slight increase in interest in flyfishing from Brandkaros to the mouth for freshwater species as well as for flathead mullet *M. cephalus*, elf *P. saltatrix* and leervis *L. amia*. This aspect of recreational angling has potential for a low-key tourist activity.

Total catch from the Orange-Senqu River mouth, comprising both legal and illegal take is estimated 5 to 10 tonnes per annum.

Hunting

Since the cessation of mining activities and access control on the South African side, hunting with dogs has become a regular occurrence on the islands of the estuary. Apart from the quarry, this hunting is also causing death by stampede and drowning of gemboks and cattle grazing in the floodplain of the system (pers comm, Dr SJ Lamberth, 2013).

Grazing

Domestic livestock, cattle and goats, regularly graze in the South African side of the Ramsar site and frequently cross over the river into the Namibian section of the site. Livestock grazing further degrades the saltmashes, compete with indigenous herbivores and detract from the tourism value of the site. The management plan for the Sperrgebiet National Park does not make provisions for domestic animals in the park and strays may be destroyed if within the park borders. Mechanisms to manage the grazing concession, reduce grazing pressure on the saltmashes and/or effectively exclude livestock grazing from the Ramsar site need to be developed and implemented.

2.4 Land-use related

Dykes and roads

The first dykes were constructed in 1974 to protect Alexkor agricultural land from flooding. The dykes cut off two flood channels that used to extend southwards into the saltmarsh (CSIR, 1991), thus reducing flood flow to the saltmarsh. At present sewage oxidation ponds exist within these non-operational channels. These ponds, however, are now being decommissioned.

An extension of the dyke along the southern river bank towards the mouth mainly served as a causeway that provided vehicular access to the beach. This causeway is elevated to approximately 3 m mean sea level, i.e. about 1.5 m above the adjacent saltmarsh (CSIR, 1991). It cut off major flood and tidal channels from the estuary. These alterations to the estuary are believed to be one of the primary reasons for the collapse of the saltmarsh habitat on the South African section of the Ramsar site (CSIR, 2011). Sections of the causeway have been removed since 1995.

In addition to the remnants of the causeway, a number of smaller dirt roads cross the floodplain, causing habitat destruction and leading to the disturbance of fauna. The existing road network is also not designed for tourist access and is having a negative impact on the aesthetics of the Ramsar site. Rationalisation of the road network is therefore recommended in order to limit environmental impacts whilst enhancing recreational and tourism use.

Slimes dams

Alexkor have constructed a number of slimes dams to the south of the saltmarsh. Fine material from these slimes dams and overburden removal in the region is transported by wind into the saltmarsh. Saline seepage water from the heavy-media separation (HMS) plant was also historically discharged into the peripheral saltmarsh (resulting in hypersalinity). The excess of fine material and influences on salinity have contributed to the die-back of marsh vegetation.

Old earth-moving equipment buried in the sand berm near the mouth

The river mouth is currently in a far southern position on the South African side. This position has exposed the wreckage of old earth-moving equipment (Figure 4) buried in the sand berm across from where the old causeway used to cross the system. The wreckage was buried there to prevent the further southwards migration of the mouth, i.e. prevent the erosion of the causeway and the diamond processing plant.

Figure 4. Wreckage of old earth-moving equipment buried in the sand berm near the mouth of the Orange-Senqu River mouth. (Source: SJ Lamberth).

The further south the mouth of the estuary moves, the more friction the inlet channel develops; which ultimately would assist with closure under low flow conditions. Therefore the removal of this wreckage would assist with reinstating mouth closure under low flow conditions.

2.5 Recommendations

To improve the health of the Orange River Mouth the following ecological objectives need to be achieved in the short term:

- The condition of the Orange-Senqu River mouth saltmarshes improved through:
  - Reduction of soil salinity achieved via backflooding under closed mouth conditions;
  - Improved floodplain connectivity with main estuary channels w.r.t enhancing tidal and flood flows to optimise flushing and drainage;
  - Prevention of windblown dust from smothering floodplain vegetation and isolating high-salinity seepage from slimes dams;
  - Reducing the number of dirt roads bisecting the floodplain and restoring some of the closed areas;
  - Reducing grazing pressure; and
  - Removal of alien invasive plants.
- Estuary nursery-function enhanced to assist with the recovery of collapsed fish stock through a reduction in fishing effort, increased compliance and re-establishing habitat diversity.
- Nutrient input the lower catchment (downstream of Noordoewer/Vioolsdrift) reduced to decrease aquatic plant and reed growth.

3. Present ecological status and desired condition

3.1 Present ecological status

The health scores allocated to the various abiotic and biotic parameters for the Orange-Senqu River mouth are used to calculate the overall health score. The Orange-Senqu River mouth has an overall health score of 51 relative to the natural condition (Louw, D et al., 2013a). This is mostly attributed to the following factors:

- Significant freshwater flow modification – both loss of floods and increased baseflows;
- Lack of estuary mouth closure and resulting backflooding of saltmarshes with fresher water;
- Road infrastructure in the form of the old causeway across the saltmarshes and old bridge crossings;
- Nutrient input from catchment downstream of Noordoewer/Vioolsdrift;
- Gill netting of indigenous fish species and considerable fishing effort at the mouth on both sides of the estuary;
- Riparian infrastructure – levees preventing backflooding;
- Mining activities;
- Wastewater disposal (sewage and mining return flow); and
- Grazing and hunting.

The estuary health score for the Orange-Senqu River mouth under present conditions and the study confidence levels are provided below in Table 1. The rationale for selecting these variables, as well as further details on the estuary importance index, are discussed in Turpie et al. (2002) and updated in 'Resource Directed Measures for protection of water resources; Volume 5: Estuarine component (DWA, 2008)'.

Table 1. The estuary health score for the Orange-Senqu River mouth, the estimated estuary health score with non-flow-related impacts removed, and confidence levels.

Variable	***Weight***	***Health score***	***Confidence***
Hydrology	25	44	Low/Medium
Hydrodynamics and mouth condition	25	70	Low
Water quality	25	53.2	Medium
Physical habitat alteration	25	78	Medium
Habitat health score		**61**	**Medium**
Microalgae	20	40	Low
Macrophytes	20	50	Medium
Invertebrates	20	45	High
Fish	20	50	Medium
Birds	20	23	Medium
Biotic health score		**42**	**Medium**
Estuary health score		51	
Present ecological status		D	
Overall confidence			**Medium**

The overall health score translates to a present ecological status (PES) of D, representing a largely modified system (see Table 2 below).

Table 2. Ecological health score, present ecological status and descriptions.

Estuary health score	***Present ecological status***	***General description***
91 – 100	A	Unmodified, natural
76 – 90	B	Largely natural with few modifications
61 – 75	C	Moderately modified
41 – 60	D	Largely modified
21 – 40	E	Highly degraded
0 – 20	F	Extremely degraded

3.2 Desired ecological condition

The ‘recommended ecological category’ (REC) represents the level of protection assigned to an estuary. The first step is to determine the 'minimum ecological category’, based on its present condition.

The PES sets the minimum REC. The degree to which the REC needs to be elevated above the PES depends on the level of importance and level of protection, or desired protection, of a particular estuary, as shown in Table 3 below.

Table 3. Protection status and importance and recommended ecological category.

Protection status and importance	***Recommended ecological category***	***Policy basis***
Protected area Desired protected area	A or BAS*	Protected and desired protected areas should be restored to and maintained in the best possible state of health
Highly important	PES + 1, min B	Highly important estuaries should be in an A or B category
Important	PES + 1, min C	Important estuaries should be in an A, B or C category
Of low to average importance	PES, min D	Estuaries to remain in a D category

* BAS = Best Attainable State

The PES for the Orange-Senqu River mouth is a D. The mouth is rated as 'highly important', it is a designated Ramsar Site, a protected area on the Namibian side; and a desired protected area in the South African Biodiversity Plan for the 2011 National Biodiversity Assessment (Turpie et al., 2012). The REC for the estuary is therefore an A or it's Best Attainable State (BAS) which is estimated as a Category C (Louw, D et al., 2013a).

4. Recommendations

4.1 Interventions

To improve the health of the Orange-Senqu River mouth the following mitigation measures are required:

- Local-level physical interventions
  - Removal of the remnant causeway that still transects the saltmarshes to improve circulation during high flow and floods events. This will also assist with increasing the water circulation into the intertidal and lower marsh areas.
  - Removal of old earth-moving equipment buried in the sand berm near the mouth of the Orange. They were buried to prevent southwards migration of the mouth, but the further south the mouth moves, the more friction the inlet channel develops; which ultimately would assist with closure under low flow conditions.
  - Controlling wind-blown dust and wastewater from mining activities to reduce smothering of saltmarshes
  - Controlling the fishing effort on both the South African and Namibian side through increased compliance and law enforcement. This also requires the alignment of the fishing regulations (e.g. size and bag limits) and management boundaries on both sides of the transboundary estuary There also needs to be strict enforcement of the prohibition of gillnetting in the estuary.
- Local level supporting interventions
  - Vehicular access to the berm should comply with the South African Integrated Coastal Management Act (ICMA, 2008) and be restricted to landowners that need to access private land via the berm. Angler access to the berm should be strictly by foot.
  - Livestock grazing by domestic (and feral) cattle needs to be appropriately managed as it further degrades the saltmashes, competes with the indigenous large herbivores and detract from the tourism value of the site and compete for valuable grazing resources.
  - Illegal dog-hunting and predation by feral dogs on the floodplain and islands needs to be curtailed.
  - Alien invasive plants in the floodplain need to be controlled in order to restore the integrity of estuarine vegetation and maintain the meandering nature of the estuary channels. Large strands of alien invasive trees have been establishing themselves on the islands and flood plain in the upper reaches of the estuary after the 2010/11 floods which is in urgent need to intervention.

  - A Lidar survey[2] of the Orange River mouth shall be conducted, to assist with identifying elevated areas that obstruct tidal intrusion and drainage of flood plain after high flow events. The same data would also assist in determine the maximum water level (relative to mean sea level) at which critical infrastructure and developments will be inundated and at which artificial breaching needs to be conducted.
- Local-level institutional interventions
  - The existing dirt-road network crossing the Orange River mouth floodplain needs to be rationalised to limit impacts on estuarine habitat and provide access to the Ramsar sites in an ecological sensitive manner while enhancing tourism in the area.
  - Reviewing and developing a joint zonation scheme to manage activities within the Ramsar sites and/or protected area(s). This includes revisiting the boundaries of the site and formal protected areas, as well as the planning schemes for Alexander Bay and Oranjemund.
  - As artificial breaching of an estuary mouth/inlet requires legal approval, a mouth management plan (i.e. artificial breaching protocol) needs to be proactively formalised to provide guidelines for when and how the estuary mouth may be breached (e.g. water level, position, trench size, what equipment etc).
- Longer term interventions outside of the Orange-Senqu River mouth
  - Decreasing nutrient input from the catchment downstream of Noordoewer/ Vioolsdrift, through improved agricultural practices. The effect of increased nutrient loads were very apparent in August 2013 under low flow condition.
  - Decreasing the winter baseflows sufficiently to allow for mouth closure and related backflooding of the saltmarshes with brackish water to reduce soil salinities.

4.2 Other stakeholders

The following national and regional authorities are involved:

The 'Working for the Coast' programme of the South African National Department of Environmental Affairs provides an opportunity for collaboration and possibly co-funding of:

- • Removal of the remnant causeway;
- • Removal of the old earth-moving equipment in the mouth region;

[2] Lidar (light detection and ranging) is a remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light.

- Controlling wind-blown dust and wastewater from mining activities;
- Rehabilitation by removal of historical dirt-roads bisecting the floodplain; and
- Controlling alien invasive plants in the floodplain (This is normally a Working for Water programme function, but due to the remoteness of the site it might be more appropriate if the same programme executes this function as well).

The South Africa and Nambian National Departments of Environmental Affairs need to be engaged for possible (co-)funding of the Lidar topographical survey of the flood plain to ensure that the entire area is covered.

The South African National Department of Agriculture, Forestry and Fisheries and Namibian National Department of Fisheries need to play central roles in controlling the fishing effort.

The South African and Namibian National Departments of Water Affairs need to lead initiatives on decreasing nutrient input from the catchment downstream of Noordoewer/Vioolsdrift.

This is mostly attributed

4.3 Risks

The main risks that the above proposed projects pose are related to mouth closure. They include:

- Inundation of developments/infrastructure (e.g. golf course) and farm land on the flood plain during the closed phase.
- Fish recruitment failure if estuary mouth remains closed during spring and summer recruitment peak whilst acknowledging that this happed under natural conditions as well.
- Increased aquatic macrophyte blooms under low flow conditions before mouth closure.

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