5. Mudflats and Sandflats (habitat associated with **Saltmarsh and Samphire**, and **Mangroves**)

Figure 5.1: Mudflats and Sandflats in NY NRM Region. (A) Winninowie Conservation Park and Yatala Harbour. (B) Port Pirie to Port Davis; (C) Fisherman's Bay, Port Broughton. All images (c) Google Earth.

Asset	**Mudflats and Sandflats**
Description	Mudflats are mineral-rich coastal soils within and above high tide level, which are low in oxygen, often saline, and have a high organic content. Mudflats are often fronted by mangroves, and backed by saltbush shrubland. In some areas, the organic content is lower, and the grain size is high, and such areas could be defined as sandflats. In the NY NRM region, most but not all areas of "bare" mudflat and sandflat are associated with saltmarsh, including samphire communities. Such areas provide important habitat for mud and sand-dwelling invertebrates such as crabs, shells and worms; sheltered habitat for larval and juvenile fishes; and are an important feeding area for various bird species, including migratory shore birds.
Examples of Main Species	***Birds*** • Sooty Oystercatcher and Pied Oystercatcher • White-faced Heron • Little Egret • Red-capped Plover • Migratory shorebirds listed under international treaties, such as Bar-tailed and Black-tailed Godwit, Curlew Sandpiper and Sharp-tailed Sandpiper, Red-kneed Dotterel, Red-necked Stint, Grey Plover, Red Knot and Great Knot, Eastern Curlew, Common Greenshank, Ruddy Turnstone, Grey-tailed Tattler, Whimbrel and Eastern Great Egret ***Bony Fishes*** • juvenile King George Whiting • juvenile Yellowfin Whiting juvenile Greenback Flounder and several other flounder species • juvenile Southern Blue-spotted Flathead, Rock Flathead / Grass Flathead and other flathead species • Small-mouthed Hardyhead and Pikehead Hardyhead • Western Striped Grunter • Wood's Siphonfish • Smooth Toadfish and occasionally other toadfish species (e.g. Prickly Toadfish • Blue-spotted Goby and Southern Longfin Goby Estuary Catfish • Soldier Fish

	Invertebrates • Haswell's Shore Crab / Mud Crab, Smooth Pebble Crab and several other small crab species • juvenile Blue Swimmer Crab • juvenile Western King Prawn • amphipods, copepods, isopods, and other small crustaceans • Fragile Air-breather (sand snail), Sand-plough Snail, Southern Creeper, Impoverished Whelk, trochid shells and more than 15 other marine and estuarine snail species • mussels, tellen shells, mud cockles, lantern shells and other bivalve molluscs • several species of sea cucumber • flatworms • more than 50 species of polychaete worms, including tube worms and other worms
Main Locations	<u>Northern and Eastern Spencer Gulf</u> • Port Augusta • Winninowie / Redcliff Point / Yatala Harbour • Port Germein and Port Pirie south to Port Davis Creek / Jarrold Point • Fisherman Bay near Port Broughton • Warburto Point / Bird Islands <u>Eastern Yorke Peninsula</u> • north of Troubridge Point • north of Sultana Point • around Troubridge Island • Salt Creek Bay • Giles Point area • south of Port Vincent • Pine Point • Mac's Beach, Tiddy Widdy beach (NE of Ardrossan) and Mangrove Point <u>Northern and North-eastern Gulf St Vincent</u> • Price / Wills Creek / Shag Creek • Clinton Conservation Park • Samphire Coast (Port Gawler to Sandy Point / Bald Hill, including Light River delta and Light Beach, Port Prime, Thomson's Beach, Middle beach to Port Parham, Port Wakefield Proof Range and Experimental Establishment).

Description

Mudflats are mineral-rich coastal soils within and above high tide level, often fronted by mangroves, and backed by saltbush shrubland. Mudflats are comprised of layers of fine mud, due to ongoing deposition of estuarine silts, clays and marine animal detritus. The fine sand and mud are deposited by the tides, in sheltered bays and estuaries. In some areas, the organic content is lower, and the grain size is high, and such areas could be defined as sandflats. In the NY NRM region, most but not all areas of "bare" mudflat and sandflat are associated with saltmarsh, including samphire communities, and most are in the intertidal zone, and are thus submerged and exposed approximately twice daily due to tidal movements. Similar to the soils in saltmarsh / samphire areas, the mudflats of NY NRM are often saline, with little fresh water input, and consist of sandy silts and clay soil, often with a high salt content and organic content, an accumulation of sulphide minerals, and low oxygen content. Numerous types of invertebrates live in and on the muddy and sandy soils, and many wading birds and shore birds feed in these areas at low tide, and fishes at high tide, including post-larvae and juveniles of fish species which also utilise other marine habitats. There are ecological links between the mudflats and sandflats in the intertidal, and shallow seagrass beds in the subtidal.

In parts of the NY NRM region, extensive mudflats and sandflats exist within and above tide level, and extend more than 1km seaward in some areas. Some mudflats and sandflats are covered with algal mats; some with fine seagrass (*Zostera*); some are dissected by tidal channels; and some are connected to mangrove stands.

In the northern part of the NY NRM region, in north-western Spencer Gulf, mudflats and sandflats been created over time due to the particular geology, coastal geomorphology (evolution of land forms) and oceanography of the region. Geologically, northern Spencer Gulf occupies the Torrens Sunkland (Tertiary and Quaternary out-wash deposits), which lies between two raised areas between geological faults, the Flinders Ranges on the east and the Stuart Shelf to the west. The Torrens Sunkland is regarded as one of the most active seismic zones in Australia (Morelli and de Jong 1995). There has been extensive build-up of sediments over time, due to flooding of the northern gulf several thousand years ago, when the coast was up to 5km further inland than it is now, and the sea level was 4m higher, followed by geological uplift, and the consequent development of broad samphire flats and mangrove woodlands about 1,400 years ago (Belperio et al. 1984; Belperio 1995, cited by DEH 2000). Deposits of minerals such as gypsum and dolomite have formed in the sediment flats above tide level (Harris and O'Brien 1998).

The oceanographic conditions of far northern Spencer Gulf also support the development of extensive coastal mudflats and sandflats. The area is relatively sheltered and shallow, with minimal fresh water input, and high levels of evaporation. The wave energy is very low, particularly in the upper reaches. The high salinities of the water (Johnson 1981; Bye 1981; Burne and Colwell 1982; Nunes and Lennon 1986, Harris and O'Brien 1998) from evaporation, saline water run-off, and groundwater seepage (Gostin et al. 1984; Bye and Harbison 1991), contribute to the saltiness of the coastal soils in the area. The area is also characterised by a large seasonal range in sea surface temperature (e.g. 13 - 29^{o}C at Port Augusta); extreme tidal ranges, with highs more than 3m (Johnson 1981; Noye 1984; Harris and O'Brien 1998), and regular period of "dodge" tide with limited water movement (Nunes and Lennon 1986). There are large sea level oscillations which influence the central banks area in northern Spencer Gulf, and also and extensive coastal flats, consequent significant variation in exposed surface area and depth (Radok 1978).

Within, above and below tide level, the sandflats and mudflats of northern Spencer Gulf are connected with other low energy depositional environments in the area, such as the saltmarsh and samphire low shrublands on tidal flats; the intertidal mangrove forests; the tidal creeks; the shingle and sandy beaches in some areas, and the shallow seagrass meadows and sand bottom areas below tide. The fine seagrass *Zostera mucronata* is prevalent on the intertidal sand flats in some areas. Large bivalves such as Razorfish (*Pinna bicolor*), Hammer Oysters (*Malleus meridianus*), and other molluscs, crustaceans, ascidians and other bottom fauna are associated with this seagrass habitat (Shepherd 1983a; McLaren and Wiltshire 1984; SARDI S.A. Benthic Survey data 1995; Edyvane and Baker 1996).

Ecological Significance of Mudflats and Sandflats

Similar to saltmarshes with samphires, intertidal mudflats and sandflats are an important buffer zone between the land and sea, particularly in area with mangroves. Such areas help to reduce erosion and flooding by reducing water flow; they filter pollution, and reduce the load of suspended sediment entering estuarine environments, and thus help to purify the coastal waters. Often adjacent to samphire saltmarsh, the mudflats in NY NRM have little or no visible vegetation, and at low tide, soft muddy sediments are exposed to the air. Mudflats are made up of very fine particles that restrict water movement into the soil and have little oxygen below the surface. This environment supports bacteria which thrive in thick airless mud, and contributes to the black colour and the sulphurous odour produced in these habitats. Mudflats play a role in soluble nutrient recycling in estuarine system, including storing and releasing nutrients such as phosphorus, nitrogen and carbon, as well as trace elements (Odum 1988, cited by McComb et al. 1995).

Within the NY NRM Region, the extensive samphire saltmarsh, and the intertidal mud flats, tidal creeks, and mangrove areas of the shallow, highly saline northern Spencer Gulf and northern Gulf St Vincent ecosystems are important decomposition areas, and the site of a significant detritus-based food chain, with drifting and decomposing plant material, and microbes as the basis. The saltmarsh and mangrove sediments supply abundant nutrients to filamentous blue-green algae, which trap the sediments and form algal mats (Ward et al. 1983, cited by Baker 2004). Organic carbon produced by the algal mats becomes the primary energy source for sulphate-reducing bacteria, which produce the hydrogen sulphide that accumulates beneath the algal mats (Warren 1981). By binding the silt and clay particles together, the algal mats help to stabilise sediments, which reduces turbidity and erosion, and contributes to a continuous advancement of the shoreline, known as progradation.

Mudflat soils, similar to saltmarsh soils, are an important source of tiny algae, primary producers that form part of estuarine food webs. The surface films of photosynthetic bacteria (cyanobacteria) and tiny algae (diatoms) in such areas have important ecological roles. Diatoms are an important group at the base of the food chain, and there is a rich community of such algae in the muds of the northern gulfs (Butler et al. 1975; Womersley and Thomas 1976). Mudflats are important sites for the accumulation, consumption and re-mineralisation of organic matter, and the sediment-water interface provides optimum conditions for the degradation of organic detritus (Edyvane 1995; Connolly 1999, cited by NSW EPA 2000). When sandflats and mudflats are flushed by extreme high tides, they also contribute significantly to nutrient recycling and replenishment (e.g. in soluble form) in estuarine ecosystems, since they are a source of ammonia, silicates, phosphate and dissolved organic nitrogen (Haines 1979). Marine animals move in during high tides, and many of these burrow into the mud or sand, or feed on the surface.

These habitats provide feeding and breeding areas for crustaceans (crabs, shrimps etc) and various shell species. Such habitats support high numbers of small mollusc shells, insects, larvae, and other food sources for estuarine fish, and coastal wading birds and shore birds (Morton et al 1987; Edyvane 1995; Morrisey 1995; Adam 1995; Butler and Jernakoff 1999; Connolly et al. 1997, Connolly 1999). Most of the shell species in mudflat habitats eat microscopic algae on the mud surface, or decaying plant material, and this helps to recycle and nutrients through the system. In NY NRM region, some of the major prey for shorebird species on sandflats and mudflats includes bivalve molluscs (e.g. cockles and venus shells) and gastropod molluscs (snails), as well as small crustaceans, insects, worms, bryozoans, cnidarians, echinoderms and larval fishes (Purnell et al. 2012). Most animals that live in the mud construct burrows or have other adaptations that enable them to extract oxygen from the water above. Some of the animals which live in mudflats and sandflats of NY NRM region are illustrated in the section below, on ***Invertebrates in Mudflats and Sandflats***

Worms, small crustaceans such as crabs and burrowing shrimp, and various snails and other molluscs are common in mudflats, and many of these animals use as food the decomposing organic debris washed into these areas (Parks Victoria 2014). A visible indication of the productivity in mudflats is the abundance of worms and other small invertebrates in the soils; and the number of birds, marine snails, crabs and small fishes that feed on or in the mudflats. Small gastropod and bivalve molluscs, polychaete worms, barnacles, shrimps, sea lice, insects (including mosquitoes) and other small fauna and their larvae have important ecological roles (e.g. as food source for juvenile fish and crustaceans, and some coastal bird species).

Tidally-inundated sandflats and mudflats are important feeding grounds and refuges from predators for larval and juvenile fish, such as juveniles of commercially and recreationally significant species , as well as small fishes such as Gobies and Hardyheads. These habitats function as "nursery areas" and an important link to the continued productivity of gulf waters (Jones 1984; Edyvane 1996; Dalgetty 1997). Mudflats and sandflats, particularly those associated with extensive tidal channels, are important feeding areas for many coastal wading birds and shore birds, including local, regional and migratory species).

In summary, mudflats (including algal mats) and sandflats of the upper gulfs are part of a linked system, connected ecologically with the samphire, mangrove, and seagrass communities. All are important primary producers, and have been described as "a major nutrient pool for Upper Spencer Gulf" (Harbison and Wiltshire 1993, cited by DEH 2000). These habitats have outstanding ecological significance, and are recognised as important contributors to the biological productivity and ecological functioning of the gulfs, particularly the northern part.

Mudflat and Sandflat Distribution in NY NRM Region

Within the NY NRM region, Caton et al. (2007, cited by NY NRM Board 2009) listed several types of intertidal and supratidal (above tide) habitat which are not covered with vegetation, these being

- intertidal mudflat
- intertidal cyanobacteria mat (1,098 hectares)
- supratidal cyanobacteria mat (1,605 hectares)

To this could be added intertidal sandflats. Various sandflats in Northern Spencer Gulf differ in dominant species composition. Kinhill Engineers (1987) described "broad sand flats", dominated by bivalve molluscs, and "mangrove sand flats" of greater species richness and species density, dominated by polychaete worms and gastropod molluscs.

At the north-western edge of the NY NRM region, the bay south of Point Paterson, northwards to Snapper Point, is generally an area of low wave energy and low water circulation. The coastal habitats adjacent to Port Augusta include large intertidal sand and mud flats and low red cliffs composed of Pleistocene Hindmarsh Clay (Gostin et al. 1984; Hails et al. 1984, cited by Harris and O'Brien 1998). There are mangroves lining the majority of the coast in this zone (see chapter on **Mangroves**). The estuarine area of Northern Spencer Gulf has been classified as modified, in an assessment by the National Land and Water Resources Audit (Barnett 2001).

In northern Spencer Gulf there are extensive mudflats and sandflats both between and above tide level, extending more than 1km seaward in some areas. Some mudflats and sandflats are covered with algal mats; some with fine seagrass (*Zostera*); some are dissected by tidal channels; and some are connected to mangrove stands. The mud flats are dissected by a network of tidal channels, some of which include Chinaman Creek, First to Seventh Creeks, Fisherman Creek and Port Davis Creek (Morelli and de Jong 1995). The area above tide level is dominated by bare carbonate sand flats (Gostin et al. 1984, cited by Edyvane 1995), covering approximately 7% of the northern Spencer Gulf area. There are stranded sandy and shelly beach ridges indicating the position of former shorelines. Various sandflats in northern Spencer Gulf differ in dominant species composition. Kinhill Engineers (1987) described "broad sand flats", dominated by bivalve shells, and "mangrove sand flats" of greater species richness and species density, dominated by polychaete worms and gastropod shells (snails).

The nationally significant Northern Spencer Gulf wetlands (Morelli and de Jong 1995) are discussed in the chapter on **Mangroves**, and the Redcliff area is part of that region. The coastal area adjacent to this park includes substantial areas of saltmarsh; sandflats and mudflats within and above the tidal range, and intertidal mangroves on the mudflats, and bordering tidal creeks. Some of the samphire areas are associated with cyanobacteria mats on mudflats, constructed by a number of different species of blue-green algae. Coastal marine sediments of the mud flats contain gypseous clay and silty clay (DEH 2000). Previous surveys have reported that the lower mudflats in this area are covered by a low open samphire shrubland comprising *Suaeda australis*, *Sarcocornia quinqueflora*, *Sarcocornia blackiana* and *Tecticornia halocnemoides* (Morelli and de Jong 1995; DEH 2000). Mangrove forests border the shorelines and tidal channels on the intertidal mud and sand flats.

One of the most significant areas of tidal mudflat in northern Spencer Gulf is the Redcliff Point to Yatala Harbour area, including Winninowie Conservation Park, which covers 28km of the northern Spencer Gulf coastline, and most of the reserve is low-lying coastal plain. The Winninowie Conservation Park is characterised by a system of tidal creeks with collectively cover 60km, bordered by mangrove woodland extending into low lying temporary lakes (playas) and samphire communities. Around 95 percent of the reserve is subject to tidal inundation during king tides(DEH 2000), and flooding occurs over the low-lying parts twice daily, while high areas are flooded two to three times per fortnight (Reilly 1991, cited by Baker 2004). Mangrove forests border the shorelines and tidal channels on the intertidal mud and sand flats. The mudflats in this area are dissected by a network of small tidal creeks and a number of major ones. Chinaman Creek is the largest creek in the reserve. The eelgrass *Zostera mucronata* is prevalent on the intertidal sandflats in some areas.

Yatala Harbour Aquatic Reserve (south of, and adjoining Winninowie Conservation Park), on the eastern side of Spencer Gulf is characterised by its extremely high spring tides, and supports a broad expanse of intertidal sand and mudflats (see **Figure 5.1A**). In the Redcliff Point – Yatala Harbour area, seaward of the mudflats and sandflats, there is a band of the intertidal fine seagrass *Zostera* (Shepherd 1983a).

The Port Pirie region, extending from Point Jarrold (Port Davis) to Germein Bay / Port Germein is based on coastal clay pans and stranded shelly and quartz sand ridges (i.e. part of the St Kilda Formation), extending more than 5km inland, with minor salt pans in places (Department of Mines and Energy 1983). There is a broad muddy sand beach at Port Germein, extending for several kilometres (**Figure 5.2**). The main Port Germein beach is around 1.7 km long south of the jetty, and 1.4 km on the northern side, terminating in mangrove woodland at the northern end. Beaches on either side jetty are fronted by sand flats at least 900m wide (Surf Lifesaving Australia, undated).

The tidal flats in the Germein Bay area extend between Baroota and Woods Point, including Ward Spit. Depers (1974) reported that the sediment in the intertidal originated below tide level, and supports *Zostera* seagrass, gastropod shells and smaller shelly organisms (foraminifera). The coastal habitats adjacent to Port Pirie are predominantly the extensive intertidal mud flats (1 to 2 km wide) backed by mangrove swamps (2 to 4 km wide). Recorded density of animals in the unvegetated intertidal flat area of Germein Bay was >280 / m^2 and was as great as 2,612 / m^2 in the intertidal seagrass habitat (Hutchings et al. 1993).

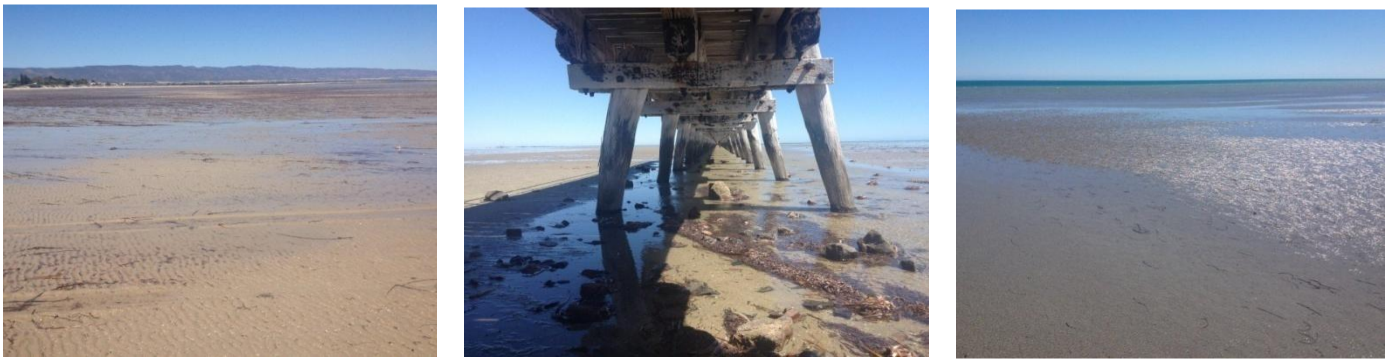

Figure 5.2: The broad sandflats at Germein Bay. (A) south of jetty; (B) adjacent to jetty; (C) north of jetty. Photos: (c) J. Baker

The coastal section from the Point Jarrold area northwards to Germein Bay comprises an extensive network of tidal creeks, such as Deep Creek, Port Davis Creek, Fisherman Creek, Seventh, Sixth, Fifth, Fourth, Third, Second and First Creek, some backed by swamplands. The major habitats include sandflats and mudflats, tidal saltmarsh (see chapter 6 of this report, on **Saltmarsh and Samphire**), extensive mangrove areas (see chapter 7 on **Mangroves**), and shallow subtidal seagrass.

At Port Davis Creek, Third Creek, Second Creek and First Creek, more than 75% of the original catchment area has been cleared, and the National Land and Water Resources Audit (NLWRA - GeoScience Australia 2001) classified all of these creeks as severely modified (see Bucher and Saenger, 1989; Barnett 2001). Fisherman Creek and Port Pirie have also been classified as severely modified estuaries (Barnett 2001). Bucher and Saenger (1989, cited by Edyvane, 1995b) mapped and described the remaining habitat at some of these creek areas, as follows:

- Port Davis Creek: 12.07km^2 of intertidal sand/mudflats
- Third Creek: 0.89km^2 of intertidal sand/mudflats
- Second Creek: 2.3km^2 of intertidal sand/mudflats
- First Creek: 8.04km^2 of intertidal sand/mudflats

There are also several square kilometres of intertidal flats in the fisherman Creek area (Australian Estuaries Database 1998; GeoScience Australia 2001), and 0.71 km^2 of intertidal flats was recorded. At Port Broughton, there is an area of intertidal mudflats (3.7 km^2), associated with saltmarsh, and a small stand of mangroves. Further south on western Yorke Peninsula are the Bird Islands and Bird Reef. Tidal deposits of sand and fine silt fringe the shallows of the inner islets.

Further south, in the Bird Islands / Warburto Point area, the tidal mudflats are rich in organic matter, and provide a highly productive food supply for organisms that utilise the saltmarsh, mangrove and mudflat environment of the area. The nutrient levels of the tidal mudflats are reflected in the densities of invertebrates that thrive in the "ooze". Fishers have reported annual "swarms" of blood worms in the Bird Islands area, which are ecologically important in terms of their role as food for fish and some bird species, and nutrient recycling. This abundant food supply, combined with the shelter and protection offered by the mangroves, also provides a refuge for larvae and small juveniles of various fish and crustacean species, which in turn provide important food sources for the local bird fauna (Robinson et al. 1996). Tidal deposits of sand and fine silt fringe the shallows of the inner islets, blanketing the reef outcrops with low sand dunes and mudflats, the latter of which are regularly inundated by tides. Mangrove stands surround the entire West Bird Island, except for the north-western tip (Australian Heritage Commission, undated; Robinson et al. 1996; DTUP 2003), and on the coast east and south-east of the Bird Islands (PIRSA, SARDI and DEH map, in Bryars 2003).

Warburto Point is the headland closest to the Bird Islands, and around 50km south of Warburto, on the bay side of Reef Point there is a small area of samphire, backed by bare stranded tidal deposits that extend inland (DEH map, in DTUP 2003). In the Port Victoria area, there is a bare intertidal sand flat towards the Port Victoria township (DEH map, in DTUP 2003). Further south, between Port Minlacowie and Hardwicke Bay, there is a samphire strip along the coast, fronted by bare intertidal sand.

Along the southern coast of Yorke Peninsula, there are few mudflats due to the exposed nature of the coast, facing Investigator Strait. One of the only calm water areas where extensive deposition of sand occurs is Point Davenport, which is discussed in the chapter on **Saltmarsh and Samphire.**

Tidal flats occur along the "heel" of Yorke Peninsula, from north of Troubridge Point, up to north of Giles Point, and the most extensive areas of tidal flats include areas north of Sultana Point; also around Troubridge Island, and at Salt Creek Bay (PIRSA, SARDI and DEH map, in Bryars, 2003). These areas are discussed in other chapters of this report, such as **Sand Islands**, **Sandy Beaches** and **Mixed** (**Sand**, **Mud**, **Rock** / **Cobble**) **Beaches**. There is a coastal lagoon (Salt Creek Swamp) inland from Salt Creek Bay, and the area supports sandy-mud tidal flats with mats of cyanobacteria (blue-green algae) Bay.

There are tidal sandflats along many parts of eastern Yorke Peninsula. South of Port Vincent, there is a calm, low energy beach fronted by 200m wide sandflats. North of Point Julia, the beach is fronted by 200m wide sand flats, covered with intertidal seagrass. At Pine Point, there is a narrow, moderately steep shelly sand beach, with patch reef and sand flats extending out to about 400m seaward. Sandflats also occur in the Tiddy Widdy and Mac's Beach area. Macs Beach, near Mangrove Point, is part of a low energy beach which runs for about 11km. Mac's Beach, which is fronted by 300m wide sand flat and back by a shelly high tide beach with seagrass debris, runs south for 8 km, and becomes Tiddy Widdy Beach at the coastal settlement, then Young's Beach towards the southern end of the beach strip, at Ardrossan (Surf Lifesaving Australia, undated).

Further north, along the eastern side of Yorke Peninsula, the Price area (including Wills Creek Conservation Park) supports sandflat and mudflat areas, associated with saltmarsh both above and between the tide line, and intertidal mangroves. There are salt evaporation fields adjoining the system. The area is subject to regular inundation by seawater, and has two tidal creeks (Wills Creek and Shag Creek) which form shallow estuaries at Mangrove Point. Mangrove forests line the coast and are dissected by numerous small tidal channels, which provide drainage when the tide recedes. Much of the area lies below high tide level, and is therefore subjected to daily inundation (Seager, unpublished, cited by Morelli and de Jong 1995). North of Mangrove Point, the tidal channels are lined with seagrass. There is also bare sand forming an intertidal strip along the coast between Mangrove Point and Port Clinton (DEH Saltmarsh Mapping, in DTUP 2003).

From Port Clinton township around the head of Gulf St Vincent, and south to 1km north of Port Wakefield township is the Clinton Conservation Park, which covers around 1964 hectares (Morelli and de Jong 1995). This Park encompasses the continuous coastal fringe of samphire, mudflats and sandflats both between and above tide level, and intertidal mangroves with many large, mangrove-fringed tidal channels (extending as far as 600m inland). The sediment flats are composed of stranded beach ridges of shelly and swampy deposits, some fringed by *Zostera* seagrasses. Mudflats in the area are mostly bare, with the exception of the blue-green algae *Oscillatoria* and a rich community of diatoms (see Butler et al. 1975). Mangrove forests back the sandflats and mudflats, and in some places these dissected by tidal channels. The hinterland is incised with small creek gullies, which either fan out onto the tidal flats, depositing red clay loam and gravel on the surface, or continue across to the sea (Martin 1980, cited by Morelli and de Jong, 1995; DEH data, cited in DTUP 2003). The River Wakefield is the only major drainage channel in the area, and the only major input of freshwater into the tidal flat system of far northern Gulf St Vincent. The mangrove areas and bare intertidal mud and sand flats grade into intertidal fine seagrasses (*Zostera* and *Heterozostera*).

Along north-eastern Gulf St Vincent is the Samphire Coast, which starts at Port Gawler at the southern edge of the NY NRM region, and continues north for 57 km to Sandy Point / Bald Hill. This area is discussed in more detail in the chapter on **Saltmarsh and Samphire.** Between Sandy Point and Parham, in the Prohibited Area used for weapons proofing, the coastal strip of intertidal bare sand is around 1km – 1.5km wide, backed by a thin band of vegetated beach ridges (degraded in places), behind which lies stranded samphire and bare flats, extending several km inland (DEH mapping data, in DTUP 2003). Similarly in the Parham area, and also between Port Prime and the northern end of the Light River delta, the coast comprises vegetated beach ridges, samphire, and bare saline flats salt pans. Further south, towards Great Sandy Point, there is sand and patchy seagrass in the intertidal. The sand beach is around 9km long southwards from Port Prime. At the southern edge of the NY NRM region, between Middle Beach and Port Gawler, there are degraded vegetated beach ridges (cheniers), fronted by intertidal sand, mangroves and patchy seagrass.

Fishes in Mudflats and Sandflats

Some of the small fishes which inhabit mudflats and sandflats in the NY NRM region are residents, and others are found in a variety of habitats (Payne and Gillanders 2009). The sheltered shallow water provided a protected habitat for post-larvae and juveniles of wide ranging commercially and recreationally significant species such as King George Whiting, Yellowfin Whiting (Bryars 2003) and Yelloweye Mullet. Such species feed on polychaete worms which inhabit the intertidal mudflats (Connolly et al. 2005). Studies to date in southern Australian mudflat habitats which are inundated by the tide (e.g. Crinall and Hindell 2004; Payne and Gillanders 2009) have shown that fewer fishes utilise such habitats, compared with adjacent tidal creeks and mangroves. Some example of fish species which utilise saltmarsh habitat within the NY NRM region are shown in **Table 5.1** below. Small fishes in the families Gobiidae and Atherinidae are abundant in mudflats habitats, as is the Western Striped Grunter *Pelates octolineatus* (Payne and Gillanders 2009).

Table 5.1: Examples of fish species which are associated with inundated saltmarsh of the NY NRM region (from Connolly 1994; Connolly et al. 1997; Payne and Gillanders 2009; ALA 2014)

Common Name and Latin Name	Representative Image	Common Name and Latin Name	Representative Image
juvenile King George Whiting *Sillaginodes punctata*	 **© Reef Life Survey**	juvenile Yellowfin Whiting	 **© D. Muirhead**
juvenile Yellow-eye Mullet *Aldrichetta forsteri*	 **© Auckland Council**	Western Striped Grunter *Pelates octolineatus*	 **© R. Stuart-Smith, RLS**
juvenile Greenback Flounder *Rhombosolea tapirina* and several other flounder species	 **© R. Stuart-Smith, Reef Life Survey**	juvenile Southern Blue-spotted Flathead *Platycephalus speculator*	 **© S. Speight, CC Licence**
Rock Flathead / Grass Flathead *Platycephalus laevigatus*	 **© R. Stuart-Smith, Reef Life Survey**	Small-mouthed Hardyhead *Atherinosoma microstoma,* and Pikehead Hardyhead *Kestratherina esox*	 **© D. Muirhead**
Wood's Siphonfish *Siphamia cephalotes*	 **© G. Short, CC Licence**	Smooth Toadfish *Tetractenos glaber* and occasionally other toadfish species (e.g. *Contusus* species)	 **© S. Rohrlach, CC Licence**

Table 5.1 (continued):

Common Name and Latin Name	**Representative Image**	**Common Name and Latin Name**	**Representative Image**
Blue-spotted Goby *Pseudogobius olorum*	 **© Aquaculture Council of WA**	Southern Longfin Goby *Favonigobius lateralis*	 **© A. Green, Reef Life Survey**
Estuary Catfish *Cnidoglanis macrocephalus*	 **© R. Ling, Flickr. CC Licence**	Soldier Fish *Gymnapistes marmoratus*	 **© J. Finn, Museum Victoria. CC Licence**

Invertebrates in Mudflats and Sandflats

The ecological significance of the numerous invertebrates in mudflat and sandflat habitats of the NY NRM region is discussed above. Many of these species are important food sources for fishes, which are swept into the area on high tides. Mud crabs *Helograpsus haswellianus* are abundant in the northern parts of both gulfs, and feed on the film of diatoms and algal slime which coats the surface of the saltmarsh muds (Womersley and Thomas 1976; Morelli and de Jong 1995; Fotheringham and Coleman 2008). When the mud crabs produce larvae seasonally, into the outgoing spring tides, many fishes in the nearby creeks feed on the larvae. A number of other crab species occur in the mudflats and sandflats of the gulfs, and some of the species serve a similar ecological function as the mud crab. In some of the sandier areas, the Smooth Pebble Crab *Bellidilia laevis* can be abundant. In other sand flat habitats, such as Port Germein, tellen shells and other bivalves are dominant (**Figure 5.3**), along with sand-dwelling worms. Most of the shell species in mudflat and sandflat habitats eat microscopic algae on the sediment surface, or decaying material which is washed in on the tide, and this helps to recycle and nutrients through the system. Some of the bivalve shells are suspension feeders, and take microscopic food from the water when the sediment flats are flooded. Various crustaceans (e.g. crabs, shrimps, amphipods, isopods), shells (limpets, clams, and snail shells), worms, and other invertebrates (such as flatworms) feed and breed in the mudflat and sandflat. Various types of worms, as well as small crustaceans such as amphipods, and insects in the sandy and muddy intertidal habitats are all important components of the diet of small fishes, such as hardyheads, gobies and juvenile mullet (Crinall and Hindell 2004).

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Figure 5.3: Examples of molluscs which dominate the intertidal muddy sandflat habitat at Port Germein.

In north-eastern Gulf St Vincent, mud cockles and razorfish shell (*Pinna bicolor*) are abundant the area. Razorfish are considered to provide "micro-reef" habitat, by housing a rich assemblage of attached fauna, such as sponges, ascidians, bryozoans ("lace corals"), tube worms (Shepherd and Sprigg, 1976), and provide the hard substrate required for some species to settle, in areas of soft muddy and sandy sediment. Mud Cockles (*Katelysia*), of which there are three main species in the area, may have important ecological roles due to being abundant suspension-feeders in the system. Mud Cockles are also a food source for some fauna in the area. There is also a high abundance of some other estuarine invertebrate groups e.g. worms, small crab species and other small crustaceans. Tube worms (Terebellidae) and beach worms (family Onuphidae) in the area play a role in sediment processing and nutrient recycling, and are a food source for some fauna of the mudflats and sand flats. Seaweed worms (garden worms) are also found in the area, where dead seagrass is washed up, and also have a similar role in nutrient recycling, and as a food source for birds and other fauna.

Table 5.2: Examples of some invertebrate species which are associated with mudflats and sandflats of the NY NRM region (Womersley and Thomas 1976; Morelli and de Jong 1995; Bryars 2003; Fotheringham and Coleman 2008; Dittman and Baggalley 2014; maps in Atlas of Living Australia 2014)

Common Name and Latin Name	Representative Image	Common Name and Latin Name	Representative Image
Haswell's Shore Crab / Mud Crab *Helograpsus haswellianus*	 **© M. Marmach, CC Licence**	Smooth Pebble Crab *Bellidilia laevis*	 **© H. Crawford**
juvenile Blue Swimmer Crab *Portunus armatus*	 **© J. Lewis**	juvenile Western King Prawn *Penaeus* (*Melicertus*) *latisulcatus*	 **© Museum Victoria**
amphipods, copepods, and isopods, and other small crustaceans	 **© Nova Southeastern University**	isopods, such as *Platynympha longicaudata*	 **© M. Marmach Museum Victoria CC Licence**
Fragile Air-breather sand snail *Salinator fragilis*	 **© T. Alexander, ausmarinverts.net**	Sand-plough Snail *Polinices conicus*	 **© National Library of Australia. Image by Dr. I. Bennett**

Table 5.2 (continued):

Common Name and Latin Name	Representative Image	Common Name and Latin Name	Representative Image
Trochid shells, such as *Austrocochlea* species (e.g. *A. porcata*)	 © D. Beechey www. seashellsofnsw.org.au	Southern Creeper *Zeacumantus diemenensis*	 © www.idscaro.net CC Licence
Impoverished Whelk *Nassarius pauperatus* and other whelk species	 © T. Alexander, ausmarinverts.net	Mussels (e.g. *Brachiodontes erosus* and *Xenostrobus inconstans*	 © J. Delsing, CC Licence
Decussated Tellen *Pseudarcopagia victoriae,* Deltoid Tellen *Macomona* (prev. *Tellina*) *deltoidalis*, and other tellen shells	 © D. Staples Museum Victoria, CC Licence	mud cockles *Katelysia* species (e.g. *K. scalarina* and *K. peronii*)	 © D. Staples, Museum Victoria CC Licence
Razorfish shell *Pinna bicolor*	 © H. Crawford	Hammer Oyster *Malleus meridianus*	 © Howies SCUBA
Creccina Lantern Shell *Laternula creccina*	 © L. Altoff, MRG of FNCV	sea cucumbers, such as *Taeniogyrus roebucki*	 © L. Altoff, MRG of FNCV
More than 50 species of polychaete worms, including tube worms, bait worms, and other worms. (Head and jaws of *Neanthes vaali* shown here)	 © G. Rouse, CC Licence	flatworms, such as *Notoplana* species	 © J. Baker

Coastal Bird Species in Mudflat and Sandflat Habitats

The sandflats and mudflats of the NY NRM region provide important habitat (especially feeding grounds) for local and migratory wading birds and other coastal sea birds (Butler et al. 1973; Close and McCrie 1986; Morelli and de Jong 1995; Copley 1996; Smith 2002). The mudflats and sandflats of the upper gulfs also contain feeding areas for some coastal bird species which are listed under schedules of the *South Australian National Parks and Wildlife Act 1972*, including Little Egret (*rare*), and the migratory wading bird Eastern Curlew (*vulnerable*) (Matheson 1976; Morelli and de Jong 1995 and DEH 2000).

Numerous migratory wading birds and shore birds also utilise these habitats. Migratory bird species of conservation significance, including species listed under JAMBA, CAMBA and/or Bonn Convention visit intertidal sand flats and mudflats in the Region (Smith 2002; Baker 2004 and references therein; DEH 2009). Some of the species which have been recorded in the sheltered mangrove and saltmarsh / samphire habitats within the NY NRM region are included in the chapters on **Mangroves,** and **Saltmarsh and Samphire.** For specific locations where these species occur seasonally, the reader is referred to chapters in Baker (2004). A number of areas within NY NRM region which support mudflats or sandflats, are listed as being of international and national importance for shorebirds, and are used seasonally as feeding grounds. These include:

- Winninowie Conservation Park / Chinaman Creek (e.g. important breeding and feeding habitat for Black-faced Cormorant and Pied Cormorant)
- Point Jarrold
- Bird Islands
- Port Price / Wills Creek / Shag Creek area: around 49 bird species have been recorded in the Port Price area (which includes Wills Creek and Shag Creek), with at least 18 species listed under international treaties.
- Clinton Conservation Park: 38 bird species have been recorded, with than a dozen listed on international treaties

(Wanke 1971; Taylor and Taylor 1977; Martin 1980; Watkins 1993; Matthew 1994, cited by Morelli and de Jong 1995; Bird Life Australia reports).

Some areas of mudflat and sandflat within NY NRM Region which are significant for shorebirds are discussed in more detail below. Some of these locations also have saltmarsh with samphire cover, and others areas do not.

- *Port Price area, including Wills Creek and Shag Creek*. At Price there is 1064 hectares of salt evaporating ponds, surrounded by saltmarsh, mangrove and mudflats. Price Saltfields supports the greatest diversity of species of shorebirds Gulf St Vincent, with a total of 31 species (Purnell et al. 2009). As migration “stop-over” areas, the Port Price area (including Wills Creek and Shag Creek) provides habitat for at least 18 species listed under international treaties (Morelli and de Jong 1995). Examples of some of the bird species which utilise the Price salt field habitat are shown in **Table 6.5** of the chapter on **Saltmarsh with Samphire**.

- *Clinton Conservation Park, at the head of Gulf St Vincent*. As a migration “stop-over” area, Clinton provides habitat for at least 11 shorebird species listed under international treaties (Morelli and de Jong 1995). Over 3,500 shorebirds were recorded at Clinton Conservation Park in 2009 (Purnell et al. 2012). Example of migratory species which are listed under international treaties and occur in the area of Clinton Conservation Park include many of coastal birds which utilise mudflats and sandflats for feeding, such as Bar-tailed Godwit, Common Greenshank, Eastern Curlew, Great Knot, Red Knot, red-necked Stint, Grey Plover, Red-capped Plover, Grey-tailed Tattler, Red-necked Stint, Ruddy Turnstone and Sharp-tailed Sandpiper (Purnell et al. 2013).

- *The Samphire Coast, including Light River Delta* is an important habitat various coastal birds. Smith (2002) recorded 40+ species of shore birds along the Samphire Coast, of which 17 species were wetland birds. Examples of areas contain mudflats and/or sandflats which provide feeding grounds for coastal bird species include Light River delta and Light Beach, Port Prime, Thomson’s Beach, Middle beach to Port Parham, Port Wakefield Proof Range and Experimental Establishment, and Sandy Point / Bald Hill (Smith 2002; Purnell et al. 2009, 2013). This coast is important for migratory birds listed under the CAMBA, JAMBA and/or ROKAMBA international treaties (see chapters on **Mangroves,** and **Saltmarsh with Samphire**). For some bird species, the numbers in the area are of global significance (e.g. Banded Stilt, Sharp-tailed Sandpiper, Red-capped Plover and Red-necked Stint) or national significance (e.g. Ruddy Turnstone, Bar-tailed Godwit, Red Knot, Grey Plover, Common Greenshank and Curlew Sandpiper.

Table 5.3: Some examples of bird species which utilise mudflats and sandflats in NY NRM Region. (From Morelli and de Jong 1995; Copley 1996; Smith 2002; Baker 2004 and references therein; Purnell et al. 2013; Birdlife Australia records, cited in ALA 2014).

Common Name and Latin Name	**Common Name and Latin Name**
Sooty Oystercatcher *Haematopus fuliginosus* (Listed as Rare, under the *NPW Act* in SA)  **© J.J. Harrison, CC Licence**	Pied Oystercatcher *Haematopus longirostris* (Listed as Rare, under the *NPW Act* in SA)  **© J.J. Harrison, CC Licence**
Eastern Curlew *Numenius madagascariensis* (Listed as *Vulnerable*, under the *NPW Act* in SA. Listed under Bonn Convention, CAMBA, and JAMBA)  **© D. Daniels (http://carolinabirds.org/), CC Licence**	White-faced Heron *Egretta novaehollandiae*  **© G. Fergus, CC Licence**
Little Egret *Egretta garzetta* (Listed as Rare, under the *NPW Act* in SA)  **© F. Folini, CC Licence**	Eastern Great Egret *Ardea modesta* (*Ardea alba*) (listed under Bonn Convention, CAMBA, and JAMBA) 
Grey Plover *Pluvialis squatarola* (listed under Bonn Convention, CAMBA, and JAMBA)  **© G. Buissart, CC Licence**	Common Greenshank *Tringa nebularia* (listed under Bonn Convention, CAMBA, and JAMBA)  **© A. Trepte, CC Licence**

Table 5.3 (continued):

Common Name and Latin Name	**Common Name and Latin Name**
Red-necked Stint *Calidris ruficollis* (listed under Bonn Convention, CAMBA, JAMBA ,and ROKAMBA)  **© J.J. Harrison, CC Licence**	Red-capped Plover *Charadrius ruficapillus*  **© J.J. Harrison, CC Licence**
Curlew Sandpiper *Calidris ferruginea* (listed under Bonn, CAMBA, JAMBA, ROKAMBA)  **© J.J. Harrison, CC Licence**	Sharp-tailed Sandpiper *Calidris acuminata* (listed under Bonn, CAMBA, JAMBA, ROKAMBA)  **© Alnus, CC Licence**
Red Knot *Calidris canutus* (listed under Bonn, CAMBA, JAMBA, ROKAMBA)  **© H. Hillewaert, CC Licence**	Great Knot *Calidris tenuirostris* (listed under Bonn, CAMBA, JAMBA, ROKAMBA)  **© M. Nishimura, CC Licence**
Grey-tailed Tattler *Tringa brevipes* (listed under Bonn, CAMBA, JAMBA, ROKAMBA)  **© J.J. Harrison, CC Licence**	Whimbrel *Numenius phaeopus* (listed under Bonn, CAMBA, JAMBA, ROKAMBA)  **© Aviceda, CC Licence**

Table 5.3 (continued):

Common Name and Latin Name	**Common Name and Latin Name**
Red-kneed Dotterel *Erythrogonys cinctus*  **© J.J. Harrison, CC Licence**	Ruddy Turnstone *Arenaria interpres* (listed under Bonn, CAMBA, JAMBA, ROKAMBA)  **© A. Trepte, CC Licence**
Bar-tailed Godwit *Limosa lapponica* (listed under Bonn, CAMBA, JAMBA, ROKAMBA)  **© U.S. Fish and Wildlife Service, CC Licence**	Black-tailed Godwit *Limosa limosa* (listed under Bonn, CAMBA, JAMBA, ROKAMBA)  **© Frebeck, CC Licence**