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Mangroves of the South-west Australian Shelf

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Abstract

Mangroves of the South-west Australian shelf is a regional ecosystem subgroup (level 4 unit of the IUCN Global Ecosystem Typology). It includes the marine ecoregions of Great Australian Bight, Houtman, Leeuwin, South Australian Gulfs, and Western Bassian. The South-west Australian shelf mangrove province mapped extent in 2020 was 198.8 km^2 across, representing 0.1% of the global mangrove area. The biota is characterised by one species of mangrove.

Mangroves in this province are confined to sheltered shores of large embayments like the Gulf of Saint Vincent and Spencer Gulf, and protected bays, like those on the Eyre Peninsula. Low rainfall generally corresponds with the scarcity of estuaries, with limited freshwater, nutrients and sediments entering the sea. Mangroves are mostly found seaward of saltmarshes and often interspersed with seagrass beds and mudflats. They range from extensive and dense forests to sparse and isolated stunted trees at more extreme settings.

Today the South-west Australian shelf mangroves cover 5% less than the estimated area in 1970. However, the mangrove net area change has been -2.3% since 2007. If this trend continues an overall change of -3.4% is projected over the next 50 years. Furthermore, under a high sea level rise scenario (IPCC RCP8.5) ≈-12.0% of the South-west Australian shelf mangroves would be submerged by 2060, although landward migration may occur. Moreover, 0.3% of the province's mangrove ecosystem is undergoing degradation, with the potential to increase to 0.9% within a 50-year period, based on a vegetation index decay analysis. Overall, the South-west Australian shelf mangrove ecosystem is assessed as **Least Concern** (**LC**).

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Ecosystem classification:
MFT1.2 Intertidal forests and shrublands

Assessment's distribution:
South-west Australian shelf province

Criterion	A	B	C	D	E	Overall
Subcriterion 1	**LC**	**LC**	**DD**	**DD**	**NE**	**LC**
Subcriterion 2	**LC**	**LC**	**LC**	**LC**		
Subcriterion 3	**LC**	**LC**	**DD**	**DD**		

CR: Critically Endangered, EN: Endangered, VU: Vulnerable, NT: NearThreatened, LC: Least Concern, DD Data Deficient, NE: Not Evaluated

Mangroves of the South-west Australian Shelf

LC

1. Ecosystem Classification

IUCN Global Ecosystem Typology (version 2.1, Keith *et al.* 2022):

Transitional Marine-Freshwater-Terrestrial realm

MFT1 Brackish tidal biome

MFT1.2 Intertidal forests and shrublands

MFT1.2_4_MP_57M_58x Mangroves of the South-west Australian shelf

IUCN Habitats Classification Scheme (version 3.1, IUCN 2012):

1 Forest

1.7 Forest – Subtropical/tropical mangrove vegetation above high tide level

12 Marine Intertidal

12.7 Mangrove Submerged Roots

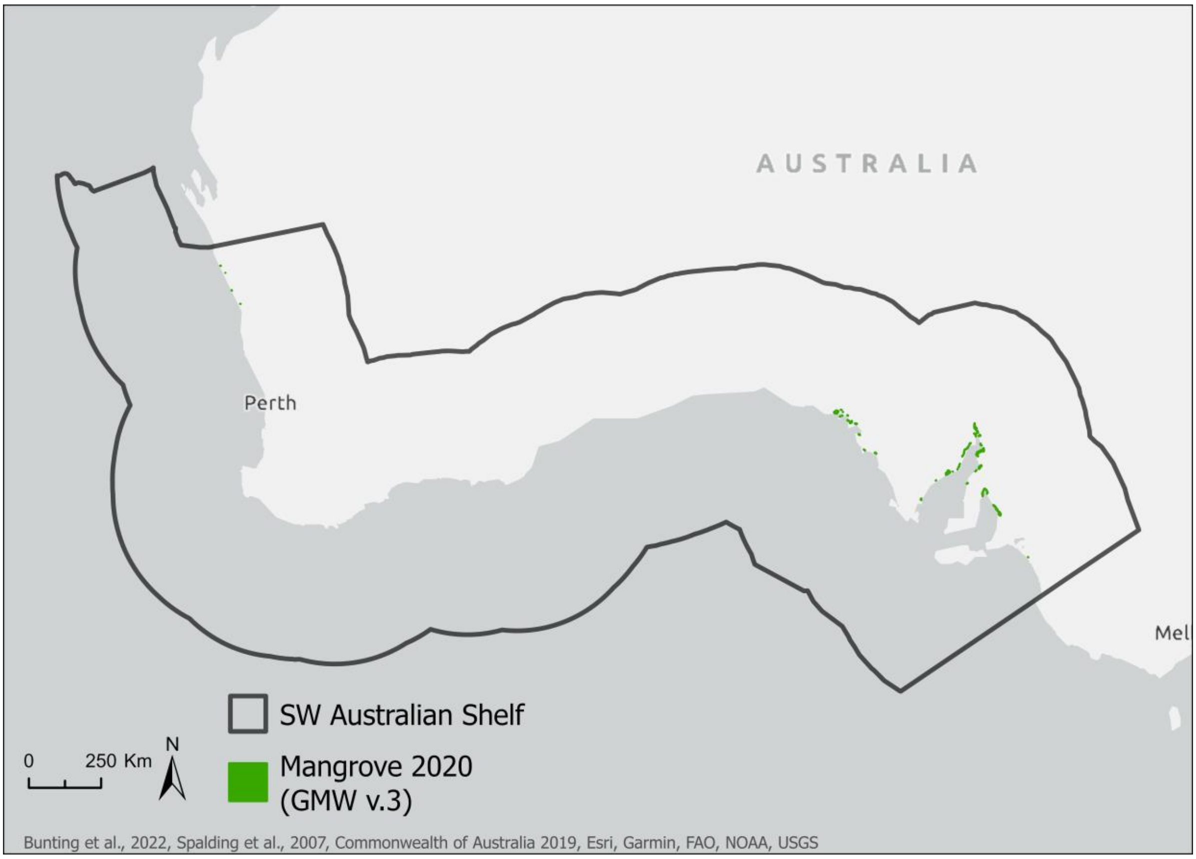


Figure 1. The mangroves of South-west Australian shelf. Note: the isolated enclave of mangroves in Leschenault Inlet, Bunbury, Western Australia, are not visible at this scale due to their small extent. But they are part of the South-west Australian Shelf province and represent one of the most isolated mangrove populations in Australia.

2. Ecosystem Description

Spatial distribution

The South-west Australian Shelf province (SWAS) lies within the single country jurisdiction of Australia, spanning its south-western coastline. It covers two State jurisdictions and borders the Great Southern and Indian Oceans, extending from the north of Perth in Western Australia to Cape Jaffa in South Australia. The Mangroves of this province include intertidal forest and shrublands that are mostly found in the marine ecoregions of the Great Australian Bight and South Australian Gulfs.

Mangroves in Gulf St Vincent (Photo Steve Crooks)

The estimated extent of mangroves in this province is 198.8 km^2 in 2020, representing about 0.1% of the global mangrove area (Bunting *et al*., 2022). There has been a -2.3 % net area change since 2007. An earlier estimate from 1996 indicates a mangrove area of 189.6 km². While this value appears lower than subsequent years, the overall change to 2020 is modest (~5%). Based on data derived from modelling by the Australian Department of Climate Change, Energy, the Environment and Water (DCCEEW, 2021), the pre-colonisation extent of mangroves within the EC-SE Shelf Province was 161.1 km^2. This represents an estimated 23% increase in the province's mangrove habitat in the period 1750 to 2020.

Several resources provide summaries of the extent, composition, and condition of mangrove habitats both in this province and across Australia. The National Land and Water Resources Audit (NLWRA, 2007) inventories all Australian estuaries, recording 29 estuaries within the SWAS province with a combined intertidal area of 545.6 km² (composed of mangrove, tidal marsh, and tidal flat habitats). Although the 2007 NLWRA database reported mangroves present in all 29 estuaries, and Edyvane (1999 a and b) reports 3 km^2 of "patchy mangroves" within Port Douglas (Coffin Bay), neither the Swan River estuary nor Coffin Bay currently have mangroves associated with them. In total, the province's mangrove habitats covered 107.7 km^2, with most located in South Australia, which has 19 estuaries (total area of 538 km^2) and 105.7 km^2 of mangroves. Comparatively, DCCEEW's National Vegetation Information System (NVIS) Version 6.0 includes mangroves in its national vegetation cover dataset. An analysis of the current spatial dataset (DCCEEW, 2020), constrained to the SWAS Province, estimates 141.5 km^2 of mangrove habitat. However, this "point in time" estimate does not accurately represent the national mangrove extent in any specific year, as updates occur at irregular intervals based on state-level contributions.

The most accurate record of Australia's annual gains and losses in mangrove extent comes from satellite remote sensing techniques, based on Landsat imagery. The publicly available National Forest and Sparse Woody Vegetation data (DCCEEW, 2022) incorporates a 3-class forest classification (no forest, sparse woody forest, forest) and extends from 1988 to the current reporting year and is updated annually. Analysis of this dataset, constrained to the SW Shelf Province, and with a maximum extent mangrove mask applied (GMW_v3_union_vec; Bunting *et al.,* 2022), estimates that 184.4 km^2 of mangrove were present in 2020. This is 14.4 km^2 less than the estimation based on the Global Mangrove Watch spatial data (Bunting *et al*., 2022). The discrepancy in these three measures indicates that further research is needed to accurately assess mangrove extent and condition across this region of Australia to inform conservation and policy development and implementation.

Biotic components of the ecosystem (characteristic native biota)

Mangrove Plants

The mangroves of the South-west Australian shelf province are characterised by a single mangrove species, the grey mangrove *Avicennia marina* (Semeniuk, 1993, Duke, 2006). This species exhibits two varietal forms, var. *marina* and var. *australasica* (Duke *et al*., 1998a). Populations in Spencer Gulf and Bunbury are aligned closely with var. *marina*, while those to the east are aligned with var. *australasica*. In Adelaide, trees are genetically intermediate between these two forms.

Mangroves within this province form dense, closed canopies (Pen, *et al*., 2000; Duke, 2006), which relates to the cold and/or arid nature of the SWAS coastlines where it is typically dry all year (Duke, 2006; Morrisey, 2010; Feher *et al*., 2017; Kang *et al*., 2024). Although winter rainfall does occur, it has declined markedly since the late 1960s (Smith *et al*., 2000).

Dense closed canopy mangrove stands near Bunbury bordering Leschenault Inlet (Photo D Kleine)

Mangrove in Franklin Harbour, Eyre Peninsula. (Photo S Dittmann)

Mangroves are mostly confined to sheltered shores of large embayments like the Gulf of Saint Vincent and Spencer Gulf, and protected bays, like those on Eyre and Leschenault Peninsulas. The rest of the coastline along the Great Australian Bight is mostly a high energy coastline unsuitable for mangrove habitat except where suitable sheltered estuaries exist, such as at Davenport Creek near Ceduna (Macleay *et al*., 2003). The low rainfall coupled with few estuaries, results in limited freshwater, nutrients and sediments entering the sea. Consequently, coastal waters are mostly oligotrophic, except for seasonal upwelling events off the Eyre Peninsula and in the south-east of the province (Kampf *et al*., 2004). Low rainfall and high evaporation also result in "inverse estuaries", where salinity is higher in these estuaries compared to coastal waters (Petrusevics, 1993; Kämpf *et al*., 2010). Water temperatures fluctuate widely within the intertidal zone compared to those within the channels and towards the estuarine mouth. Mangroves are mostly found seaward of saltmarshes and often interspersed with seagrass beds and mudflats. They range from extensive and dense forests to sparse and stunted, isolated trees.

Seaward, dense, high biomass stands of A. marina near Adelaide (Photo NC Duke).

Old mangrove forest north of Adelaide (Photo: K. Beaumont).

Mangrove fauna

Three hundred and twenty-one animal species listed in the IUCN Red List of Threatened Species (IUCN, 2022) have natural history collection records, or observations, within the distribution of this province (GBIF, 2022), with two-thirds of these species being birds.

Mangroves offer a range of habitats that are suitable for a wide variety of fauna that, in turn, contribute to healthy ecosystem function. Although the focus of the current IUCN list is on vertebrates (6 taxa, 213 species), the invertebrates, including the meiofauna, are highly diverse and abundant. Many are major contributors to nutrient recycling (Lee, 2008; Nerot *et al*., 2009), and are an important food source for both terrestrial and marine vertebrates (Kathiresan and Bingham, 2001; Abrantes and Sheaves, 2009). Invertebrates also influence mangrove structure and function through herbivory, propagule predation, and bioturbation (Cannicci, *et al*., 2008).

Polychaetes, crustaceans, and molluscs are the dominant aquatic macro-invertebrates in Australian mangroves and echinoderms, ascidians and coelenterates are also present (Hutchings and Recher, 1982). A study of South Australian mangrove infauna (Komarudin, 2003) concluded that, across three mangrove habitats, the polychaete taxa dominated benthic communities in both density and diversity, of which the Capitellidae and Nereididae were the major contributors and widely distributed. The insects were also well represented by the Neanuridae.

The arboreal environment, on the other hand, is dominated by other arthropods, namely insects and arachnids (Hutchings and Recher, 1982).

Mangroves are known to provide vital spawning grounds and nurseries for multiple fish species and provide refugia from predation and commercial fishing (Robertson and Duke, 1990 a,b; Lee, 1999; Bloomfield and Gillanders, 2005; Payne and Gillanders, 2009). However, these associations appear less obvious in the temperate mangrove systems of South Australia. Henkens *et al*. (2022) reported that the feeding intensity of fish within South Australian mangrove creeks was low and suggested that most fish species observed in mangroves at high tide do so primarily for shelter, and feed mainly in adjacent habitats such as seagrass meadows. Amphibians are not represented in South Australia's mangrove habitat. Most amphibians are unlikely to access tidal wetlands due to their intolerance to saline habitats (Kutt, 1997). Cane toads (*Rhinella marina*), which are tolerant of brackish conditions (Liggins and Grigg, 1985), are not established in the SWAS but are occasionally observed in South Australia. They are present in coastal wetlands, including mangrove margins, along Australia's tropical and sub-tropical east coast and the Northern Territory (Catling *et al*., 1999; Hines and McDonald, 2007, Shine, 2010), and represent a significant threat to the SWAS native wildlife should they become established.

The Eyre Peninsula supports a varied reptilian community comprising about 25 snake and 73 lizard species (Schwaner *et al*., in Twidale *et al*., 1985, pp 159-169). However, terrestrial reptiles were not surveyed in the Eyre Peninsula's mangrove environment in this or a survey by Brandle (2010). Brandle (2010) observed 17 snake and 72 lizard species and reported that inter-dune and (freshwater) swamp sites, and sites with lower sand content, had lower species richness. This may indicate habitat preferences for reptile species that preclude mangrove habitat. A survey of coastal fauna of the western Eyre Peninsula (Ling and McGregor, 2014) failed to observe any reptiles within mangrove habitat even though 22 reptile species were observed across other surveyed coastal habitats. Community observations within the St Kilda mangrove and saltmarsh system record the presence of five reptile species (iNaturalist, 2024). Reptiles, therefore, may be occasional visitors that venture into mangroves for temporary shelter or food.

Three species of marine turtles, the Loggerhead (*Caretta caretta*), the Green Turtle (*Chelonia mydas*) and the Leathery Turtle (*Dermochelys coriacea*) have been observed in South Australian waters but are likely vagrant (Schwaner *et al*., in Twidale *et al*., 1985, pp 159-169; Greenwood and Gum, 1986; Edyvane, 1999).

Across Australia, there are twenty-five bird species that are mangrove specialists compared with eleven in New Guinea (Ford, 1982). Australian mangrove bird assemblages are mostly insectivores and nectarivores (Mohd-Azlan *et al*., 2012). Australian temperate mangroves host diverse bird assemblages with at least 41 species recorded in mangroves near Newcastle, New South Wales (Goodenough, 2009) compared to more than seventy species reported in North Queensland mangroves (Kutt, 1997). Ling and McGregor (2014) listed fifty bird species associated with Western Eyre Peninsula mangroves out of 285 Ayre Peninsula bird species, including 9 non-native species, recorded in the Biological Database of South Australia (Brandle, 2010). Ling and McGregor (2014) reported seven species that exhibit a preference for mangroves, and a further twelve species that commonly utilise mangrove creek channels, or adjacent mud and sand flats and tidal seagrass beds at low tide.

Mohd-Azlan *et al*. (2015) studied the role of mangrove complexity in overall bird species richness and density. They found that high bird species richness and density correlated with plant species richness, the density of the understory and food resource distribution. The low species richness and poorer structural diversity of Australia's temperate mangroves, compared to tropical mangrove forests, likely support a lower level of bird species richness and density than observed in North Queensland mangroves.

Although Australian mammals are not considered endemic to mangroves this habitat does support feeding and roosting activities for both regular and seasonal visitors, particularly bats (Kutt, 1997; Hutchings and Recher, 1982). Nationally, thirteen species of bat are associated with mangrove habitat (Rog *et al*., 2020). The grey-headed flying-fox *(P. poliocephalus*), which is listed as Vulnerable according to the Red List of Threatened Species (RLTS) spatial data (IUCN, 2022), may establish temporary roosting colonies in mangrove canopies (Kathiresan and Bingham, 2001; Timmiss, *et al*., 2020). Other smaller bat species associated with mangrove habitat, as listed in the SA Flora and Fauna Data Dashboard (DEW, 2024a), include Gould's Wattled Bat (*Chalinolobus gouldii*), Chocolate Wattled Bat (*Chalinolobus morio*), and the Southern Free-tailed Bat (*Mormopterus planiceps*). Seven species of small insectivorous bats were captured in a survey of mangrove and tree lined river channels at St Kilda and the Light River channel (Armstrong *et al*., 2017). These smaller bats can also roost in mangrove habitat, including maternity roosting, where they take advantage of tree hollows in old growth mangroves (McConville, *et al*., 2013; Law, *et al*., 2023).

There are several introduced and introduced mammals that are observed in South Australia's mangroves, including dogs (*Canus lupis*), cats (*Felis catus*), foxes (*Vulpus vulpus*) and rodents, namely the Black Rat and House Mouse (*Rattus rattus, Mus musculus*). These species can cause ecosystem disruption through competition and predation. Trapping data from within mangroves and other coastal vegetation indicated that, whereas *Mus musculus* was observed within all coastal environments, including at the two mangrove-based trap sites, *Rattus rattus* had a more restricted distribution with observations occurring adjacent to mangroves rather than within them (Armstrong *et al*., 2017). Introduced hooved ungulates, are present in South Australia but not regularly observed in its mangroves (Armstrong *et al*., 2017, ALA, 2024; DEWa, 2024), include cattle (*Bos* taurus), pigs (*Sus scrofa*) and rusa and fallow deer (*Cervus timorensis* and *Cervus dama*). These species cause significant damage to mangrove habitats elsewhere in Australia through sediment disturbance through their hard hooves and by wallowing, propagule predation, predation of fauna, and introduction of weeds.

Several studies indicate that, despite their high primary productivity, mangrove plants are not the sole, nor necessarily the major contributor of nutrient resources for resident primary and secondary consumers and the broader estuarine community (Kieckbusch, *et al*., 2004; Abrantes, 2008; Heithaus 2011), although other studies indicate they support food webs (Abrantas et al. 2015, Then et al. 2021). A comparative study demonstrated that a similar four level trophic structure existed within both a tropical (Malaysia) and temperate (south-east Australia) mangrove ecosystems in which sediment organic matter rather than mangrove detritus was the base trophic resource (Mazumder, *et al*., 2019). Marley *et al*. (2019) demonstrated that, for mangroves fringing an adjacent mudflat, the mangrove and mudflat food webs were connected by highly mobile top predators that included birds and caimans. Mangrove structure provides substrate for marine animals, burrowing invertebrates, and plant epiphytes, and in the provision of shelter for resident and visiting vertebrate and invertebrate consumers (Kieckbusch, *et al*., 2004, Grol *et al*., 2008, Dorenbosch *et al*. 2009).

Mangroves are also beneficial to human economies and wellbeing through the provision of environmental services including coastal protection, food and materials for shelter and cooking fires (Clarke *et al*., 2021; Bell, *et al*., 1984; Meynecke *et al*., 2007; Knight, 2011; Siwiendrayanti *et al*., 2020). Respondents to a survey of the cultural value of Adelaide coastal wetlands mostly rated environmental qualities as important or very important and engaged in a range of recreational, leisure and social activities centred on these wetlands (Clarke *et al*., 2021). The Kaurna meyunna (people), the First Nations people of the north and eastern coasts and hinterlands of the Gulf St Vincent, experienced almost immediate loss of access to coastal wetlands with the establishment of Adelaide's first port facilities (Old Port) at Port River in 1837 (Telfer *et al*., 2012). Remnant Kaurna fish traps, present along the Perth's metropolitan coastline, serve as reminders of the Kaurna meyunna's historical reliance on mangroves and other coastal habitats for food and cultural practice during their long occupation in this region, estimated at 25,000 year or more (Telfer *et al*., 2012).

Abiotic Components of the Ecosystem

The abiotic components that influence mangrove distribution, phenology and plant community structure within SWAS include wave energy, hydroperiod, tides, air and water temperatures, freshwater inputs that moderate salinity of porewater, and sediment type and availability (Martinez-Diaz and Reef, 2022). These in turn are influenced by climate and oceanography, coastal and hinterland geomorphology, geological history and major changes from human development, e.g. in Western Australia the opening of estuaries to the ocean has occurred which has altered hydrology. Various isostatic and/or eustatic processes that influence the velocity and acceleration of relative sea level change also affect some mangrove communities within SWAS (Belperio, 1993, Coleman, 1998; Cann *et al*., 2009, Ward *et al*., 2016, Cann and Jago, 2018; Saintilan *et al*., 2021).

The SWAS coastline is broadly characterised by swell and storm waves from the Southern and Indian Oceans acting as dominant physical processes that produce high energy environments along a mostly open coastline with coarse surface sediments bordered by semi-arid or arid landscapes with little coastal drainage (Gostin *et al*., 1988, Richardson *et al*., 2005, Bourman *et al*., 2016). However, *Avicennia marina* normally requires low energy tidal environments that provide regular aerial exposure of their pneumatophores at the seaward edge and regular tidal flushing that removes accumulated salt from around their roots at the landward edge (Clarke and Myerscough, 1993, Cann *et al*., 2009, Osland *et al*., 2019, Devaney *et al*., 2021, Martinez-Diaz and Reef, 2023). Mangroves are therefore restricted to SWAS's sheltered coastlines, bays and estuaries, which are limited geographic features outside of the northern reaches of the South Australian Gulfs and coastal embayments on the Eyre peninsula.

The SWAS coastal zone forms part of the world's largest aeolianite (dune limestone) temperate sedimentary carbonate province that extends from Western Victoria to north of Shark Bay, Westen Australia (Richardson *et al*., 2005, Bourman *et al*., 2016, p 395). The South Australian Gulfs at SWAS's eastern boundary (Gulf St Vincent and Spencer Gulf) have a mixed terrigenous-carbonate sand substrate (Richardson *et al*., 2005), although the percentage of carbonate varies greatly within and between mangrove communities (Butler *et al*., 1977).

The Gawler River, a stream within greater Adelaide, terminates at Port Gawler in a well-studied example of a South Australian tidal estuary. It provides relatively little freshwater and terrigenous sediments into its estuary so that the estuary's muds are classed as autochthonous, the organic component mainly derived from seagrass, algae, mangrove and samphire plant matter (Cann *et al*., 2009).

Grain size and cohesion of the carbonate bioclasts may play an important role in the distribution of *Avicennia marina* within SWAS's semi-arid and arid estuaries and bays, as demonstrated by Cann *et al*. (2009; *See also* Harbison, 1986a; Harbison 1986b). Mangroves at Port Gawler were observed to expand from a landward stand into a nearby shallow seagrass meadow (*Zostera muelleri*) that had accumulated a mud layer, but not into the intervening intertidal sandflat (Cann *et al*., 2009). The authors suggested that the presence of mud over the sand layer was necessary for effective mangrove establishment as their propagules were unable to easily penetrate and establish on the intervening sandflats whose carbonate and quartz sands were bound by cyanobacterial mats (Cann *et al*., 2009).

An inundation free period is normally required to enable rapidly developing mangrove roots to penetrate deeply enough into sediment to withstand subsequent seedling dislodgement by returning tidal currents and waves (Balke, *et al*., 2011). Tides along Adelaide's coastline are semi-diurnal and classed as mesotidal (2 – 4 m tidal range), which represents the maximum range observed during a spring tide. However, most of the monthly tide cycle is lower and considered microtidal (< 2m) (Pattiaratchi and Jones, 2005). Conditions for propagule establishment may therefore be most favourable at neap low tides when tidal flows are lowest or, within the Gulf St Vincent, at the equinoxes when the diurnal components of the tide cancel each other out and the tide cycle skips over several days to produce South Australia's dodge tide (Pattiaratchi and Jones, 2005). A combination of ease of root penetration into mud, rather than consolidated sands, and reduction in tidal currents during neap or dodge tides, and reduction in tide and wave action by surrounding seagrass combines to facilitate the local pattern of mangrove establishment observed within the Gawler estuary, and applies more broadly within South Australia's Gulfs (Sabine Dittmann, pers. comm.).

Climate has always been an important determinant of mangrove distribution. Palynostratigraphy has revealed the past existence of *Nypa, Sonneratia and Barringtonia* alongside *Avicennia* within Victorian, Tasmanian and SW Western Australian coastal locations during the early to mid-Eocene period (Srivastava and Prasad, 2019). Rhizophoraceae cuticle was present in early Eocene plant fossil assemblages collected at Regatta and Strahan Points within Macquarie Harbour, Tasmania (Pole, 2007). Pole (2007) considered that this indicated the presence of another mangrove taxon based on the cuticle's affinities to extant *Bruguiera*, *Ceriops*, and *Rhizophora*, and its presence with Nypa. By the late Eocene, as the world cooled, the Tasmanian mangrove communities disappeared and strictly tropical mangroves, such as *Nypa*, had contracted to one site on Melville Island in the NT, and a small number of sites in northern Queensland (Duke, 2025). A less floristically diverse mangrove community, that included *Avicennia*, continued to survive in South Australia due to its warmer coastal waters (MacPhail, 2007).

The last post-glacial sea-level rise 7000 years ago reached its maximum transgression along Australia's southern coastline at one to three meters above current sea-level. Since then, slow continuous or stepped regressions and transgressions to current sea-levels have followed that are the result of ongoing climate, hydro-isostatic and eustatic adjustments (Belperio *et al*., 2002, Haworth *et al*., 2002, White *et al*., 2014, Bourman *et al*., 2016). These processes facilitated movement of mangroves towards the modern coastline, their current distribution largely dependent on the infill of estuaries, the size of estuary accommodation spaces, and the retention of sediments and sediment yields within estuaries (Saintilan *et al*., 2021).

Currently, mangroves in the Port River/Barker Inlet estuary (-34.75, 138.51) in Gulf St Vincent are the southern-most naturally occurring mangroves within SWAS (McClatchie *et al*., 2006) while other potential sites for mangroves, such as Coffin Bay on the west coast of the lower Eyre Peninsula (-34.63, 135.44), and Kangaroo Island's Pelican Lagoon (-35.84, 137.76), are mangrove free. Yet both locations are well north of Australia's southern-most mangroves at Corner Inlet (-38.22, 145.30) in Victoria (Boon, 2017).

Species within the genus *Avicennia* persist at their physiological limit in arid zones (Adame *et al*., 2021) suggesting that abiotic factors related to climate may contribute to the observed SWAS latitudinal limit. Duke (1990) previously demonstrated the association of phenological trends with latitude in *Avicennia marina,* including range limitations at latitudes greater than 35°S associated with reduced fecundity and flowering success approaching zero if daily mean temperatures were below 18°C. Also, hypersalinity and low humidity, key features in many of SWAS's inverse estuaries (Kaempf, 2014), were demonstrated to reduce cold tolerance in a related species, *Avicennia germinans* (Devaney *et al*., 2021). South Australia has a semi-arid, temperate climate where annual evaporation greatly exceeding annual precipitation (Kaempf, 2014). Consequently, SWAS's south and west Australia coastlines, with mostly dry, warm to hot summers and lower annual rainfall, experience different conditions to those of Corner Inlet (Appendix 4).

There are sheltered coastal sites or enclosed bays within SWAS that do not contain mangroves but may be able to support them. Two such locations are Coffin Bay and Pelican Lagoon. Neither location exceeds the air and sea surface temperature ranges and limits reported for the genus *Avicennia*, *sensu lato* (Quisthoudt *et al*. ,2012), except for their reported warmest and coldest air temperatures (Table 1). However, neither location exceeds the maximum or minimum air temperatures observed at several West Australian estuaries (within SWAS) that currently support mangroves. Greenough River, Tourville Bay and Barker Inlet have equal or higher maximum air temperatures, and Tourville Bay and Leschenault Inlet, as well as Corner Inlet in Victoria, have equal or lower minimum air temperatures than those reported for Coffin Bay and Pelican Lagoon (Appendix 4). Further comparison with other physical and climatic characteristics of SWAS estuaries (Appendix 4) suggests that Coffin Bay and Pelican Lagoon could potentially support mangrove communities as they contain habitat similar to other South Australian and Western Australian estuaries that do support *Avicennia marina*.

Table 1: Comparison of average, minimum and maximum air and sea surface temperatures (see Quisthoudt *et al*., 2012) experienced by *Avicennia sp*. living at their latitudinal limits in either hemisphere, against those reported for Coffin Bay (Lower Eyre Peninsula) and Pelican Lagoon (Kangaroo Island) that do not currently support established mangroves (BOM and Sea Temperature Info data). The differences may be attributed to the use of derived temperature values extracted from a 10x10 arcmin spatial resolution climate dataset (Quisthoudt *et al*., 2012), whereas the local weather data, that included maximum and minimum air temperatures, was recorded at a weather station at or near each locality listed here and in Appendix 4.

Abiotic factor	Literature values	Pelican Lagoon, Kangaroo Island, SA[j, j]	Coffin Bay, SA[h, j]
Literature average cool climate air temperature vs locality average minimum temperature (°C)	13.5[e]	9.0	12.4
Literature coldest cool climate air temperature vs locality lowest recorded minimum temperature (°C)	8.1[a]	-2.4	3.4
Literature average warm climate air temperature vs locality average maximum temperature (°C)	27[e]	21.0	21.3
Literature hottest warm climate air temperature vs locality highest recorded maximum temperature (°C)	35.6[b]	45.4	43.4
Literature average sea surface temperature vs locality average winter sea surface temperature[i] (°C)	18.8[e]	13.3	12.5
Literature coldest sea surface temperature vs locality lowest recorded winter sea surface temperature[i] (°C)	12.7[d]	13.3	12.5
Literature average sea surface temperature vs a locality average summer sea surface temperature[i] (°C)	26.7[e]	22.0	20.2
Literature hottest observed sea surface temperature vs locality highest recorded sea surface summer temperature[i] (°C)	32.8[c]	21.5	21.1
Literature freezing limit for mortality vs locality lowest recorded minimum temperature (°C)	> -3[f]	-2.4	3.4
Literature low temperature limit for physiological inhibition vs locality average winter temperature[k] (°C)	> 4[g]	11.4	13.4

(a) Quisthoudt *et al*., 2012 (NZ)
(b) Quisthoudt *et al*., 2012 (Saudi Arabia)
(c) Quisthoudt *et al*., 2012 (Iran)
(d) Quisthoudt *et al*., 2012 (Australia)
(e) Quisthoudt *et al*., 2012 - Average of all hot or all cold global locations
(f) Wardle, 1978 (NZ)

(g) Beard, 2006 (NZ)
(h) Coffin Bay (Point Avoid, BOM station number 018230, http://www.bom.gov.au/climate/data/). Temperature averages based on available timeseries. (2017 to 2025)
(i) Kangaroo Island (Kingscote Aero, BOM Station number 022841, http://www.bom.gov.au/climate/data/). Temperature averages based on available timeseries. (1994 to 2025)
(j) Sea surface temperatures obtained at: Coffin Bay (GAB coastal waters outside Coffin Bay) and Pelican Lagoon (coastal waters at Kingscote, Kangaroo Island). Average temperatures based on previous 10 years of data (2016 to 2025) at the locality. (https://seatemperature.info/)
(k) Average of the mean monthly maximum and minimum winter temperatures (June, July, August) for the Kingscote Aero (Pelican Bay) and Point Avoid (Coffin Bay) timeseries.

The SWAS coastline has large stretches of unsuitable habitat resulting in a fragmented distribution of mangroves along its length that may impact successful propagule dispersal and establishment into more remote locations. A study of *Avicennia marina* populations along the northwest coast of Western Australia demonstrated that significant gaps in mangrove distribution present strong barriers to stepping-stone gene flow in this species (Binks *et al*., 2018). In a separate study in southeast Australia most *Avicennia marina* propagules were observed to strand within one km of an estuary, with very few observed to disperse more than 10 km, even though propagules can remain viable for up to 5 months (Clarke, 1993). The nearest mangrove forests to these locations are much further away. In straight-line distances, Venus Bay lies 160 km NW of Coffin Bay and Barker Inlet is 134 km NE of Pelican Lagoon. Currents and prevailing winds may be important determinants of dispersal. A recent observation on the presence of mangrove propagules and seedlings on Kangaroo Island was communicated to one of us (Norman Duke) by the Island's national park rangers. This observation supports the possibility of long-distance dispersal establishing a mangrove at this remote location. The question is whether this represents an ongoing cycle that continues to fail to establish mangrove communities here, or whether a mangrove community may in time be re-established.

Feature Sub Areas – SWAS region

Notable Features – SWAS region

Unusual temperate mangrove forests

Some of the largest temperate mangrove stands in Australia. Trees of *Avicennia marina* grow to less than 8 m. These contrast with other mangrove stands with stunted growth where extreme environmental conditions prevail, as in upper reaches of the South Australian Gulfs.

Co-occurrence of mangroves and saltmarshes

This region has extensive supratidal areas of samphire saltmarsh, generally with a transition from saltmarsh to mangroves in the upper intertidal zone. Major plant genera in the saltmarsh zone include *Sclerostegia*, *Sarcocornia* and *Tecticornia*.

Co-occurrence of mangroves and seagrass beds

Low turbidity in local coastal waters often allows proximity between seagrasses and mangroves. Most large and small mangrove creek estuaries have dense beds of *Heterozostera* and *Zostera* towards their seaward reaches.

This region spans Australia's south-western coastline (covering 2 State jurisdictions) bordering the Great Southern and Indian Oceans from the north of Perth in Western Australia to the Murray River mouth in South Australia. The region is influenced by cool temperate, often arid conditions, micro-tides, high winds and large waves along its open coastline. Mangroves occur naturally along sheltered sections of this coast, mostly within deep gulfs and inlets. Six sub areas are based on the types of mangrove habitat determined by varying geological and physiographic settings (adapted from Duke, 2006, Thackway and Cresswell, 1995).

Geraldton sandplain - Sandy coastline with headlands and cliffs tending to vast mobile sand sheets further south

Murchison River (Kalbarri) to Moore River (Guilderton) contains nine catchments, eight of which have mangroves with a total area less than 2 km^2 (NLWRA, 2007, Mangrove Canopy Cover 30m 3.0.0 (Landsat, Collection 3; https://portal.ga.gov.au/). There are several rivers with small estuaries at the north-west end of SWAS, including the Hutt, Bowes, Greenough, and Irwin Rivers, that contain small areas of mangrove habitat (Lymburner *et al*., 2020; Mangrove Canopy Cover 30m 3.0.0, Landsat, Collection 3; https://portal.ga.gov.au/). These estuaries are located within the Geraldton Sandplains bioregion of Western Australia (Thackway and Cresswell, 1995) whose northern coastal geomorphology consists of sand beach embayments between headlands and bluffs, rocky cliffs, and a straight and exposed sandy coastline that includes both stable and mobile dune systems (Stevens and Collins, 2011). The southern half of the Geraldton Sandplains bioregion, however, is dominated by extensive mobile sand sheets (Stevens and Collins, 2011).

Southwest & Nullarbor Plain (SW) - Sandy Coastal Dunes

Moore River to Esperance – 16 local catchment areas in total. Climate is generally temperate subhumid to humid. This southern region has just one mangrove species, *Avicennia marina*, in one estuarine lagoon, Leschenault Inlet around Bunbury, with a total mangrove area of ~1 km^2 (Semeniuk *et al*., 2000). The state capital, Perth on the Swan River Estuary, is the only mainland capital to have no mangroves in its vicinity (Duke, 2006).

Nullarbor Plain (NW) – Desert Exposed Southern Coast

Esperance to Eucla – a broad, very exposed and dry coast with no appreciable catchment flow channels. The climate is arid. There are no mangroves in this region.

Ceduna Coast (CS) - Arid Exposed Coast

Nullarbor to the western side of Eyre Peninsula – a coastal area of numerous dry channels with intermittent flows. This coast is exposed with moderate to severe wave energy from the Great Australian Bight. Mangroves occur in sheltered intertidal bays near Ceduna between Tourville Bay and Smoky Bay, with additional isolated patches in Streaky, Venus and Anxious Bay. The region has a total mangrove area of ~26 km^2.

Flinders' Gulfs (FS) - Cool and Moist Inverse Estuaries

Port Lincoln on Eyre Peninsula to Spencer Gulf, to Gulf Saint Vincent and Fleurieu Peninsula – 9 local catchment areas. The two large gulfs are inverse estuaries with low to moderate wave energy comprising extensive inter- and supratidal areas characterised by micro- to mesotidal ranges at their respective heads. Mangroves occur chiefly along the top ends of these gulfs, from Cowell to Port Broughton in Spencer Gulf, and from Price River near Port Clinton to Baker Creek south of Port Wakefield in Gulf St. Vincent. The most extensive mangroves in Spencer Gulf are in Franklin Harbour, Tumby Bay, and around Port Augusta, with Chinaman Creek having the largest undisturbed mangrove forests in South Australia. Further extensive mangrove forests occur north of Adelaide between the Barker Inlet estuary and the Light River delta. The region has a total mangrove area of less than 200 km^2.

Murray Coorong (MS) - Exposed Southeast and Kangaroo Island

The Millicent Coast, including Kangaroo Island to the River Murray. This exposed south facing coastline is affected by high wave and low tidal energy. The region has no naturally occurring mangroves. Some isolated mangroves were planted on the south coast of Hindmarsh Island, near the mouth of the River Murray, in the 1950s (Edyvane *et al*., 1996).

Key processes and interactions

Mangroves act as structural ecosystem engineers possessing traits such as pneumatophores, salt excretion glands, vivipary, and propagule buoyancy that promote survival and recruitment in poorly aerated, saline, mobile, and tidally inundated substrates. They exhibit high efficiency in nitrogen use and nutrient resorption. Mangroves produce large amounts of detritus (e.g., leaves, twigs, and bark), which is either buried in waterlogged sediments, consumed by crabs and gastropods, or more commonly decomposed by fungi and bacteria, thus mobilising carbon, and nutrients to higher trophic levels. These ecosystems also serve as major blue carbon sinks, incorporating organic matter into sediments and living biomass.

Coastal wetland habitats, which include mangrove, tidal marsh and seagrass, are threatened by the combined pressures of human and natural drivers of change. These habitats experience highly dynamic physical and climatic conditions and commonly undergo damage-recovery cycles. Change occurs when coastal wetland systems are exposed to repeated damage over intervals shorter than recovery time.

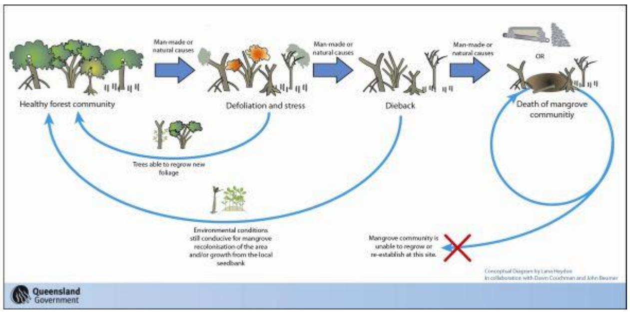


Figure 2. Drivers of change in mangrove habitat include human pressures along with natural influences (*https://ozcoasts.org.au/conceptual-diagrams/science-models/processes/mangrove/*)

Coastal wetland habitats are interlinked and so some threats are common to all habitats or, if affecting a subset, have indirect and/or direct effects through their shared linkages.

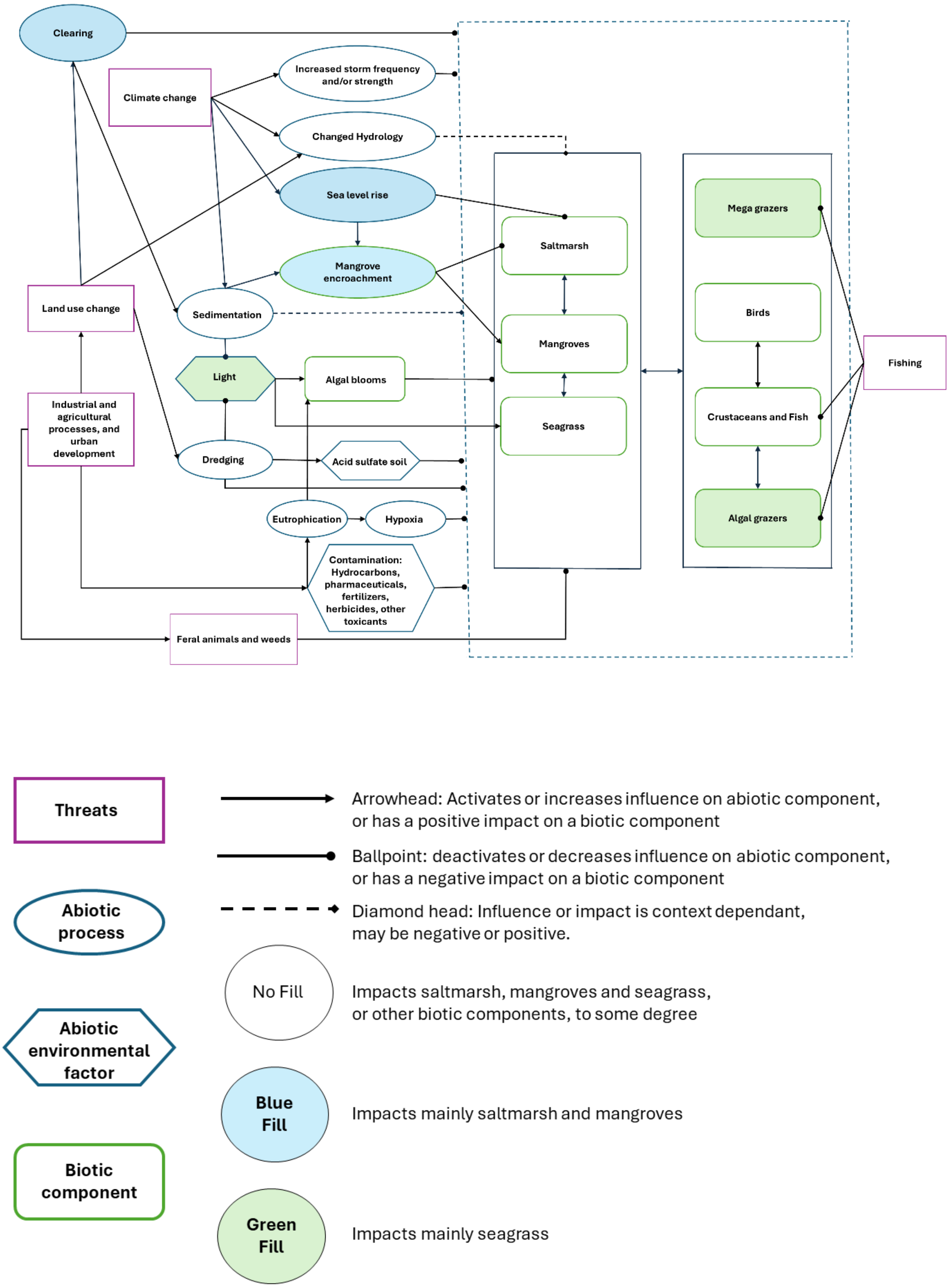


Figure 3. A conceptual model of key processes and threats to the linked inshore and tidal ecosystems of the Southwest and Australian Shelf province (modified from Figure 2 in Sievers *et al*., 2020). The key threats relevant to this province, represented generically in this diagram, are described below.

3. Ecosystem Threats and vulnerabilities

Main threatening processes and pathways to degradation

Mangroves of the SW Shelf border southern oceanic waters, between Australia and Antarctica. In these high latitudes (>37° S), weather conditions are often harsh, with temperatures rarely exceeding 20°C. Only one cold-adapted mangrove species is present, and growth is constrained by low rainfall and high salinity, which limits both stand height and biomass. Positioned in intertidal zones, mangroves are particularly vulnerable to sea-level rise due to climate change. Additionally, intense storms pose a significant threat, causing direct defoliation and tree destruction, along with mass mortality of associated animal communities. Sea level rise resulting from climate change poses a significant threat to mangroves (Lovelock *et al*., 2015), particularly in locations with low tidal range. Based on the tide gauge in Port Adelaide, sea levels have risen progressively since 1943 (Figure 4; PSMSL, 2024). And, because mangrove ecosystems are tightly constrained by sea level (between mean sea level and highest tide levels), their ability to survive and persist, is dependent on being able to colonise higher topographic areas upland. This involves establishment of propagules at higher elevations. There is a real threat of this natural re-establishment process being outpaced by rising sea levels and hindered by barriers due to human infrastructure. Established trees may drown at the waters-edge if mangroves are low in the intertidal zone and vertical accretion is insufficient to maintain their position in the intertidal zone as sea level rises (Lovelock *et al*., 2015, Saintilan *et al*., 2023). Global models of the impacts of sea level rise by 2100 on coastal wetlands in the region indicate both losses and gains of habitat are possible (Schuerch *et al*., 2018), and thus projection of the impacts of sea level rise remain uncertain in this region. Local anthropogenic actions in coastal locations may also contribute to apparent sea level rise. Land subsidence due to surficial soil compaction associated with wetland reclamation and groundwater extraction is observed at the Port Adelaide Estuary and contributes about 75% (1.8 to 2.2 mm per year) to recorded sea level rise (2.5 to 2.9 mm per year) at the two local tide gauges (Belperio, 1993).

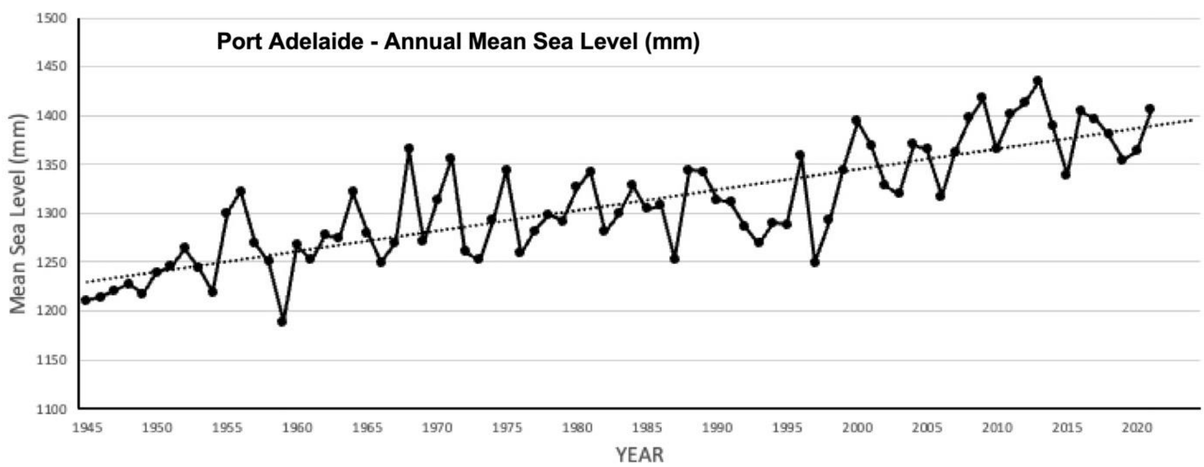


Figure 4. Annual mean sea level records (in mm) for Port Adelaide from 1945 to 2022. There has been an overall rise of close to 200 mm over the last 7-8 decades (~2 mm/yr). (PSMSL, 2024)

Mangrove deforestation also arises from direct human-related factors, including salt production, urbanisation, associated coastal development, and pollution stemming from domestic, industrial, and agricultural land use.

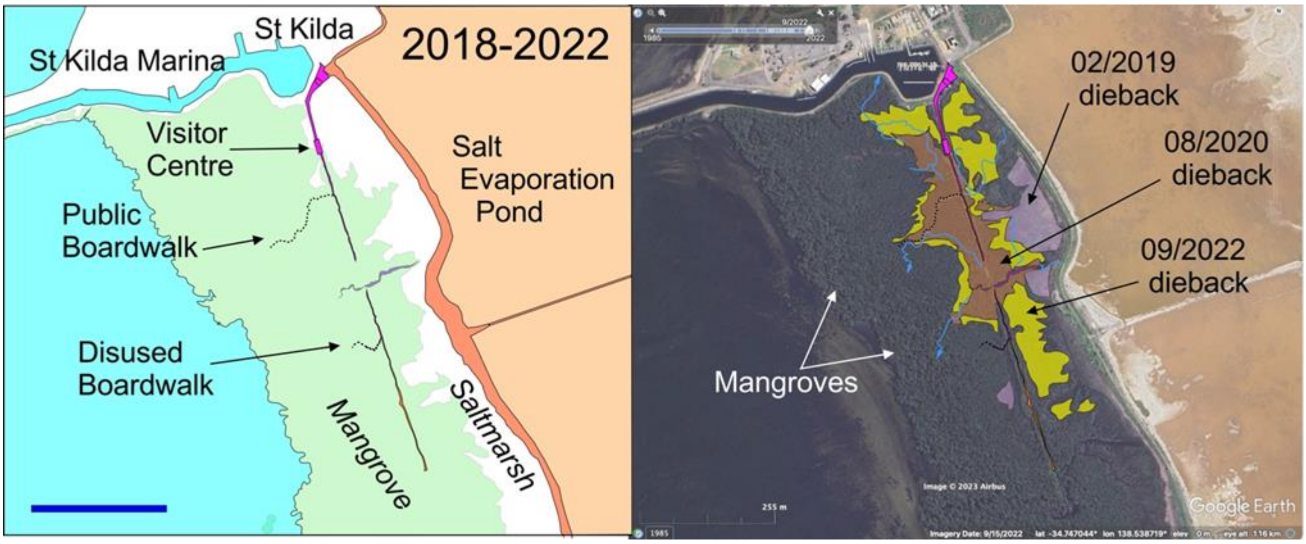
An assessment of South Australia's coastal and marine vulnerabilities was made by the Marine Parks Scientific Working Group (MPSWG, 2011) and extended from Tourville Bay on South Australia's west coast and then through both the Spencer and St Vincent Gulfs down to Port Gawler and Barker Inlet. The study listed several potential threats that arise out of human activity that, directly or indirectly, impact mangroves, including development, pollution, disturbance of acid sulphate soils and climate change associated sea level rise. Areas reported as impacted were mostly adjacent to urban, industrial or port infrastructure. Several former mangrove areas within Barker Inlet affected by land degradation now contain thick layers of acid sulphate soils (Fitzpatrick *et al*., 2008; Thomas *et al*., 2003, 2004).

Historically, port, marina and industrial development (dredging, land reclamation, estuary truncation (reduced sediment availability) and bunding/tidal barriers), and nutrient pollution were reported to have contributed to mangrove loss (Edyvane, 1999; MPSWG, 2011). Since 1956 more than 250 ha of mangrove has been lost from the coast north of Adelaide and this has been attributed to the discharge of nutrient pollution from the then newly operating Bolivar sewage treatment plant (Overton, 1993: Australian Marine Parks, 2001; MPSWG, 2011). Eutrophication of the coastal waters resulted in excessive growth of local seaweeds such as *Ulva* sp., *Gracilaria* sp., *Giffordia* sp. and enhanced epiphytic algal growth on mangrove pneumatophores. Excess biomass from the seaweeds drifted in with the tides and, combined with the excess algal growth already present, smothered the pneumatophores leading to mangrove dieback (Edyvane, 1999; MPSWG, 2011). There was no direct impact on the mangroves from the nutrient pollution, but dieback was induced because other elements of the linked coastal system were altered.

A more recent example, originally observed in 2020, involves the dieback of St Kilda mangroves (Barker Inlet) due to hypersaline brine contamination from the Dry Creek Salt Fields (Dittmann *et al*., 2022; Leyden *et al*., 2022). The Dry Creek Salt Field was established in the 1930's, with the first salt harvested in 1939. At its greatest extent it comprised about 5,500 ha of salinas (salt ponds) along 28 km of coastline north of Adelaide. Dry Creek is at the southern end of the complex. Operations ceased in 2013 and an interim care and maintenance plan implemented prior to the development and regulatory acceptance of a final closure strategy. The interim plan included retention of water levels in some salinas, with planned discharge and refill operations to prevent excessive salt buildup in these, and permanent drainage of others (Buckland Dry Creek Pty Ltd, 2020).

Mangroves surrounding the St Kilda Mangrove Trail were killed around 2020 following leachate contamination from disused salt extraction ponds nearby (NC Duke).

Ponds adjacent to the impacted wetlands were recharged with brine from a neighbouring pond. Surface cracking of the pond's gypsum crust enhanced recharge of that pond's underlying groundwater with hypersaline solution and the increased hydraulic pressure transported that solution towards the intertidal zone (Leyden *et al*., 2022). This resulted in the destruction of 9 hectares of mangroves and 10 ha of saltmarsh (Dittmann *et al*., 2022).



Dieback of mangroves around the St Kilda mangrove boardwalk between 2018 and 2023 (Google Earth).

Further, a study on recovery and propagule dispersal within the dieback zone concluded that, in the three years since the event, there was little evidence for the re-establishment of mangroves in the dieback area (Coleman and Coleman, 2023). A study on groundwater salinities within a section of the impacted tidal marsh area (stations SK8, 9 and 10, adjacent to pond PA6) showed a decline in salinity at all stations in the period December 2020 to June 2022 (Leyden *et al*., 2022). In December 2020 the Total Dissolved Solids (TDS) varied between stations within the range of 150,000 and 260,000 mg/L (average 391 mg/L) and was reduced to between 145,000 and 60,000 mg/L (average 178 mg/L) by June 2022. Assuming that the Mg/Na ratio of the brine is similar to that of seawater then the groundwater salinity range reduced from 469 – 270 ppt to 262 - 108 ppt, the latter representing a range of 748 - 310 % seawater. *Avicennia marina* has a high salt tolerance, including at the germination and seedling stages, maintaining active photosynthesis in seedlings grown in 150% seawater (Tuan *et al*., 1996). However, optimum seedling growth and development were observed at levels at or below 50% seawater salinity (Ball 1988; Clough 1984; Tuan *et al*., 1996; Ye *et al*., 2005; Patel *et al*., 2010). It is therefore unlikely that substantive natural mangrove recovery will be observed until the groundwater TDS is reduced to at least 30,000 mg/L, but more likely 20,000 mg/L, which represents average seawater at 35 ppt. Current management recommendations are to prevent further salt intrusion by keeping the pond level low to minimise the hydraulic head difference between pond and the external tidal zone, and to rely on tidal flushing as the primary means of diluting the excess salt out of the sediment in the tidal zone (Leyden *et al*., 2022).

The South Australian Department for Environment and Water (DEW) mapped the extent of the dieback in 2021 and concluded that there was "no significant expansion of previous dieback areas or appearance of new dieback areas" (DEW, 2024b). However, there is also an expanded zone of stressed mangroves adjacent to the "dead zone" (Dittmann *et al*., 2022; Leyden *et al*., 2022). Mangroves subject to hypersalinity and low humidity also have reduced cold tolerance (Davaney *et al*., 2021), an additional seasonal factor that may cause further perturbation in this temperate habitat.

Mangroves died without signs of physical damage with wilting and loss of leaves and reproductive material (NC Duke).

Perturbation to mangrove habitat may occur through various abiotic and biotic mechanisms that operate conjointly or sequentially, resulting in complex stress scenarios that can lead to cumulative or continued vulnerability in affected mangrove forests (Fan *et al*., 2024). Consequently, the cause or causes of observed degradation may be obscured because of the complexity of interactions between natural processes and anthropogenic influences (Yando *et al*., 2021). For example, along the west Eyre coastline near Ceduna livestock have destabilised vegetated ridges resulting in the development of a 6 km^2 active dune area, with dunes up to 10 m high now migrating into neighbouring mangroves (Bourman *et al*., 2016).

The tanker 'Era' was holed by a tug during final stages of berthing in August 1992. Oil released from the tanker landed along 12-15 km of coastal mangroves to the southwest of Port Pirie in Spencer Gulf. Of the 75-100 ha of oiled mangrove habitat, around 2.3 ha died within a few months (Duke *et al*., 1998c). Subsequent surveys found that both the short- and long-term effects of oil was greatest in areas of lowest water exchange, being those areas along the margins of sheltered tidal creeks and away from areas influenced by wave wash at seaward margins. Leaf loss and plant death were recorded for both seedlings, saplings and young trees, particularly in heavily oiled areas. However, in moderately and lightly oiled areas, leaf loss was sometimes followed by leaf flushing and recovery of saplings and trees. A study of fish assemblages 3-6 months after the spill showed juvenile fishes were significantly smaller in oil affected creeks than in unoiled creeks. Using aerial imagery, Connolly *et al*. (2020) found that very little recovery occurred within 10 to 25 years after the oil spill.

Mangroves near the smelter in Port Pirie are also exposed to some of the highest heavy metal concentrations recorded in marine sediments, but despite accumulation in leaves and pneumatophores, mangrove health did not appear affected (Kastury *et al*., 2023). Effects of the heavy metal contamination on other biota in these mangroves is unknown.

Mangroves around Port Pirie in Spencer Gulf were affected by a large oil spill in 1992 (Chris Harty).

Mangroves of the Southwest Australian Shelf may be vulnerable to ecosystem degradation. Their total area is fragmented and dispersed over a long coastline, some with substantial distances between them. Significant mangrove habitat is concentrated in and around South Australia's gulfs and estuaries. These estuaries are generally urbanised and may host port and industrial facilities. Urban and industrial development can lead to loss of habitat and habitat change.

Habitat loss or change within mangroves or their adjacent terrestrial or marine ecosystems results in altered ecosystem function that may lessen ecosystem resilience and robustness. Williams (2020) study, described in the "mangrove fauna" section, illustrated that *Avicennia marina* makes use of an extensive adjacent terrestrial pollinator network. However, these results were not reflected in a separate study in which Hermansen *et al.* (2014b) concluded that, although 38 insect species were observed to visit *Avicennia marina* flowers in two estuaries in central (Georges River) and southern (Minnamurra River) New South Wales, *Apis mellifera* was the dominant pollinator of *Avicennia marina* at both locations.

The observed differences in the effectiveness and composition of the native pollinator networks may reflect differences in study design, an issue Hermansen *et al.* (2014b) discussed with respect to other, earlier studies. However, Williams (2020) study area (Manning River estuary) was adjacent to a significant area of native vegetation, while the Hermansen *et al*. (2014a, b) study areas were surrounded by highly urbanised (Georges River) or mixed urban and agricultural landscapes (Minnamurra River). Altered landscapes and habitat fragmentation adversely affect native pollinators (Potts *et al*., 2010, Chatterjee *et al*., 2025) and may explain the discrepancy in pollinator network diversity between the two studies. Also, the impact of *Apis mellifera* may not be a factor as its status as a competitor to Australian native pollinators is uncertain (Prendergast, *et al*., 2023).

Chatterjee *et al*. (2025) observed that, in tropical mangroves, insect abundance was directly associated with floral abundance, while Hermansen *et al*. (2014a) showed that the smaller temperate *Avicennia marina* stands attracted fewer *Apis mellifera* visits compared to large stands. Also, *Apis mellifera* is an inefficient pollinator in other habitats, an aspect not fully compensated for by its higher visitor rate to flowers with respect to native pollinators, and which results in slightly lower seed set (Page and Williams, 2022). The smaller *Avicennia marina* stands also experienced higher rates of same plant pollen deposition (geitonogamy) resulting in reduced cross-pollination (Hermansen *et al*., 2014a).

Although land use change and habitat fragmentation reduces pollinator numbers and the composition of pollinator networks the impacts on *Avicennia marina* communities may not be immediately obvious. *Avicennia marina* has protandrous flowers that should promote outcrossing but experience some geitonogamy because of the sequencing and synchrony of flowering and pollinator behaviour. This results in higher rates of maternal abortions of fruit due to inbreeding depression in those flowers (Clarke and Myerscough, 1991). Yet geitonogamy may also support some level of fruit set in isolated colonising plants (Primack *et al*., 1981) that supports local reproduction and promotes growth of frontier populations around new colonisers (Nathan and Gruner, 2023).

The impact of reduced pollen transfer within or between *Avicennia marina* communities due to decreased pollinator effectiveness may be counteracted by propagule dispersal away from the parent community (Aluri, *et al*., 2012). However, gene flow between mangrove communities can also be impeded along coastlines where there are strong barriers to propagule dispersion (Binks, *et al*., 2018), a situation present along much of the SWAS coastline west of Spencer Gulf. In this region, clonal growth, arising from the process of ground layering when branches are in contact with the sediment surface, is proposed to maintain populations of *A.marina* (Semeniuk 1994). This characteristic has been observed also in *A.marina* in northern NSW and southern Queensland, and more broadly in sprawling *Rhizophora* thickets in tropic areas.

Definition of the collapsed state of the ecosystem

Ecosystem collapse is recognized when the tree cover of mangrove species dwindles to zero, indicating complete loss of cover (100%). Collapsed mangrove ecosystems may transition to open water, unvegetated salt flats or mudflats or to saltmarsh. Collapsed mangrove ecosystems have abiotic characteristics that exceed tolerances of mangroves. For example, the duration of inundation may be too long or salinity too high to support mangrove growth. Indicators of collapse may include loss of mangrove canopy cover, increases in the area of open water and bare soil, increasing patchiness, or loss of soil surface elevation. However, mangroves can exhibit remarkable dynamism, with species distributions adapting to local shifts in sediment distribution, tidal patterns, and variations in local inundation and salinity gradients. Disruptive processes can trigger shifts in this dynamism, potentially leading to ecosystem collapse (Duke 2001; Duke *et al*., 2021.

The reduction or total loss of mangrove trees will result in the loss of ecosystem services they provide. This results in enhanced shoreline erosion and coastal sedimentation, loss of habitat and food provision. Neighbouring terrestrial, coastal and offshore ecosystems may be impacted by the loss of protective and trophic services provided by mangroves.

Ecosystem collapse would be manifest through the following mechanisms (e.g., Duke *et al*., 2021; 2022; 2024): a) restricted recruitment and survival of mangroves due to adverse climatic conditions (e.g., low temperatures); b) alterations in rainfall, river inputs, waves, and tidal currents that destabilize and erode substrates or smother pneumatophores causing mangrove death and hindering recruitment and growth; c) shifts in rainfall patterns and tidal flushing altering salinity stress and nutrient loadings, impacting overall survival; d) impacts of decadal climate patterns such as the interannual variability in sea level associated with El Niño-Southern Oscillation (ENSO) cycle; e) catastrophic events such as cyclones, severe flooding or tsunami wave.

Threat Classification

IUCN Threat Classification (version 3.3, IUCN-CMP 2022) relevant to mangroves of the South-west Australian shelf province:

1. Residential & commercial development

- 1.1 Housing & urban areas
- 1.2 Commercial & industrial areas
- 1.3 Tourism & recreation areas

2. Agriculture & aquaculture

- 2.3 Livestock farming & ranching
    - 2.3.2 Small-holder grazing, ranching or farming
    - 2.3.3 Agro-industry grazing, ranching or farming
    - 2.3.4 Scale Unknown/Unrecorded
- 2.4 Marine & freshwater aquaculture
    - 2.4.1 Subsistence/artisanal aquaculture
    - 2.4.2 Industrial aquaculture

    - 2.4.3 Scale Unknown/Unrecorded

3. Energy production & mining

- 3.1 Oil & gas drilling
- 3.2 Mining & quarrying
- 3.3 Renewable energy

4. Transportation & service corridors

- 4.1 Roads & railroads
- 4.2 Utility & service lines
- 4.3 Shipping lanes
- 4.4 Flight paths

5. Biological resource use

- 5.1 Hunting & collecting terrestrial animals
    - 5.1.1 Intentional use (species being assessed is the target)
    - 5.1.2 Unintentional effects (species being assessed is not the target)
    - 5.1.3 Persecution/control
    - 5.1.4 Motivation Unknown/Unrecorded
- 5.2 Gathering terrestrial plants
    - 5.2.1 Intentional use (species being assessed is the target)
    - 5.2.2 Unintentional effects (species being assessed is not the target)
    - 5.2.3 Persecution/control
    - 5.2.4 Motivation Unknown/Unrecorded
- 5.4 Fishing & harvesting aquatic resources
    - 5.4.1 Intentional use: subsistence/small scale (species being assessed is the target) [harvest]
    - 5.4.2 Intentional use: large scale (species being assessed is the target) [harvest]
    - 5.4.3 Unintentional effects: subsistence/small scale (species being assessed is not the target) [harvest]
    - 5.4.4 Unintentional effects: large scale (species being assessed is not the target) [harvest]
    - 5.4.5 Persecution/control
    - 5.4.6 Motivation Unknown/Unrecorded

6. Human intrusions & disturbance

- 6.1 Recreational activities
- 6.2 War, civil unrest & military exercises
- 6.3 Work & other activities

7. Natural system modifications

- 7.1 Fire & fire suppression
    - 7.1.1 Increase in fire frequency/intensity

- 7.1.2 Suppression in fire frequency/intensity
- 7.1.3 Trend Unknown/Unrecorded

- 7.2 Dams & water management/use
  - 7.2.1 Abstraction of surface water (domestic use)
  - 7.2.2 Abstraction of surface water (commercial use)
  - 7.2.3 Abstraction of surface water (agricultural use)
  - 7.2.4 Abstraction of surface water (unknown use)
  - 7.2.5 Abstraction of ground water (domestic use)
  - 7.2.6 Abstraction of ground water (commercial use)
  - 7.2.7 Abstraction of ground water (agricultural use)
  - 7.2.8 Abstraction of ground water (unknown use)
  - 7.2.9 Small dams
  - 7.2.10 Large dams
  - 7.2.11 Dams (size unknown)
- 7.3 Other ecosystem modifications

8. Invasive & other problematic species, genes & diseases

- 8.1 Invasive non-native/alien species/diseases
  - 8.1.1 Unspecified species
  - 8.1.2 Named species
- 8.2 Problematic native species/diseases
  - 8.2.1 Unspecified species
  - 8.2.2 Named species
- 8.3 Introduced genetic material
- 8.4 Problematic species/diseases of unknown origin
  - 8.4.1 Unspecified species
  - 8.4.2 Named species
- 8.5 Viral/prion-induced diseases
  - 8.5.1 Unspecified "species" (disease)
  - 8.5.2 Named "species" (disease)
- 8.6 Diseases of unknown cause

9. Pollution

- 9.1 Domestic & urban waste water
  - 9.1.1 Sewage
  - 9.1.2 Run-off
  - 9.1.3 Type Unknown/Unrecorded
- 9.2 Industrial & military effluents
  - 9.2.1 Oil spills

        - 9.2.2 Seepage from mining
        - 9.2.3 Type Unknown/Unrecorded
    - 9.3 Agricultural & forestry effluents
        - 9.3.1 Nutrient loads
        - 9.3.2 Soil erosion, sedimentation
        - 9.3.3 Herbicides & pesticides
        - 9.3.4 Type Unknown/Unrecorded
    - 9.4 Garbage & solid waste
    - 9.5 Air-borne pollutants
        - 9.5.1 Acid rain
        - 9.5.2 Smog
        - 9.5.3 Ozone
        - 9.5.4 Type Unknown/Unrecorded
    - 9.6 Excess energy
        - 9.6.1 Light pollution
        - 9.6.2 Thermal pollution
        - 9.6.3 Noise pollution
        - 9.6.4 Type Unknown/Unrecorded

10. Geological events

- 10.2 Earthquakes/tsunamis
- 10.3 Avalanches/landslides

11. Climate change & severe weather

- 11.1 Habitat shifting & alteration
- 11.2 Droughts
- 11.3 Temperature extremes
- 11.4 Storms & flooding
- 11.5 Other impacts

12. Other options

- 12.1 Other threat

4. Ecosystem Assessment

Criterion A: Reduction in Geographic Distribution

Subcriterion A1 measures the trend in ecosystem extent during the last 50-year time window. Unfortunately, there is currently no common regional dataset that provides information for the entire target area in 1970. However, country-level estimates of mangrove extent can be used to extrapolate the trend between 1970 and 2020. Accordingly, we compiled reliable published sources (see appendix 3) that contain information on mangrove area estimates close to 1970 (both before and after) for each country within the province. These estimates were then used to interpolate the mangrove area in 1970 in each country. By summing up these estimates, we calculated the total mangrove area in the province. We only considered the percentage of each country's total mangrove area located within the province and the estimated values for 1970 should be considered only indicative (see appendix 3 for further details of the methods and limitations).

In contrast, to estimate the South-west Australian shelf mangrove area from 1996 to 2020, we used the most recent version of the Global Mangrove Watch (GMW v3.0) spatial dataset. The mangrove area in the province (and in the corresponding countries) was corrected for both omission and commission errors, utilising the equations in Bunting *et al.* (2022).

Results from the analysis of subcriterion A1 (Annex 3) show that the South-west Australian shelf mangrove province lost approximately 5.2% of its mangrove area over the last 50 years (1970-2020). Given that the change in geographic distribution is < 30%, the ecosystem is assessed as **Least Concern (LC)** under subcriterion A1.

Mangroves of the South-west Australian shelf	Area 2020* (Km^2)	Area 1970* (Km^2)	Net area Change (Km^2)	% Net Area Change	Rate of change (%/year)
	198.8	209.8	10.9	-5.2	0.001

** Details on the methods and references used to estimate the mangrove area in 1970 are listed in appendix 3.*

Total mangrove area in 2020 is based on the Global Mangrove Watch Version 3 (GMW v3.0) dataset.

Subcriterion A2 measures the change in ecosystem extent in any 50-year period, including from the present to the future. Data was not available for the period 1970 to 1995. Therefore, based on available data from the Global Mangrove Watch time series (Bunting *et al*., 2022), the South-west Australian shelf province mangroves show a net area change of -2.3% (2007-2020). This value reflects the offset between average areas gained (+0.4%/year) and lost (-1.0%/year) for that period. The 1996 area was considered an outlier (Professor Sabine Dittmann, pers comm) and was not included in this calculation. The available data from within this period was used to estimate the areas for both 1970 and 2070 by linear regression. Based on this analysis, it is estimated that a further 6.8 km^2 of mangrove habitat may be lost between 2020 and 2070, representing a net % change of -3.4%. Therefore, the prospective change in geographic distribution over the period 2020 to 2070 is < 30% and the ecosystem is assessed as **Least Concern** (**LC**) under subcriterion A2.

Subcriterion A3 measures changes in mangrove area since 1750. Based on data derived from Australia's pre-1750 vegetation model (DCCEEW, 2021), the province gained 37.7 km2 between 1750 and 2020, which is a gain of 23% of the original mangrove extent. Therefore, the East Central and Southeast Australian Shelf mangrove ecosystem is assessed as **Least Concern** (**LC**) under subcriterion A3.

Overall, the ecosystem is assessed as **Least Concern** (**LC**) under subcriterion A.

Rate of change: 0.2 % / Year R^2=0.3

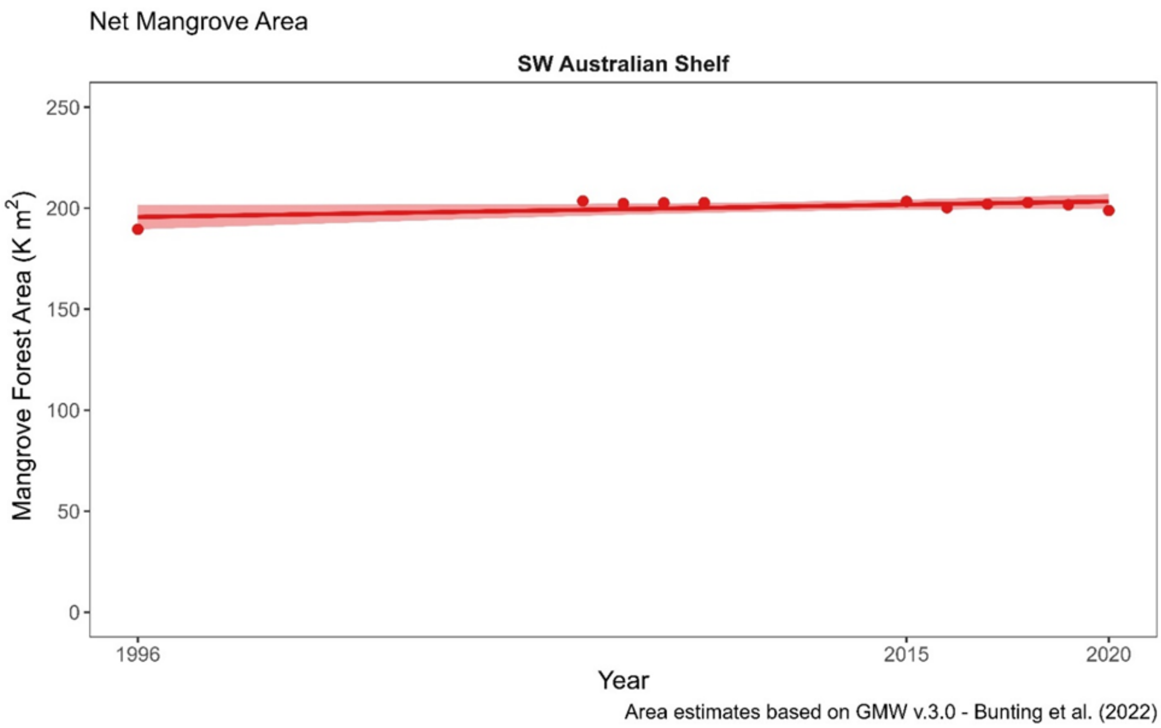


Figure 4 South-west Australian shelf mangrove ecosystem between 1996 and 2020. Circles represent annual mangrove extent based on the GMW v3.0 dataset and equations in Bunting *et al*., (2022). The solid line shows a linear regression, with the shaded area representing the 95% confidence interval.

Criterion B: Restricted Geographic Distribution

Criterion B measures the risk of ecosystem collapse associated with restricted geographical distribution, based on standard metrics (Extent of Occurrence EOO, Area of Occupancy AOO, and Threat-defined locations). These parameters were calculated based on the 2020 South-west Australian shelf province mangrove extent (GMW v.3).

Province	Extent of Occurrence EOO (Km^2)	Area of Occupancy (AOO > 1%)	Criterion B
The South-west Australian shelf	501046.1	54	**LC**

For 2020, AOO and EOO were measured as 96 grid cells 10 x 10 km and 501046.1 km^2, respectively (Figure 5). Excluding from the AOO those grid cells that contain patches of mangrove forest that account for less than 1% of the grid cell area, (< 1 km^2), the AOO is measured as 54, 10 x 10 km grid cells (Figure 5, red grids).

Considering the very high number of threat-defined-locations, there is no evidence of plausible catastrophic threats leading to potential disappearance of mangroves across their extent. As a result, the South-west Australian shelf mangrove ecosystem is assessed as **Least Concern** (**LC**) under criterion B.

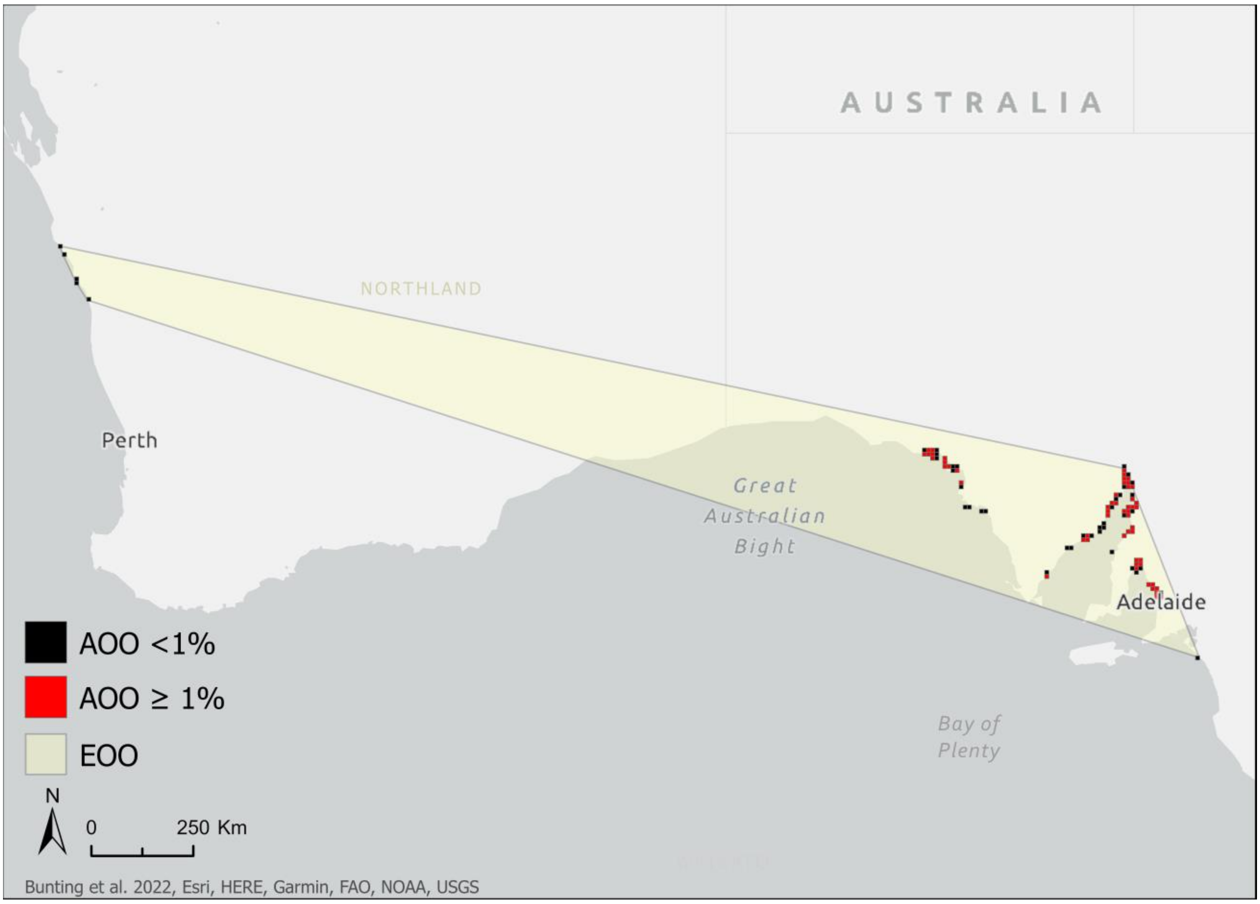


Figure 5. The South-west Australian shelf mangrove Extent Of Occurrence (EOO) and Area Of Occupancy (AOO) in 2020. Estimates based on 2020 GMW v3.0 spatial layer (Bunting *et al.*, 2022). The red 10 x 10 km grids (n=54.) are more than 1% covered by the ecosystem, and the black grids <1% (n= 42). Note: No spatial data was available for a small isolated mangrove stand in Leschenault Inlet near Bunbury (< 1km^2), which was excluded from this analysis (Fig. 1).

Criterion C: Environmental Degradation

Criterion C measures the environmental degradation of abiotic variables necessary to support the ecosystem.

Subcriterion C1 measures environmental degradation over the past 50 years: There are no reliable data to evaluate this subcriterion for the entire province, and therefore the South-west Australian shelf mangrove ecosystem is classified as **Data Deficient** (**DD**) for subcriterion C1.

Subcriterion C2 measures environmental degradation in the future, or over any 50-year period, including from the present. In this context, the impact of future sea level rise (SLR) on mangrove ecosystems was assessed by adopting the methodology presented by Schuerch *et al.* (2018). The published model was designed to calculate both absolute and relative change in the extent of wetland ecosystems under various regional SLR scenarios (i.e medium: RCP 4.5 and high: RCP 8.5), with consideration for sediment accretion. Therefore, Schuerch *et al.* (2018) model was applied to the South-west Australian shelf mangrove ecosystem boundary, using the spatial extent in 2010 (Giri *et al*., 2011). For this assessment, we selected the "no landward migration" option within the model to reflect a conservative estimate, assuming that mangroves cannot expand inland due to topographic or anthropogenic constraints. While this represents a worst-case scenario, landward migration may be possible in some areas, and results should therefore be interpreted with appropriate caution and acknowledgment of this uncertainty.According to the results, under an extreme sea-level rise scenario of a 1.1-meter rise by 2100, the projected submerged area is ~ -12.0% by 2060, which remains below the 30% risk threshold. Therefore, considering that no mangrove recruitment can occur in a submerged system (100% relative severity), but that -12.0% of the ecosystem extent will be affected by SLR, the South-west Australian shelf mangrove ecosystem is assessed as **Least Concern** (**LC**) for subcriterion C2.

Subcriterion C3 measures change in abiotic variables since 1750. There is a lack of reliable historic data on environmental degradation covering the entire province, and therefore the South-west Australian shelf province is classified as **Data Deficient** (**DD**) for this subcriterion.

Overall, the ecosystem is assessed as **Least Concern** (**LC**) under criterion C.

Criterion D: Disruption of biotic processes or interactions

The global mangrove degradation map developed by Worthington and Spalding (2018) was used to assess the level of biotic degradation in the South-west Australian shelf province. This map is based on degradation metrics calculated from vegetation indices (NDVI, EVI, SAVI, NDMI) using Landsat time series (≈2000 and 2017). These indices represent vegetation greenness and moisture condition.

Mangrove degradation was calculated at a pixel scale (30m resolution), on areas intersecting with the 2017 mangrove extent map (GMW v2). Mangrove pixels were classified as degraded if two conditions were met: 1) at least 10 out of 12 degradation indices showed a decrease of more than 40% compared to the previous period; and 2) all twelve indices did not recover to within 20% of their pre-2000 value (detailed methods and data are available at: https://maps.oceanwealth.org/mangrove-restoration/). The decline in vegetation indices has been used to identify mangrove degradation and abrupt changes, including mangrove die-back events, clear-cutting, fire damage, and logging; as well as to track mangrove regeneration (Lovelock *et al.,* 2017; Santana, 2019; Murray *et al.,* 2020; Aljahdali *et al.,* 2021; Lee *et al.,* 2021). However, it is important to consider that changes observed in the vegetation indices can also be influenced by data artifacts (Akbar *et al.,* 2020). Therefore, a relative severity level of more than 50%, but less than 80%, was assumed.

The results from this analysis show that over a period of 17 years (~2000 to 2017), 0.3% of the South-west Australian shelf mangrove area is classified as degraded, resulting in an average annual rate of degradation of 0.02%. Assuming this trend remains constant, +0.9% of the South-west Australian shelf mangrove area will be classified as degraded over a 50-year period. Since less than 30% of the ecosystem will meet the category thresholds for criterion D, the South-west Australian shelf mangrove province is assessed as Least Concern (LC) under subcriterion D2b.

Several sources document local to regional biotic degradation of mangroves in the South-West Australian shelf, including historical nutrient pollution from the Bolivar sewage treatment plant (Edyvane, 1999; MPSWG, 2011), eutrophication-induced dieback (Overton, 1993), and more recent hypersaline contamination from the Dry Creek Salt Fields (Dittmann *et al*., 2022; Leyden *et al*., 2022). However, quantitative spatial and temporal data to assess the severity and extent of biotic disruption over the past 50 years (Subcriterion D2) or since 1750 (subcriterion D3) are limited. Thus, both subcriteria are classified as Data Deficient (DD,) despite the presence of reported degradation events. Overall, the South-west Australian shelf ecosystem remains **Least Concern (LC)** under criterion D.

Criterion E: Quantitative Risk

No model was used to quantitatively assess the risk of ecosystem collapse for this ecosystem; hence criterion E was **Not Evaluated (NE)**.

5. Summary of the Assessment

CRITERION			
A. Reduction in Geographic Distribution	**A1** Past 50 years	**A2** Future or any 50y period	**A3** Historical (1750)
	LC	LC	LC
B. Restricted Geo. Distribution	**B1** Extent of Occurrence	**B2** Area of Occupancy	**B3** # Threat-defined Locations > 5
	LC	LC	LC
C. Environmental Degradation	**C1** Past 50 years (1970)	**C2** Future or any 50y period	**C3** Historical (1750)
	DD	LC	DD
D. Disruption of biotic processes	**D1** Past 50 years (1970)	**D2** Future or Any 50y period	**D3** Historical (1750)
	DD	LC	DD
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	LC		

DD = Data Deficient; LC = Least Concern; NE = Not Evaluated

Overall, the status of the South-west Australian shelf mangrove ecosystem is assessed as **Least Concern (LC).**

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The term “true mangrove” is considered misleading, erroneous and redundant, as determined during the recent IUCN Mangrove Specialist Group Red List Workshop in Abu Dhabi (April 2025). As such, we have not used the unnecessary descriptor in this publication.

7. Appendices

1. List of Key Mangrove Species

List of plant species considered mangroves according to Red List of Threatened Species (RLTS) spatial data (IUCN, 2022). We included species whose range maps intersected with the boundary of the marine provinces/ecoregions described in the distribution section.

Class	Order	Family	Scientific name	RLTS category
Magnoliopsida	Lamiales	Acanthaceae	*Avicennia marina*	LC

2. List of Associated Species

List of taxa that are associated with mangrove habitats in the Red List of Threatened Species (RLTS) database (IUCN, 2022). We included only species with entries for Habitat 1.7: "Forest - Subtropical/Tropical Mangrove Vegetation Above High Tide Level" or Habitat 12.7 for "Marine Intertidal - Mangrove Submerged Roots", and with suitability recorded as "Suitable", with "Major Importance" recorded as "Yes", and any value of seasonality except "Passage". We further filtered species with spatial point records in the GBIF (some species are excluded due to mismatch in taxonomic names, or lack of georeferenced records). The common names are those shown in the RLTS, except common names in brackets, which are from other sources.

Class	Order	Family	Scientific name	RLTS category	Common name
Magnoliopsida	Lamiales	Acanthaceae	*Avicennia marina*	LC	Grey Mangrove
Magnoliopsida	Malvales	Malvaceae	*Lagunaria patersonia*	NT	Norfolk Island Hibiscus
Magnoliopsida	Lamiales	Scrophulariaceae	*Myoporum montanum*	LC	Western Boobialla
Gastropoda	Ellobiida	Ellobiidae	*Cassidula aurisfelis*	LC	Cat's Ear Cassidula
Gastropoda	Ellobiida	Ellobiidae	*Laemodonta striata*	LC	NA
Gastropoda	Littorinimorpha	Tateidae	*Ascorhis occidua*	LC	NA
Gastropoda	Littorinimorpha	Tateidae	*Ascorhis tasmanica*	LC	NA
Gastropoda	Pylopulmonata	Amphibolidae	*Salinator solida*	LC	NA
Gastropoda	Sorbeoconcha	Thiaridae	*Sermyla riqueti*	LC	NA

Class	Order	Family	Scientific name	RLTS category	Common name
Chondrichthyes	Carcharhiniformes	Carcharhinidae	*Negaprion acutidens*	EN	Sharptooth Lemon Shark
Chondrichthyes	Rhinopristiformes	Pristidae	*Pristis zijsron*	CR	Green Sawfish
Actinopterygii	Aulopiformes	Synodontidae	*Synodus sageneus*	LC	Speartoothed Grinner
Actinopterygii	Beloniformes	Zenarchopteridae	*Zenarchopterus dispar*	LC	Feathered River-garfish
Actinopterygii	Beloniformes	Zenarchopteridae	*Zenarchopterus gilli*	LC	Shortnose River Garfish
Actinopterygii	Gobiiformes	Gobiidae	*Asterropteryx semipunctata*	LC	NA
Actinopterygii	Gobiiformes	Gobiidae	*Parachaeturichthys polynema*	LC	Lancet-tail Goby
Actinopterygii	Mugiliformes	Mugilidae	*Planiliza subviridis*	LC	Greenback Mullet
Actinopterygii	Perciformes	Apogonidae	*Fowleria variegata*	LC	Variegated Cardinalfish
Actinopterygii	Perciformes	Caesionidae	*Caesio cuning*	LC	Redbelly yellowtail fusilier
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus coioides*	LC	Orange-spotted Grouper
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus malabaricus*	LC	NA
Actinopterygii	Perciformes	Haemulidae	*Diagramma labiosum*	LC	Painted Sweetlips
Actinopterygii	Perciformes	Haemulidae	*Plectorhinchus gibbosus*	LC	Brown Sweetlips
Actinopterygii	Perciformes	Lethrinidae	*Lethrinus nebulosus*	LC	Spangled Emperor
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus fulviflamma*	LC	Dory Snapper
Actinopterygii	Perciformes	Microdesmidae	*Parioglossus formosus*	LC	NA
Actinopterygii	Perciformes	Pomacentridae	*Dascyllus trimaculatus*	LC	Threespot Damselfish
Actinopterygii	Perciformes	Pomacentridae	*Neopomacentrus azysron*	LC	Yellowtail Damsel
Actinopterygii	Perciformes	Sparidae	*Acanthopagrus morrisoni*	LC	Western Yellowfin Bream
Actinopterygii	Perciformes	Toxotidae	*Toxotes jaculatrix*	LC	Banded Archerfish
Actinopterygii	Pleuronectiformes	Cynoglossidae	*Cynoglossus puncticeps*	LC	NA
Actinopterygii	Pleuronectiformes	Paralichthyidae	*Pseudorhombus arsius*	LC	Largetooth Flounder
Actinopterygii	Pleuronectiformes	Rhombosoleidae	*Ammotretis rostratus*	DD	Longsnout Flounder
Actinopterygii	Pleuronectiformes	Soleidae	*Brachirus aspilos*	LC	Dusky Sole

Class	Order	Family	Scientific name	RLTS category	Common name
Actinopterygii	Syngnathiformes	Syngnathidae	*Kaupus costatus*	LC	Deep-bodied pipefish
Actinopterygii	Tetraodontiformes	Monacanthidae	*Colurodontis paxmani*	DD	Paxman's Leatherjacket
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Arothron stellatus*	LC	Stellate Puffer
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Contusus brevicaudus*	LC	Prickly Toadfish
Aves	Accipitriformes	Accipitridae	*Accipiter hiogaster*	LC	Variable Goshawk
Aves	Accipitriformes	Accipitridae	*Accipiter melanochlamys*	LC	Black-mantled Goshawk
Aves	Accipitriformes	Accipitridae	*Accipiter novaehollandiae*	LC	Grey Goshawk
Aves	Accipitriformes	Accipitridae	*Megatriorchis doriae*	NT	Doria's Goshawk
Aves	Caprimulgiformes	Caprimulgidae	*Eurostopodus papuensis*	LC	Papuan Nightjar
Aves	Charadriiformes	Charadriidae	*Charadrius mongolus*	LC	Lesser Sandplover
Aves	Charadriiformes	Charadriidae	*Pluvialis fulva*	LC	Pacific Golden Plover
Aves	Charadriiformes	Scolopacidae	*Actitis hypoleucos*	LC	Common Sandpiper
Aves	Charadriiformes	Scolopacidae	*Xenus cinereus*	LC	Terek Sandpiper
Aves	Ciconiiformes	Ciconiidae	*Ephippiorhynchus asiaticus*	NT	Black-necked Stork
Aves	Columbiformes	Columbidae	*Ducula bicolor*	LC	Pied Imperial-pigeon
Aves	Columbiformes	Columbidae	*Goura cristata*	VU	Western Crowned-pigeon
Aves	Coraciiformes	Alcedinidae	*Ceyx pusillus*	LC	Little Kingfisher
Aves	Coraciiformes	Alcedinidae	*Dacelo gaudichaud*	LC	Rufous-bellied Kookaburra
Aves	Coraciiformes	Alcedinidae	*Syma torotoro*	LC	Yellow-billed Kingfisher
Aves	Coraciiformes	Alcedinidae	*Todiramphus chloris*	LC	Collared Kingfisher
Aves	Coraciiformes	Alcedinidae	*Todiramphus macleayii*	LC	Forest Kingfisher
Aves	Coraciiformes	Alcedinidae	*Todiramphus sanctus*	LC	Sacred Kingfisher
Aves	Falconiformes	Falconidae	*Falco severus*	LC	Oriental Hobby
Aves	Gruiformes	Rallidae	*Megacrex inepta*	LC	New Guinea Flightless Rail
Aves	Passeriformes	Acanthizidae	*Acanthiza iredalei*	LC	Slender-billed Thornbill
Aves	Passeriformes	Acanthizidae	*Acanthiza lineata*	LC	Striated Thornbill

Class	Order	Family	Scientific name	RLTS category	Common name
Aves	Passeriformes	Acanthizidae	*Gerygone chloronota*	LC	Green-backed Gerygone
Aves	Passeriformes	Acanthizidae	*Gerygone levigaster*	LC	Mangrove Gerygone
Aves	Passeriformes	Acanthizidae	*Gerygone magnirostris*	LC	Large-billed Gerygone
Aves	Passeriformes	Acanthizidae	*Gerygone mouki*	LC	Brown Gerygone
Aves	Passeriformes	Acanthizidae	*Gerygone tenebrosa*	LC	Dusky Gerygone
Aves	Passeriformes	Artamidae	*Artamus cinereus*	LC	Black-faced Woodswallow
Aves	Passeriformes	Artamidae	*Artamus personatus*	LC	Masked Woodswallow
Aves	Passeriformes	Artamidae	*Melloria quoyi*	LC	Black Butcherbird
Aves	Passeriformes	Campephagidae	*Coracina boyeri*	LC	Boyer's Cuckooshrike
Aves	Passeriformes	Campephagidae	*Coracina novaehollandiae*	LC	Black-faced Cuckooshrike
Aves	Passeriformes	Campephagidae	*Coracina papuensis*	LC	White-bellied Cuckooshrike
Aves	Passeriformes	Campephagidae	*Edolisoma melas*	LC	New Guinea Cicadabird
Aves	Passeriformes	Campephagidae	*Edolisoma tenuirostre*	LC	Slender-billed Cicadabird
Aves	Passeriformes	Campephagidae	*Lalage atrovirens*	LC	Black-browed Triller
Aves	Passeriformes	Campephagidae	*Lalage leucomela*	LC	Varied Triller
Aves	Passeriformes	Corvidae	*Corvus fuscicapillus*	NT	Brown-headed Crow
Aves	Passeriformes	Dicruridae	*Dicrurus bracteatus*	LC	Spangled Drongo
Aves	Passeriformes	Locustellidae	*Poodytes gramineus*	LC	Little Grassbird
Aves	Passeriformes	Maluridae	*Malurus amabilis*	LC	Lovely Fairy-wren
Aves	Passeriformes	Meliphagidae	*Bolemoreus frenatus*	LC	Bridled Honeyeater
Aves	Passeriformes	Meliphagidae	*Cissomela pectoralis*	LC	Banded Honeyeater
Aves	Passeriformes	Meliphagidae	*Conopophila albogularis*	LC	Rufous-banded Honeyeater
Aves	Passeriformes	Meliphagidae	*Conopophila rufogularis*	LC	Rufous-throated Honeyeater

Class	Order	Family	Scientific name	RLTS category	Common name
Aves	Passeriformes	Meliphagidae	*Entomyzon albipennis*	LC	White-quilled Honeyeater
Aves	Passeriformes	Meliphagidae	*Entomyzon cyanotis*	LC	Blue-faced Honeyeater
Aves	Passeriformes	Meliphagidae	*Epthianura albifrons*	LC	White-fronted Chat
Aves	Passeriformes	Meliphagidae	*Gavicalis fasciogularis*	LC	Mangrove Honeyeater
Aves	Passeriformes	Meliphagidae	*Gavicalis versicolor*	LC	Varied Honeyeater
Aves	Passeriformes	Meliphagidae	*Gavicalis virescens*	LC	Singing Honeyeater
Aves	Passeriformes	Meliphagidae	*Lichenostomus melanops*	LC	Yellow-tufted Honeyeater
Aves	Passeriformes	Meliphagidae	*Lichmera alboauricularis*	LC	Silver-eared Honeyeater
Aves	Passeriformes	Meliphagidae	*Lichmera indistincta*	LC	Brown Honeyeater
Aves	Passeriformes	Meliphagidae	*Meliphaga notata*	LC	Yellow-spotted Honeyeater
Aves	Passeriformes	Meliphagidae	*Melithreptus albogularis*	LC	White-throated Honeyeater
Aves	Passeriformes	Meliphagidae	*Microptilotis analogus*	LC	Mimic Honeyeater
Aves	Passeriformes	Meliphagidae	*Microptilotis cinereifrons*	LC	Elegant Honeyeater
Aves	Passeriformes	Meliphagidae	*Microptilotis gracilis*	LC	Graceful Honeyeater
Aves	Passeriformes	Meliphagidae	*Myzomela erythrocephala*	LC	Red-headed Myzomela
Aves	Passeriformes	Meliphagidae	*Myzomela obscura*	LC	Dusky Myzomela
Aves	Passeriformes	Meliphagidae	*Myzomela sanguinolenta*	LC	Scarlet Myzomela
Aves	Passeriformes	Meliphagidae	*Philemon argenticeps*	LC	Silver-crowned Friarbird
Aves	Passeriformes	Meliphagidae	*Philemon buceroides*	LC	Helmeted Friarbird
Aves	Passeriformes	Meliphagidae	*Philemon citreogularis*	LC	Little Friarbird
Aves	Passeriformes	Meliphagidae	*Philemon corniculatus*	LC	Noisy Friarbird
Aves	Passeriformes	Meliphagidae	*Plectorhyncha lanceolata*	LC	Striped Honeyeater
Aves	Passeriformes	Meliphagidae	*Ptilotula flavescens*	LC	Yellow-tinted Honeyeater

Class	Order	Family	Scientific name	RLTS category	Common name
Aves	Passeriformes	Meliphagidae	*Ramsayornis fasciatus*	LC	Bar-breasted Honeyeater
Aves	Passeriformes	Meliphagidae	*Ramsayornis modestus*	LC	Brown-backed Honeyeater
Aves	Passeriformes	Meliphagidae	*Stomiopera flava*	LC	Yellow Honeyeater
Aves	Passeriformes	Meliphagidae	*Stomiopera unicolor*	LC	White-gaped Honeyeater
Aves	Passeriformes	Meliphagidae	*Trichodere cockerelli*	LC	White-streaked Honeyeater
Aves	Passeriformes	Meliphagidae	*Xanthotis flaviventer*	LC	Tawny-breasted Honeyeater
Aves	Passeriformes	Meliphagidae	*Xanthotis macleayanus*	LC	Macleay's Honeyeater
Aves	Passeriformes	Monarchidae	*Carterornis leucotis*	LC	White-eared Monarch
Aves	Passeriformes	Monarchidae	*Monarcha frater*	LC	Black-winged Monarch
Aves	Passeriformes	Monarchidae	*Monarcha melanopsis*	LC	Black-faced Monarch
Aves	Passeriformes	Monarchidae	*Myiagra alecto*	LC	Shining Flycatcher
Aves	Passeriformes	Monarchidae	*Myiagra rubecula*	LC	Leaden Flycatcher
Aves	Passeriformes	Monarchidae	*Myiagra ruficollis*	LC	Broad-billed Flycatcher
Aves	Passeriformes	Monarchidae	*Symposiachrus trivirgatus*	LC	Spectacled Monarch
Aves	Passeriformes	Oriolidae	*Oriolus flavocinctus*	LC	Green Oriole
Aves	Passeriformes	Oriolidae	*Oriolus szalayi*	LC	Brown Oriole
Aves	Passeriformes	Oriolidae	*Pitohui dichrous*	LC	Hooded Pitohui
Aves	Passeriformes	Oriolidae	*Sphecotheres vieilloti*	LC	Australasian Figbird
Aves	Passeriformes	Pachycephalidae	*Colluricincla harmonica*	LC	Grey Shrike-thrush
Aves	Passeriformes	Pachycephalidae	*Colluricincla megarhyncha*	LC	Little Shrike-thrush
Aves	Passeriformes	Pachycephalidae	*Pachycephala griseiceps*	LC	Brown Whistler
Aves	Passeriformes	Pachycephalidae	*Pachycephala lanioides*	LC	White-breasted Whistler
Aves	Passeriformes	Pachycephalidae	*Pachycephala leucogastra*	LC	White-bellied Whistler
Aves	Passeriformes	Pachycephalidae	*Pachycephala melanura*	LC	Black-tailed Whistler
Aves	Passeriformes	Pachycephalidae	*Pachycephala pectoralis*	LC	Golden Whistler

Class	Order	Family	Scientific name	RLTS category	Common name
Aves	Passeriformes	Pachycephalidae	*Pachycephala phaionota*	LC	Island Whistler
Aves	Passeriformes	Pachycephalidae	*Pachycephala rufiventris*	LC	Rufous Whistler
Aves	Passeriformes	Pachycephalidae	*Pachycephala simplex*	LC	Grey Whistler
Aves	Passeriformes	Paradisaeidae	*Lophorina intercedens*	LC	Growling Riflebird
Aves	Passeriformes	Paradisaeidae	*Lophorina magnifica*	LC	Magnificent Riflebird
Aves	Passeriformes	Paradisaeidae	*Lophorina victoriae*	VU	Victoria's Riflebird
Aves	Passeriformes	Paradisaeidae	*Manucodia ater*	LC	Glossy-mantled Manucode
Aves	Passeriformes	Paradisaeidae	*Phonygammus keraudrenii*	LC	Trumpet Manucode
Aves	Passeriformes	Pardalotidae	*Pardalotus striatus*	LC	Striated Pardalote
Aves	Passeriformes	Petroicidae	*Microeca flavigaster*	LC	Lemon-bellied Flyrobin
Aves	Passeriformes	Petroicidae	*Microeca tormenti*	LC	Kimberley Flyrobin
Aves	Passeriformes	Petroicidae	*Peneoenanthe pulverulenta*	LC	Mangrove Robin
Aves	Passeriformes	Pittidae	*Pitta iris*	LC	Rainbow Pitta
Aves	Passeriformes	Pittidae	*Pitta novaeguineae*	LC	Eastern Hooded Pitta
Aves	Passeriformes	Pittidae	*Pitta versicolor*	LC	Noisy Pitta
Aves	Passeriformes	Ptilonorhynchidae	*Chlamydera cerviniventris*	LC	Fawn-breasted Bowerbird
Aves	Passeriformes	Ptilonorhynchidae	*Chlamydera nuchalis*	LC	Great Bowerbird
Aves	Passeriformes	Rhipiduridae	*Rhipidura dryas*	LC	Arafura Fantail
Aves	Passeriformes	Rhipiduridae	*Rhipidura phasiana*	LC	Mangrove Fantail
Aves	Passeriformes	Rhipiduridae	*Rhipidura rufifrons*	LC	Rufous Fantail
Aves	Passeriformes	Sturnidae	*Aplonis metallica*	LC	Metallic Starling
Aves	Passeriformes	Zosteropidae	*Zosterops citrinella*	LC	Ashy-bellied White-eye
Aves	Passeriformes	Zosteropidae	*Zosterops luteus*	LC	Australian Yellow White-eye
Aves	Pelecaniformes	Ardeidae	*Butorides striata*	LC	Green-backed Heron
Aves	Pelecaniformes	Ardeidae	*Egretta garzetta*	LC	Little Egret
Aves	Pelecaniformes	Ardeidae	*Egretta sacra*	LC	Pacific Reef-egret
Aves	Pelecaniformes	Ardeidae	*Ixobrychus sinensis*	LC	Yellow Bittern

Class	Order	Family	Scientific name	RLTS category	Common name
Aves	Pelecaniformes	Threskiornithidae	*Threskiornis moluccus*	LC	Australian Ibis
Aves	Psittaciformes	Psittacidae	*Eclectus polychloros*	LC	Papuan Eclectus
Aves	Psittaciformes	Psittacidae	*Psittaculirostris cervicalis*	LC	Red-faced Fig-parrot
Aves	Psittaciformes	Psittacidae	*Psittaculirostris godmani*	LC	Yellow-naped Fig-parrot
Aves	Struthioniformes	Casuariidae	*Casuarius casuarius*	LC	Southern Cassowary
Aves	Suliformes	Fregatidae	*Fregata ariel*	LC	Lesser Frigatebird
Aves	Suliformes	Fregatidae	*Fregata minor*	LC	Great Frigatebird
Aves	Suliformes	Phalacrocoracidae	*Microcarbo melanoleucos*	LC	Little Pied Cormorant
Aves	Suliformes	Phalacrocoracidae	*Phalacrocorax varius*	LC	Great Pied Cormorant
Reptilia	Squamata	Agamidae	*Lophognathus longirostris*	LC	Long-snouted Lashtail
Reptilia	Squamata	Homalopsidae	*Myron resetari*	VU	Roebuck Bay Mangrove Snake
Reptilia	Squamata	Scincidae	*Ctenotus robustus*	LC	Robust Ctenotus
Reptilia	Squamata	Scincidae	*Emoia atrocostata*	LC	Littoral Whiptail-skink
Reptilia	Squamata	Varanidae	*Varanus semiremex*	LC	Rusty Monitor
Mammalia	Chiroptera	Emballonuridae	*Taphozous australis*	NT	Coastal Sheath-tailed Bat
Mammalia	Chiroptera	Hipposideridae	*Aselliscus tricuspidatus*	LC	Trident Leaf-nosed Bat
Mammalia	Chiroptera	Hipposideridae	*Hipposideros ater*	LC	Dusky Leaf-nosed Bat
Mammalia	Chiroptera	Hipposideridae	*Hipposideros calcaratus*	LC	Spurred Leaf-nosed Bat
Mammalia	Chiroptera	Pteropodidae	*Macroglossus minimus*	LC	Dagger-toothed Long-nosed Fruit Bat
Mammalia	Chiroptera	Pteropodidae	*Nyctimene robinsoni*	LC	Eastern Tube-nosed Bat
Mammalia	Chiroptera	Pteropodidae	*Pteropus conspicillatus*	EN	Spectacled Flying Fox
Mammalia	Chiroptera	Pteropodidae	*Pteropus macrotis*	LC	Large-eared Flying Fox
Mammalia	Chiroptera	Pteropodidae	*Pteropus neohibernicus*	LC	Great Flying Fox
Mammalia	Chiroptera	Pteropodidae	*Pteropus poliocephalus*	VU	Grey-headed Flying Fox
Mammalia	Chiroptera	Pteropodidae	*Pteropus scapulatus*	LC	Little Red Flying Fox

Class	Order	Family	Scientific name	RLTS category	Common name
Mammalia	Chiroptera	Vespertilionidae	*Scotorepens sanborni*	LC	Northern Broad-nosed Bat
Mammalia	Rodentia	Muridae	*Xeromys myoides*	VU	Water Mouse

3. National Estimates for subcriterion A1

We were unable to estimate the East Central and Southeast Australian Shelf mangrove ecosystem extent in 1970, based on reliable information on the mangrove area for each state or territory within the province around this period. We estimated the mangrove area in 1970 for the entire province by linear regression of the known extents back to that time to determine the total mangrove area in the Southwest Australian Shelf province (Table a). We assumed that the percentage of Australia's mangrove extent within state or territory included in the province remained constant over time, as the percentages did not change between 2007 and 2020 (GMW v3.0 dataset, however the 1996 data was considered unreliable for this province). However, using mangrove area estimates from different sources can lead to uncertainty (Friess and Webb 2013) and there were no regional statistics or global studies available for this period. Thus, the estimates for 1970 should be considered only indicative.

Table a Estimated mangrove area within the Southwest Australia Shelf province in 1970 and 2020. The province is contained entirely within Australia's national border. Estimates for 2020* mangrove area are based on the Global Mangrove Watch Version 3 (GMW v3.0) dataset. The mangrove area for Australia in 1970 was estimated using linear regression of the Global Mangrove Watch Version 3 (GMW v3.0) dataset, backwards to 1970. There are no national or regional datasets available that account for the total mangrove extent within the East Central and Southeast Australia Shelf province in 1970, or about that time. The closest estimate was made in 1979 (Table b).**

	Australia Total (km^2)	Within Province (km2)	Australia Total (km^2)	Within Province (km^2)
Year	**2020**	**2020**	**1970**	**1970**
Australia and SWAS	10,185	198.8	10,289	209.8

Table b. List of selected studies considered to have reliable information on mangrove area for the period around 1970 in Australia.

Country	Year	Mangrove Area (Ha)	Reference
Australia	1979	1,161,700	Galloway, R.W. 1979. Distribution and patterns of Australian mangals. Presented at the Australian National Mangrove Workshop, 18-20 April 1979
For all countries.			FAO (2007). Status and trends in mangrove area extent worldwide. By Wilkie, M.L. and Fortuna, S. Forest Resources Assessment Working Paper No. 63. Forest Resources Division.

4. Abiotic Characteristics of selected estuarine and coastal lagoon habitats along the SWAS Coastline and further elaborates on the information provided in the section Abiotic Components of the Ecosystem (Table 1). The air and sea temperature values for Coffin Bay and Pelican Lagoon are close but do not exceed the upper and lower limits encountered by SWAS mangroves. Corner Inlet (Victoria, East Coast South East Australia Shelf) represents the current southern distribution limit of *Avicennia marina* in Australia and is included for reference.

LOCATION	CORNER INLET, VICTORIA	BARKER INLET, SA, INCLUDING CONTIGUOUS MANGROVES NORTH OF THE INLET.	PELICAN LAGOON, SA	COFFIN BAY, SA	VENUS BAY, SA	TOURVILLE BAY, SA	LESCHENAULT INLET, WA	GREENOUGH RIVER, WA
Lat / long	-38.91, 146.31	-34.78, 138.56	-35.82, 137.82	-34.59, 135.41	-33.20, 134.72	-32.07,133.62	-33.28, 115.85	-28.87, 114.65
Climate -köppen-geiger classification[a]	Cfb: Temperate - no dry season, warm summer	Csa: Temperate - dry summer, hot summer	Csb: Temperate - dry summer, warm summer	Csb: Temperate - dry summer, warm summer	Csa: Temperate - dry summer, hot summer	BSk: Grassland, summer drought	Csa: Temperate - dry summer, hot summer	Csa: Semi-tropical, distinctly dry summer
Coastal waterbody type	Tide-dominated coastal embayment	Tide-dominated estuary	Tide-dominated saltwater lagoon	Tide-dominated coastal embayment	Tide-dominated coastal embayment	Tide-dominated coastal embayment	Tide-dominated estuary	Tide-dominated estuary

Streams entering	Franklin, Agnes, Albert and Tarra Rivers and Bruthen Creek	Dry Creek, Little Parra River	N/A	N/A	N/A	N/A	Collie River, Preston River	Greenough River
Sedimentology (mostly sublitoral, next to shoreline)[b]	Sublitoral mixed sediment mozaic; Mud/silt-clay: 1% Sand: 98.5% Gravel: 0.5% Seagrass habitat OM[c]: 1.72 - 5.8%	Sublitoral mixed sediment mozaic; Mud/silt-clay: 25% Sand: 70% Gravel: 5%	Sublitoral mixed sediment mozaic; Mud/silt-clay: 15% Sand: 71% Gravel: 14% overlies calcrete, clay loamy surface sediments[j]	Sublitoral mixed sediment mozaic; Mud/silt-clay: 27% Sand: 55% Gravel: 18%	Sublitoral mixed sediment mozaic; Mud/silt-clay: 35% Sand: 58% Gravel: 7%	Sublitoral mixed sediment mozaic; Mud/silt-clay: 37% Sand: 56% Gravel: 7%	Sublitoral mixed sediment mozaic; Mud/silt-clay: 43% Sand: 47% Gravel: 10%	Sublitoral mixed sediment mozaic (coastal at river mouth); Mud/silt-clay: 7% Sand: 82% Gravel: 11%
Rate of sedimentation	Not reported but possibly similar to Western Port Bay[d]: 1.65 to 4.26 mm/yr	-2.1 to -2.8 mm/yr, due to land subsidence[q]. Low sedimentation within Barker Inlet due to lack of terrigenous supply with development of salt ponds along the shoreline and reduced tidal input due to bunds.	Low sedimentation, no stream inflows. Possible tidal input.	The Bay's shoreline receives sediment from the northwest toward Point Isaac and also north toward Frenchman Bluff. There appears to be a net drift of sand in a southerly direction	Low sedimentation, no stream inflows. Possible tidal input.	Low sedimentation, no stream inflows. Possible tidal input.	Low sedimentation rate due to low terrigenous sediments from streams. Possible tidal input[o]	Low sedimentation rate due to low terrigenous sediments from streams. Possible tidal input.

				into Coffin Bay.				
Distance nearest but separate mangrove system (straight line) (km)	Western Port Bay: 74	Proof Range (South of Port Wakefield): 38	Barker Inlet: 134	Venus Bay, 160	Baird Bay, 30	St Peter Island, 12	Irwin River, Port Denison, 433	Irwin River, Port Denison, 55
Intertidal flats, bare and intertidal seagrass (ha)	40,479[e,f]	3,726[f]	2,026[k].	17,344[k]	9,552[k]	3706[k]		0
Mangrove area (ha)	2,172[e]	2,519 (1,563)[i]	0[k]	0[k]	84[k]	89[k]	1.2[o]	< 1[p]
Air temperature - annual mean minimum[g] (°c)	10.2	12.1	11.6	11.8[m]	11.8[m]	10.5	11.2	14.4
Air temperature - lowest monthly mean minimum[g] (°c)	6.5	7.6	8.3	7.9[m]	7.9[m]	5.8	7.4	10.5
Air temperature - lowest in any month[g] (°c)	-1.7	0.6	-1.1	-1.0[m]	-1.0[m]	-4.7	-3.0	0.9
Air temperature - annual mean maximum[g] (°c)	18.8	21.9	19.1	21.6[m]	21.6[m]	23.6	27.7	24.7

Air temperature - highest monthly mean maximum[g] (°c)	24.0	28.7	23.8	26[m]	26[m]	28.7	30.1	29.7
Air temperature - highest in any month[g] (°c)	43.7	46.6	41.0	44.3[m]	44.3[m]	48.9	40.8	46.4
Sea surface temperature - annual mean[h] (°c)	15.8	17.8	16.9	14.1	16.7[n]	17.9	19.3	21.6
Sea surface temperature - lowest monthly mean[h] (°c)	13.6	12.7	13.3	12.5	12.8[n]	12.4	14.4	17.8
Sea surface temperature - highest monthly mean[h] (°c)	18.2	22.8	22.0	20.2	21.6[n]	24.8	25.0	28.1
Rainfall - annual mean[g] (mm)	777.6	525.2	478.8	425.3	425.3[n]	292.9	733.7	438.0

Rainfall - lowest monthly mean[g] (mm)	48.6	0.0	0.0	11.3	11.3[n]	13.1	8.2	3.6
Rainfall - highest monthly mean[g] (mm)	173.8	217.9	148.3	193.5	193.5[n]	38.0	149.2	110.0
Evapotranspiration - annual mean - areal actual[g] (mm/yr)	600 - 700	300 - 400	300 - 400	400 - 500	300 - 400	300 - 400	800 - 900	300 - 400
Evapotranspiration - lowest monthly mean - areal actual[g] (mm/month)	20 - 30	20 - 30	30 - 40	30 - 40	30 - 40	30 - 40	30 - 40	20 - 30
Evapotranspiration - highest monthly mean - areal actual[g] (mm/month)	90 - 100	20 - 30	40 - 50	40 - 50	50 - 60	40 - 50	110 - 120	40 - 50
Solar radiation - annual mean[g] (mj/m^2)	12 - 15	15 - 18	15 - 18	15 - 18	18 - 21	18 - 21	18 - 21	18 - 21
Solar radiation - lowest monthly mean[g] (mj/m^2)	6 - 9	6 - 9	6 - 9	6 - 9	9 - 12	9 - 12	9 - 12	9 - 12
Solar radiation - highest monthly mean[g] (mj/m^2)	21 - 24	24 - 27	24 - 27	24 - 27	27 - 30	27 - 30	27 - 30	27 - 30

Notes:
a: BOM Climate classification maps, modified Koppen (Peel *et al*., 2007)
b: Geoscience Australia data set. See Li *et al*., 2011a, b, c.
c: Species dependant. See Lavery *et al*., 2013
d: Rogers *et al*., 2005
e: BMT WBM 2011; Monk *et al*., 2011
f: may contain sparse intertidal seagrass
g: BOM Climate Statistics. Based on 10 years or more data, location dependant.
h: Sea temperature info – https://seatemperature.info (Based on 10 years of data).
i: Area for total habitat extent to northern boundary Adelaide International bird sanctuary. Area in brackets for habitat extent within Barker Inlet to St Kilda. (Reference: DEW Technical Report 2021/14)
j: DEWNR: Pelican Lagoon Land System Report
k: Estimated using SA NatureMaps (https://data.environment.sa.gov.au/NatureMaps/Pages/default.aspx)
l: Estimated based on % of total area (217.4 km^2, SLU = WM-, WP-) reported in Coffin Bay Peninsula Land System Report
m: Data from Elliston, the nearest BOM station on the Eyre Peninsula west coast (120 km north)
n: Data from Elliston, the nearest recording station on the Eyre Peninsula west coast (50 km south)
o: Wurm & Semeniuk, 2000, Penn *et al*., 2000, Semeniuk *et al*., 2000, Lymburner *et al*., 2020 Geoscience Australia Mangrove Canopy Cover Collection 3
- Note that the Geoscience Australia spatial data set does not identify mangroves at this location.
- Used data from papers reported above to identify location of recorded mangroves.
- Mangroves then identified by visual inspection of spatial imagery.
- Only positively identified at southern end of Inlet at Anglesea Island, Leschenault Inlet walk, and mouth of Preston River. Mangroves not obvious along mid and northern reaches of inlet where previously identified in the literature.

p: Lymburner *et al*., 2020 Geoscience Australia Mangrove Canopy Cover Collection 3
q: Belperio, 1993, and King and Jacobi, 2005