Outlook of Critical Habitats in the Western Indian Ocean:

Salt marshes

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Background

Salt marshes are defined as "areas, vegetated by herbs, grasses or low shrubs, bordering saline water bodies (Adam et al. 1990). They are subjected to periodic flooding as a result of fluctuations (tidal or non-tidal) in the level of the adjacent water body". Salt marshes occur in arctic and temperate regions, as well as in the subtropics and tropics where they occur in areas where mangrove development is precluded, or as a component of a salt marsh-mangrove ecotone (Adam 1990). Macnae (1969) stated that in drier regions where rainfall is seasonal, the lower tidal range is occupied by mangroves and the higher shore line by salt marsh. This is supported by the distribution of salt marshes in the tropics and northern Africa where this habitat replaces mangroves where the sediment is too dry or saline. In the subtropical estuaries of South Africa mangroves occupy the lower tidal zone and salt marshes occur in the higher, drier areas (Figure 1, Adams et al. 2016). Sometimes this is a very narrow band and therefore difficult to map as a separate habitat. In addition, according to Adam (1990), on arid or strongly seasonal tropical / subtropical coasts salt marshes may not extend upwards to the highest tide level, but may be fringed on their landward side by extensive hypersaline flats, known in the Middle East as *sabkha.* These areas exist in the WIO region but have not been described in detail. In Africa salt marshes are described for the Mediterranean, north west, south and south west coasts.

Mcowen et al. (2017) defined salt marshes as "tidal communities that comprise the upper, vegetated portion of intertidal mudflats, lying approximately between mean high water neap tides and mean high water spring tides". Other global definitions of salt marshes also only consider tidal systems (e.g. Best et al. 2007; Weis and Butler 2009). However, in South Africa the seldom flooded supratidal habitat that has halophytic species has been included as salt marsh and is considered a component of the estuary. The 5 m topographical contour is used to demarcate the estuarine functional zone (EFZ) and the lateral boundaries. Supratidal salt marsh occurs at > 1.5 m above mean sea level (amsl) and an ecotone with terrestrial species can occur from > 2.5 m amsl (Veldkornet 2015). The supratidal salt marsh may only be flooded twice a year during exceptional spring tide events (Adams et al., 1999). Other studies refer to this as the high marsh (Borman 2003). Thus a description of the distribution of salt marsh is influenced by its definition. This has not been well described for the WIO region and information on this important habitat is lacking, posing a threat to conservation efforts.

Salt marsh species are typically succulents and grasses with common species including *Bassia diffusa*, *Sarcocornia mossambicensis*, *Sarcocornia natalensis, Suaeda* spp., *Sporobolus virginicus*., *Salicornia* spp., *Sesuvium portulacastrum* and *Juncus kraussii*. Some of these species (e.g. *Sarcocornia natalensis*) extend from South Africa to the lower regions of Mozambique and Madagascar. Species common in Mozambique salt marshes are *Arthrocnemon* sp., *Pemphis acidula, Portulaca oleracea, Salicornia* sp., *Sporobolus virginicus*, *Suaeda monoica* and *Suriana maritima*. In Somalia species such as *Urochondra setulosa* occur; a halophytic grass found in North West Africa and South East Asia (Khan et al. 2009). *Salicornia virginica* is also common (Carbone and Accordi 2000). In Tanzania and Madagascar sea purslane *Sesuvium partulacastrum* and *Suaeda monoica* occur on soils too saline for mangrove species. The annual *Salicornia pachystachya* occurs from Kenya to South Africa, Madagascar and other Indian Ocean islands in salt marsh associated with mangrove swamps. It is clear that salt marsh species occur widely in the WIO although the overall habitat is poorly described.

Distribution

Distribution is discussed for only some of the WIO countries below, based on available information.

Mozambique

Salt marshes occur in most areas adjacent to mangroves and estuaries, but some occur further inland associated with the brackish lakes of southern Mozambique. Salt marshes are extensive in lowland areas and in areas with a wide tidal range with limited freshwater drainage or seepage. Large salt marshes are common in Maputo Bay, the Limpopo Estuary and areas around the estuaries of Cabo Delgado and Nampula provinces (Table 1). They also occur on the Changane River, a tributary of the Limpopo , where salt tolerant species such as *Suaeda* sp. and *Salicornia* sp. are found at Chibuto village near Xai-Xai town.

In Maputo Bay salt marsh occurs in extensive areas between mangroves and terrestrial vegetation; generally in degraded mangroves and around coastal lakes (UNEP and WIOMSA 2015). Maputo Bay is surrounded by mangroves, but extensive areas, especially in the northern Maputo city regions of Bairro dos Pescadores, Mapulene and Muntanhana, are covered by salt marshes. Unfortunately, these areas have been heavily impacted by housing expansion. The Limpopo River Estuary supports extensive areas with grassy (*Sporobolus virginicus)* salt marshes. River flooding in 2000 halved the original mangrove areas enabling salt marsh colonisation (Bandeira and Balidy 2016).

Lowland areas between the sea and mangroves near Inhambane Town are colonised by salt marsh. The small Chiveve River, that runs through Beira City in central Mozambique, supports extensive salt marshes, especially around the Beira Gold Club, and dominant species include *Phragmites australis, Sporobolus virginicus, Cynodon dactylon, Panicum maximum, Pennisetum* sp*., Cyperus compressus* and *Urochloa mosambicensis*. Quelimane (on the northernmost arm of the Zambezi Delta) has extensive grassland areas adjacent to mangroves, especially around the Chuabo Dembe area. Some salt marsh species occur in the ecotone between the mangrove species and the grasses with species such as *Sporobolus* sp., *Sezivium portulacatrum*, *Arthrocnemum* sp. and *Salicornia* sp. present. Furthermore, it has been reported that new areas are being covered by sea water creating more habitat for colonisation by mangroves and salt marshes in the outer areas. There are also examples of salt marshes occurring in abandoned salt pans in areas near Quelimane, with adjacent areas such as Mirazane being used for rice farming.

In northern Mozambique salt marshes occur in several places, but information is scarce. Salt marshes have been observed in Nacala Bay (Nampula), in areas around the Memba mangroves (particularly near the northern side of the Mecuburi Estuary), between Pemba Bay and Mecufi, and in Pemba Town, especially in the lowland area of Paquitequete. Some of the dominant species here include *Suaeda monoica, Suriana maritima, Pemphis acidula* and *Sporobolus* sp. Freshwater reeds and sedges also occur around some of these areas. The delta of the Montepuez Estuary in northern Mozambique (Figure 2) has extensive salt marshes. Fieldwork is needed to verify the diversity and extent of these habitats within the Montepuez Channel, facing the southern Quirimbas Archipelago. The area from the border with Tanzania to Pemba is part of the Pemba Bay-Mtwara ? , and also lies within the Mozambique Channel.

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Table 1: Known salt marshes in Mozambique and estimates of area, habitat trend (increasing, decreasing, stable) and protection status.

Location	Region /Province	GPS Position	Estimate of Size (ha)	Habitat trend	Pressures	Protection status
Montepuéz River Estuary	Cabo Delgado	-12.522175 S, 40.441883 E	unknown	S	Agriculture	Quirimbas National Park
Paquitequete, Pemba Town	Cabo Delgado	-12.959941 S, 40.487728 E	< 10	D	Development	None
Mecúfi	Cabo Delgado	-13.301508S, 40.538581E	> 50	D	Salt plans, Road upgrade	None
Memba northern side of Mecuburi Estuary	Nampula	-14.165659 S, 40.522386 E	Unknown	S	Salt pans	None
Nacala Bay	Nampula	-14.582390 S, 40.619345 E	Unknown	D	Port development, town expansion	None
Quelimane	Zambezia	-17.869956 S, 36.865297 E	> 80	I	development, rice production	None
Cabo São Sebastião	Inhambane	-22.240042 S, 35.390492 E	Unknown	S		Area of total protection (private managed)

Limpopo Estuary	Gaza	-25.148213 S, 33.518060 E	> 300 ha	S	Flooding	Community managed wider mangrove area
Maputo City	Maputo	-25.875712 S, 32.658775 E	> 500 ha	D	Urban development	None

Saline lagoons and lakes, situated within a short distance from the coastline, are a common feature in southern Mozambique (south of Vilanculos region). From a geomorphological perspective these are mostly Pleistocene formations and are brackish or near freshwater. The vegetation in and around these lakes is dominated by *Hibiscus tiliaceus, Phoenix reclinata, Phragmites australis, Ruppia maritima* and *Typha latifolia* (Bandeira et al. 2007). The dominant succulent is *Portulaca oleracea*, though not all areas surrounding these lakes qualify as salt marshes. Some of these areas lie adjacent to the Ecologically or Biologically Significant Area (EBSA) of Save-São Sebastian region (encompassing Bazaruto Archipelago and some inland swamps). Salt marsh habitat has also been identified in the Incomati-Ponta de Ouro EBSA that encompasses Maputo Bay, Lingamo (near Maputo and Port) and Inhaca Island, and in some areas near Saco da Inhaca. Macnae (1995) identified salt marshes adjacent to the airstrip at Inhaca Island.

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Madagascar

The western and northern parts of Madagascar support large mangrove areas. Intertidal areas are generally wide and salt marsh occurs on the landward side of mangrove stands. Salt marshes occur near Tsangajoly, Toliara Province in southwestern Madagascar, while salt pans and associated marsh habitat also exists at Morondava on the west coast. Mudflats of up to 1 km wide occur together with mangroves, lakes and salt marshes in the Ambavanankarana wetlands along the western coast (Marnewick et al. 2015). Similarly, in the Mahavahavy delta in the Mahajanga region, mangroves occupy an area of 16 000 ha, and mudflats 5 200 ha. The bay has 7 500 ha of mangrove inlets, mudflats and marshes (Figure 3). Given the extent of mangroves and associated lowland areas in Madagascar, it is expected that salt marshes exist in adjacent areas. However, there is a need for detailed mapping and distribution studies to verify the full extent of salt marshes in the country.

South Africa

In South Africa intertidal salt marsh occurs below the mean spring high water mark, with supra-tidal salt marsh above this. Salt marsh plants are distributed according to inundation and salinity gradients, often resulting in distinct zonation patterns particularly in permanently open estuaries with large tidal ranges (Adams et al. 2016).

Salt marsh occurs in the sheltered estuaries across all four geographic zones (cool temperate, warm temperate, subtropical and tropical) with a total area of 14 437.2 ha (Table 2, Figure 4). The Berg Estuary on the west coast supports the largest salt marsh area in the country (4 212 ha).

Table 2: Area of salt marsh habitat types (ha) across bioclimatic regions in South Africa.

	Cool temperate	Warm temperate	Subtropical	Total area
Intertidal salt marsh	2837.62	1795.74	706.88	5340.24
Supratidal salt marsh	5375.74	2337.17	1384.05	9096.96
Total area (ha)	8213.36	4132.91	2090.93	14437.2

Importance of salt marshes

Salt marshes are productive ecosystems important for carbon storage, water purification, flood control, refugia, and habitat for other organisms such as juvenile fish (Paterson and Whitfield 2003, Barbier et al. 2011, Tabot and Adams, 2013). They also serve as critical habitat for migratory fish and birds. Juvenile fish make use of the intertidal salt marsh habitat as refugia, with a high density of fish larvae and juveniles found on the marsh-creek edge (Whitfield 2017). Marsh hydroperiod and vegetation stem density is important in determining fish access and invertebrate prey abundance (Rozas 1995). The type of vegetation is also important as *Spartina* (grass) and *Sarcocornia* (succulent) species offer different food sources and structural protection (Hettler 1989, cited in Whitfield 2017). Recent studies that have described the importance of South African estuaries as a nursery habitat are Becker et al. (2011), Whitfield and Pattrick (2015), and Edworthy and Strydom (2016). Earlier studies such as Booth (2007) found that juvenile estuarine dependant fish made up 83 % of all fish sampled in the intertidal salt marsh under flooded conditions (Kariega Estuary, South Africa).

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Salt marshes serve as important habitats for birds in terms of breeding, roosting and feeding. Birds such as herons, gulls, waders, terns and cormorants (summer migrant waders make up 90 % of the population) prey on prawns, marsh crabs, pencil bait and fish. Salt marshes also provide important high tide and overnight roosting areas and secondary feeding habitat (Saintilan et al. 2018). In Southern Africa more than 100 migratory bird species have been recorded. At least 20 of the 112 IBAs of South Africa support salt marsh habitat. The Berg Estuary on the west coast of South Africa supports in the region of 8 000 migrant waders. The peak number of birds is dependent on the productivity of the marshes, with the highest density recorded over the summer period. The urbanised Swartkops Estuary and surrounding salt pans on the southeast coast of South Africa support high bird numbers with an average of 14 500 birds per year (Birdlife South Africa 2015a). Of these birds, at least 4 000 are Palearctic migrants, present mainly in summer. Threatened species frequenting the intertidal mudflats and salt marshes of the Swartkops Estuary include the Damara Tern *Sterna balaenarum*, African Black Oystercatcher, Cape Cormorant *Phalacrocorax capensis*, Greater and Lesser Flamingo, Martial Eagle *Polemaetus bellicosus*, and Chestnut-banded Plover *Charadrius pallidus*.

The rich mud of salt marshes supports dense populations of molluscs and crustaceans. In South Africa small gastropods called marsh snails such as *Assiminea ovata, A. globulus* and *A. bifasciata* are common detritus feeders in salt marshes, occurring in very high numbers around the high water mark (Wooldridge 1998). A few crab species (*Oaratylodiplax edwardsii, Sesarma catenata* and *Paratylodiplax algoense*) are also abundant in salt marshes, but are generally confined to *Spartina maritima* stands. Various reptiles forage in the salt marsh and fringing terrestrial habitat including frogs, snakes, lizards and tortoises. Small and larger mammals also make use of this habitat, however not exclusively. Some endemic chameleons occur in the fringing vegetation of salt marshes such as the vulnerable Cape dwarf chameleon *Bradypodion pumilum* found at Rietvlei Estuary in Cape Town, South Africa, and the southern dwarf chameleon *Bradypodion ventrale* endemic to the Swartkops Estuary in Port Elizabeth, South Africa (Birdlife South Africa 2015a, b). Gronovi's dwarf burrowing skink *Scelotes gronovii*, Kasner's dwarf burrowing skink *S. kasneri*, and the large-scaled girdled lizard *Cordylus macropholis* are endemic to South Africa's west coast and occur in the xeric salt marsh of Langebaan Lagoon (Bird Life South Africa 2015c). Peringuey's Leaf-toed Gecko (*Cryptactities peringueyi*) is the only gecko in the world that lives in salt marshes. It is only known from the Kromme Estuary and a few sites near Port Elizabeth, South Africa.

Besides grazing by livestock there is little direct use of salt marsh as a food source. In Mozambique the leaves of the succulent herb *Sesuvium portulacastrum* are added to soups and salads and used for a traditional plant dish only cooked for Christmas (also known as mpfixiri) (Macamo pers. comm.). Seablight *Suaeda monoica* grows amongst mangroves, and its young leaves can be picked and eaten in salads or cooked in curries. The grass *Sporobolus virginicus* can be used for stabilization of wind-eroded shorelines, stream banks and road slopes. Traditionally, it has been used to relieve urinary tract and throat irritation (Fern 2014). In some countries Samphire *Sarcocornia*, *Salicornia* spp. as well as *Aster tripolium* are sold at comparatively high prices as sea vegetables and salad crops (Figure 5). The South American seed crop quinoa (*Chenopodium quinoa*) has gained popularity by the health conscious for its highly nutritional seeds (Ventura et al. 2017). The common ice plant *Mesembryanthemum crystallinum* is a salt tolerant succulent native to southern and eastern Africa. It is consumed as a vegetable crop in India, California, Australia, New Zealand and in some countries of Europe (Herppich et al. 2008). It is also used medicinally for its demulcent, diuretic, and antiseptic effects (Bouftira et al. 2012, Ksouri et al. 2008), and as protection from the sun (Bouftira et al. 2008).

There is potential to utilize salt marsh species for the production of bioenergy. Many of these species produce high quantities of oil producing seeds and lignocellulosic biomass suitable for biofuel production. Promising genera include *Salicornia* (glasswort), *Suaeda* (sea-blite), *Atriplex* (saltbush), arid salt grass *Distichlis* and the succulent-leaved ground cover *Batis* (Squires and Ayoub 1994, Glenn et al. 1998, Parida and Das 2005, Rozema and Flowers 2008, Abideen et al. 2011). Halophyte-based agriculture is beneficial in that marginalized land and saline water from the sea are used and limited inputs are required. Halophyte agriculture has the potential to reclaim salinized habitats in the Sahara desert, Western Australia and Southern Africa (Sharma et al. 2017).

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In terms of recreation and tourism, scenic views and vistas are created by salt marshes and this is desirable in the coastal residential property market. For example, properties on Thesen Island on the Knynsa Estuary, South Africa, are marketed for their salt marsh views (http://www.thesenislandsliving.co.za/*).*

Threats and status

In South Africa salt marshes are threatened by sea level rise at the sea interface, and development at the land interface. Other threats are salinization due to upstream water abstraction as well as changes in rainfall patterns. There has been an estimated loss of ~6000 ha of salt marsh in South Africa due to construction of bridges, causeways and jetties in the intertidal salt marsh habitat, and agriculture and development in the supratidal area (Table 3). Agriculture within the floodplain of the Berg and Gamtoos Estuaries has resulted in the loss of the largest supratidal salt marsh habitat in the country. Roughly half of the natural salt marsh habitat from the Berg and nearly 90 % from the Gamtoos Estuary has been lost due to vegetable cultivation and cattle grazing. The Orange Estuary, a Ramsar wetland of special concern, is the boundary between South Africa and Namibia. It was placed on the Montreux Record in 1995 because 300 ha of salt marsh had become desertified. This loss was attributed to leakage of diamond mine water, the effect of windblown dried slimes dam sediment on the marsh vegetation, construction of flood protection structures and a beach access road, and the elimination of tidal exchange into the wetland due to a causeway constructed at the river mouth (Shaw et al. 2008). Due to the low rainfall on the west coast and highly salinized nature of the desertified marsh area there has been little change in the salt marsh status over the last 10 years.

Other stressors that have been described but not quantified in terms of loss of salt marsh area include salinization and desiccation due to upstream freshwater abstraction (Bornman et al. 2002, 2004). Reduced freshwater inflow causes extended mouth closure of temporarily open/closed estuaries, and inundation and flooding of the salt marsh (Riddin and Adams 2010, 2012). In urbanized estuaries, salt marsh loss is related to a restriction of tidal exchange, freshening, and invasion by alien invasive plants (O'Callaghan 1990). Eutrophication, macroalgal blooms and smothering of salt marsh is a growing concern in South African estuaries (Nunes and Adams 2014, Human et al. 2016). In the rural areas, livestock browsing and trampling of the salt marsh is extensive but unquantified.

Table 3. Total salt marsh area in South Africa and changes in area for specific estuaries.

Habitat	**Past (ha)**	**Present (ha)**	**Change (ha) & %**
Intertidal salt marsh	5 373.8	4 891.7	482.2 (11 % loss)
Supratidal salt marsh	15 078.6	9 817.5	5 401.3 (35 % loss)
Estuary	**Past (ha)**	**Present (ha)**	**Loss (ha)**
Berg	4589	2545	2044
Gamtoos	710.72	80.8	629.92
Orange	1190.1	602	588.1

Mozambique's salt marshes are threatened by transformation for human settlement through the expansion of the urban areas of Maputo, Chiveve and Paquitequete in Pemba. The Maputo population, especially within the Costa de Sol and Muntanhana region, has been expanding resulting in the conversion of the nearby salt marshes and adjacent dwarf mangroves. Urbanization and an increase in freshwater run-off also threatens the salt marshes. In the past, and also to some extent today, salt pans pose a threat to salt marshes. Small scale rice production impacts salt marshes near Quelimane. Beira, the second largest town in Mozambique, is built in a former swamp and salt marsh area. This city has the highest density of man- made channels in eastern Africa. The remaining salt marsh areas are threatened by urban expansion and port development.

In Madagascar the western wetlands are affected by many different pressures, mainly drainage for agriculture and aquaculture. Pond farming often occurs behind the mangrove areas in the salt flats. This results in removal of this habitat, followed by erosion and siltation. The buffering function of this salt marsh / salt flat area cannot be underestimated. In the Mahavavy delta wetlands, mangroves and marshes have been converted to rice fields, birds have been hunted, and mangroves exploited for firewood (Marnewick et al. 2015). The declining population of the Madagascar Marsh Harrier has been attributed to this loss of habitat. Where precipitation is low and salinity is high mangroves degrade and salt marsh develops in its place. This process is known as “tannification” which results in highly saline areas with low herbaceous vegetation (Bosire et al. 2016). This can evolve into completely denuded areas and cover extensive areas of several hundred hectares as observed in the marine protected area of Ambodivahibe.

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Salt marshes are susceptible to fluctuations in abiotic conditions due to their unique placement at the interface of the sea and land. Salt marsh plants exhibit unique tolerances to abiotic conditions and thus occur in distinct zonation patterns determined by inundation and salinity gradients (Tabot and Adams 2013). Thus the different species will respond to changing climatic conditions in different ways and need to be managed accordingly. Climate change is expected to manifest in salt marshes as increased submergence, changes in salinity and drought. Salt marshes respond to increasing sea level through landward migration should suitable slopes and potential habitat be available. However, this migration is hindered by ‘coastal squeeze’ – development and hard structures in the floodplain of estuaries preventing landward movement.

In South Africa reduced freshwater inflow results in the mouth of temporarily open / closed estuaries remaining closed to the sea for long periods. An increase in water level and salt marsh submergence causes dieback of salt marsh vegetation, particularly supratidal species that are not adapted to flooding (Riddin and Adams 2008). Loss of these species decreases habitat heterogeneity, creating a more homogenous landscape with less niches. Prolonged submergence affects the ability of salt marsh plants to regenerate from seed banks and vegetative propagules. The life cycles of the plants are not completed and over time the seed banks decrease, ultimately resulting in the loss of this habitat.

Existing Protection

Table 4 indicates that there is some protection for estuaries with large salt marsh areas in South Africa. In addition, estuary management plans are a requirement of the National Environmental Management: Integrated Coastal Management Act (Act 24 of 2008). These plans can be effective in protecting sensitive habitats such as salt marshes through zonation of activities such as boating that leads to disturbance and erosion.

In Mozambique, swamps, including salt marshes and mangroves, are legally protected under the following legislation:

- The Environmental Impact Assessment Process (law 54 of 2015) regulates transformation promoted by enterprises.
- The Land Law (law 19 of 1997) defines areas of total and partial protection. Mangroves and adjacent marshes should be exempt from the allocation of land use deeds.
- The Environment Law (Law 20 of 1997), Art 12 mentions threatened species and Art 13 the need for environmental protection. Chapter 5 refers to environmental licensing and auditing for areas such as mangroves and adjacent salt marshes.

In 2015 the Chiveve River Estuary in Mozambique was expanded to assist with flood protection in Beira City, as it occurs in a lowland area. The wetlands are protected as their role in flood protection is recognized. In Madagascar some mangroves are found within existing marine parks such as the Mananara Biosphere Reserve. Here, salt marsh may occur amongst the mangroves and thus receive some protection.

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Table 4: Estuaries in South Africa with the largest salt marsh areas showing habitat trends (stable (S), increasing (I), decreasing (D)), pressures and protection status.

Estuary	GPS position	Intertidal salt marsh	Supratidal salt marsh	Habit at trend	Pressures	Protection status
Orange	-28.63030700 S; 16.449578 E	144.00	602.00	D	Salinisation	Ramsar site
Olifants	-31.70212200 S; 18.187659 E	96.60	909.50	D	Salinisation	None
Berg	-32.76974900 S; 18.143885 E	1667.00	2545.00	D	Agriculture	Partial CapeNature
Langebaan	-33.04815600 S; 18.005668 E	791.70	523.70	I	Grazing pressure removed	South African National Parks
Heuningnes	-34.71479000 S; 20.119246 E	16.20	660.40	D	Agriculture	CapeNature
Knysna	-34.08270600 S; 23.061453 E	551.93	133.00	S	Development	Partial SANParks
Swartkops	-33.86624500 S; 25.633045 E	165	5	D	Development and industry	None
Kariega	-33.68277100 S; 26.686399 E	36.05	364.43	S	Agriculture and development	None
Keiskamma	-33.28148000 S; 27.491233 E	210.37	91.26	D	Agriculture and grazing	None
Kosi	-26.89517400 S; 32.880789 E	58.00	229.00	D	Grazing, trampling, fires	ISimangaliso Wetland Park, World Heritage site

Priority options for conservation

In South Africa there is a need for formal protection status for the Berg Estuary. The estuary is currently designated as an Important Bird Area (IBA) where the water and intertidal habitat is managed by CapeNature and the local municipality. Restoration of the salt marsh at Orange River mouth is also needed as well as greater protection for the large intertidal salt marshes of Knysna Estuary. In the South African National Estuary Biodiversity Plan (Turpie et al. 2012) habitat targets were set as 20% of the total area of each estuarine habitat type, however this has not been implemented or addressed in any way.

Overall there is little protection of salt marshes in Mozambique and on a local scale management plans are needed, especially in populated areas. São Sebastião in southern Mozambique is managed as a conservation area, while the Montepuez Estuary and river occur in the Quirimbas National Park. The Bazaruto archipelago adjacent to São Sebastião, and the Zambezi delta are recognised as IBAs and the salt marshes are therefore protected.

Recommendations

Salt marshes in the WIO region form an important buffer between land and intertidal mangrove/estuarine habitats. However, in most countries this habitat has not received priority attention and future research is needed to describe the distribution and status of salt marshes in the region. It should be emphasised that once lost due to salinization and development, there is no buffer to replace salt marshes, and these areas become barren unproductive salt flats. Remote sensing approaches, supported by field studies, are recommended for identifying and quantifying habitat distribution. In addition, citizen science could be harnessed through the use of cellphones to upload geotagged photos of salt marsh to verify distribution.

Salt marshes represent an opportunity for the study of biodiversity and ecological processes in general, and restoration in particular. These studies need to be linked with wider management initiatives that may include adjacent swamps, mangroves and dune forest. Formal protection status is needed for several estuaries and associated salt marshes in South Africa, for example, while in some cases active restoration needs to take place. Ideally, buffer areas need to be identified to allow for the landward expansion of salt marshes in response to sea level rise, including the removal of hard structures where necessary. Overall it is apparent that a great deal of work needs to be done on salt marshes to fully understand their distribution and importance at a WIO regional level. Experience from some countries such as South Africa, where significant effort has been placed in mapping and researching salt marshes, needs to be harnessed for the benefit of the other countries of the region.

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Appendix

Table 1: Potential salt marsh habitat along the Mozambique coast based on Google Earth surveys

Location	Description
26°01'08.3"S 32°28'23.2"E	Maputo Bay, south of Matola
23°43'20.1"S 35°22'31.4"E	Morrumbene mangroves and salt marsh, near Maxixe
23°43'15.1"S 35°22'34.5"E	Inhambane, near Maxixe
25°10'01.6"S 33°31'05.5"E	North bank near the mouth, at Xongene Lodge on the Limpopo River in Xai Xai District
24°52'30.8"S 34°24'53.2"E	Lagoa Magombene
24°52'07.6"S 34°26'31.2"E	Inharime River (Zavala) – Lagoa Zangabade
Bazaruto Island	Salt marsh/Salinas
Saint Carolina	Salinas
Benguerua	Salinas
Moyeni	Moyeni Lodge, Vilaculos area, San Sebastian, The Sanctuary
22°55'35.0"S 35°34'17.4"E	Pomene Reserve
22°39'23.3"S 35°30'22.3"E	Masinga
22°28'36.4"S 35°28'41.1"E	Lago Cunguine (Lagoa Nhalehengue)
22°19'46.2"S 35°31'24.0"E	Vilankulo area seaward of Lago Muangane
22°18'27.1"S 35°21'16.9"E	Vilankulo south of Bazaruto on mainland
21°03'40.7"S 35°02'30.0"E	North of Lula's Paradise Lodge (Govuro)
20°49'21.8"S 34°58'56.1"E	Chiloane area south (Machanga)
20°07'48.8"S 34°44'51.3"E	Santuario Piri (north of Machanga)
19°52'41.0"S 34°43'22.2"E	Buzi River mouth area south of Beira
19°23'12.0"S 35°27'16.0"E	Chinizua river
19°17'00.1"S 35°32'42.1"E	Machese area (Muanza)
19°12'34.5"S 35°36'06.1"E	South of Ilha Gaga Muanza area
19°05'48.0"S 35°40'58.5"E	Cheringoma
Zambezi River	Marromeue National Reserve to Ilha Pambane

Table 2: Potential salt marsh habitat along the Madagascar coast based on Google Earth surveys

Location	Description
25°33'55.1"S 45°07'57.5"E	Inland salt marsh at Cap St Marie Special Reserve. https://www.protectedplanet.net/cap-sainte-marie-special-reserve
25°31'05.2"S 45°05'04.1"E	Beloha possible seep with back salt marsh or wetland (part of the above reserve)
Bay of Mahajamba	Mahajamba and Sofia rivers
25°20'35.3"S 44°48'47.6"E	Tanjona Malaipioka
25°16'03.9"S 44°30'02.2"E	Menarandra/ Bevoalavo Estuary
25°10'09.2"S 44°19'44.4"E	Ampanihy Estuary (near Ampalaza)
Mahavavy Delta	Wetlands and mangroves
Tsimanampetsotsa Lake	Freshwater
Betioky-Atsimo	Freshwater
Onilahy River	North bank Toliara mangroves
Morombe	Mangroves
Kirindy Mitea National Park	
Morondavo salt marsh	

Figure 1 Mangroves bordered by salt marsh at the Nxaxo Estuary, South Africa .

Figure 2: The Montepuez river delta leading to Montepuez Channel, Mozambique. The surrounding outer mangrove channels depicts salt marshes.

Figure 3: Delta with intertidal mudflats and mangroves in the Mahavavy delta wetland in the Mahajanga region of Madagascar.

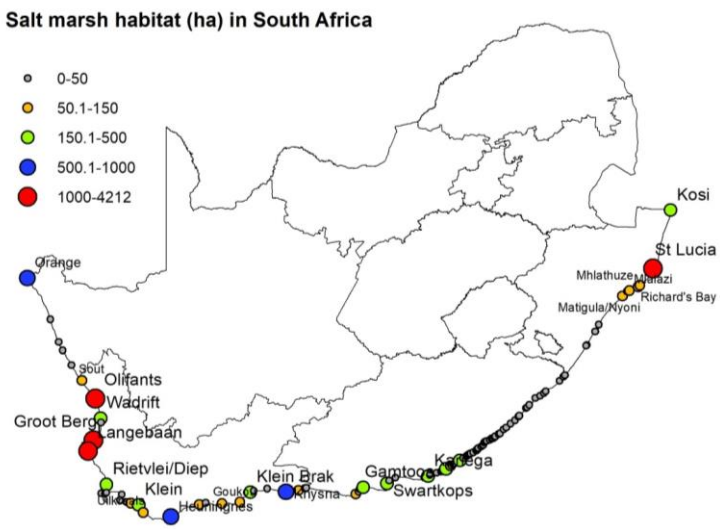

Figure 4: Distribution of salt marsh habitat in South African estuaries.

Figure 5: Samphire (*Salicornia*) sold as a vegetable at Woolworths South Africa; Sea purslane *Sesuvium portulacastrum* occurs worldwide and is harvested from the wild to be eaten as a vegetable. It also has ornamental and medicinal value and is used as a ground cover to prevent erosion in dune vegetation (Source Fern 2014).

Economic potential of salt marsh plants

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Approximately 25% of the world's soils are too saline for cultivation. As this value increases annually, alternate agricultural practices are being investigated. With the growing scarcity of freshwater, halophytes provide a viable solution for the production of food, fibre and fodder. The salt marsh genera Salicornia and Sarcocornia have extreme salt tolerances (up to 500 mM) and have had a long record of use in the wild, both for food and medicinal uses. They are sought after for their salty nature, palatability, digestibility and high nutritional value. Recent studies have shown that halophytes can yield as much as conventional crops on a commercial scale, even when irrigated with seawater. They can be cultivated under nets or in greenhouses. Halophytes harvested in the wild include species such as Sea Spinach (Aster tripolium), a Northern European plant found in salt marshes and estuaries. During times of famine in the Netherlands it was eaten, these days it is considered a delicacy. Salicornia europaea, known by a variety of names from Sea Beans, Sea Asparagus to Samphire, is eaten in salads, steamed, boiled or sautéed. In South Africa it is now being sold in shops as gourmet food. Another South African species Tetragonia decumbens is harvested for use in traditional cooking as a spinach alternative. Halophytes have also been harvested for the production of soda ash for glass and soap making, including Suaeda, Salicornia, Salsola, and Haloxylon. They are also effective biofilters, removing up to 90% of nutrients from saline aquaculture waste. Genera used include Suaeda, Salicornia, Sarcocornia, Atriplex, Tamarisk and Portulaca. The added benefit of this practice is the production of seed oil for biofuel, for example from Salicornia biglovii, as well as for human and animal consumption. Whereas the plant accumulates salt, the seeds do not. Salicornia biglovii yields up to 2 t/ha of seed which contain 28% oil and 31% protein. In Eritrea Salicornia biglovii was grown and irrigated with seawater as part of an integrated aquaculture project; an Initiative by Seawater Foundation for Greening Eritrea and the brain child of scientist Carl Hodges. The nutrient rich outflow from a shrimp farm passed through a fish farm and then through 250 acres of Salicornia plantations. Finally, water soaked through a mangrove forest into the sea. The project was unfortunately shutdown due to various socio-political reasons. A similar such project in Adu Dhabi looked at this intercropping of Salicornia and mangroves for the production of renewable jet fuel. Recent studies in Spain have shown the potential of growing of Salicornia biglovii with Seabass in marine aquaponics, the combination of hydroponics and aquaculture. This eliminates the leaching of salts and nutrients into freshwater aquifers. Plants are either grown in sand or in floating rafts on top of the fish tanks. Grown in this manner, the plant was nutritionally better than the wild harvested plants. There was the additional benefit of the farmed fish as a food protein source. No fertilizer is used and there is a complete re-use of water compared to the example in Eritrea. Production values of 5 kg/ha has been estimated. All of these applications need investigation and implementation in the WIO region.

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