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Mangroves and Salt Marshes in Westernport Bay, Victoria

BY

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INTRODUCTION

Mangroves and salt marshes grow in the intertidal zone of quiet estuaries and bays, protected from strong currents and wave action. In tropical northern Australia, mangrove communities are highly diverse, while salt marshes are species-poor. Mangrove species diversity declines with increasing latitude, while salt marsh diversity increases (Saintilan & Williams 1999). This is possibly due to lower temperatures (Shapiro 1975). Only one mangrove species, *Avicennia marina* subsp. *australasica*, grows in Victoria. It grows as trees or shrubs, up to 2.4 meters tall (Bird 1971). Salt marshes in Victoria are highly diverse. *Sclerostegia* (formerly *Arthrocnemum*) and *Salicornia* usually dominate. Salt marshes are frequently associated with mangroves and may abut against them, with salt marsh growing inshore of the mangroves (Hutchings & Saenger 1987). This zonation is common in Westernport Bay. The mangrove zone occurs inshore of seagrass, sand and mud flats. These distinct communities occur generally parallel to the shore, except where drainage channels or creeks alter the surface topography (Chamberlain 1979). In Westernport Bay, swamp paperbark (*Melaleuca ericifolia)* is often present on the landward side of the salt marsh (Bird 1971). The mangrove-salt marsh vegetation is generally 100 to 300 meters wide. At Watson Inlet it is up to 1 kilometre wide (Bird 1974).

In Victoria, mangroves occur in Corner Inlet, Anderson's Inlet, Westernport Bay and near Barwon Heads. Mangroves once grew in Port Phillip Bay at the mouth of Kororoit Creek and in Corio Bay. By 1975, only a few trees remained in Corio Bay, at Hovells Creek and Limeburners Bay (Calder 1975). There were no subsequent studies of these remnant populations. The last mangroves at Kororoit Creek were destroyed by an oil spill in 1951. The most developed and extensive Victorian mangrove populations occur in Westernport Bay, making it a logical study site.

Westernport has a greater diversity of marine biota than any other Victorian inlet, including some species and communities of international significance (Champion 1974; Opie *et al.* 1985). In 1981 the Victorian Ministry for Conservation proclaimed the French Island (East) and French Island (North) Reference Areas (Victorian Government 1981). These natural ecosystems were maintained and protected for use as areas to which researchers could refer when studying the impacts of development in the region. Under the same legislation, a further sanctuary zone was later recommended for the northern coast of French Island, which included mangrove communities and extended into the subtidal seagrass beds (Land Conservation Council 1996). The French Island National Park was proclaimed in 1997, which included land at Red Bluff on the mainland. Mangroves and salt marshes will be protected in proposed Marine National Parks at Yaringa, North Westernport and Rhyll Inlet (Environment Conservation Council 1999). Special management areas are proposed at Honeysuckle Reef, Crawfish Rock, Observation Point, San Remo and the Bass River Delta.

The Portuguese possessed maps of Westernport Bay in 1493, though George Smythe was the first European explorer in the area in 1798 (Murphy 1997). The French and British carried out subsequent explorations in 1801-02 (Bird 1974). Prior to settlement, black wattle was harvested from the mainland for use in tanning. The British settled temporarily at Rhyll, then moved to Corinella in 1826-27. At that time sealers were frequent visitors to the area (Murphy 1997). The seal populations of Westernport Bay were severely depleted by hunting, and by 1832 the sealing industry was no longer viable.

Westernport Bay is the deepest and second largest bay in Victoria. Its close proximity to Melbourne and deep channels have made it a site for major industrial and shipping activities for over 150 years (Bird 1975). The environmental effects of industrial and urban development in the region have generally been overlooked. More than 75 % of the Westernport catchment has been cleared (Jaremovic *et al.* 1992). Mangrove and salt marsh clearing began in Westernport Bay as early as 1840, when the region was used as a loading point for cattle and produce (Bird & Barson 1975). By the 1970s, oil and steel industries were established in the Hastings area (McDonald 1980).

The mangrove-salt marsh communities of Westernport Bay are interconnected; changes in one part of the system impact on adjacent areas (Chamberlain 1979). The outer mangrove fringe holds muddy sediments in the system which would otherwise be washed away by offshore winds. Clearing of small areas of mangrove exposes nearby mangroves and salt marsh to increased tidal flow, erosion, and sedimentation, creating further dieback. Sand deposits may drown mangroves through smothering their pneumatophores (Ashton 1972). *Avicennia marina* grows best in soft mud, protected from wave action (Bird 1986). The arrival of drifting sand into areas once occupied by mangroves impedes their regeneration (Bird & Barson 1975). Mangroves may be killed by reduced water salinity associated with fresh drainage waters being diverted into them.

The earliest detailed scientific study of salt marsh in Westernport Bay was carried out in 1942 (Patton 1942). Concern for the environmental effects of development in the area culminated in a major government and industry-sponsored study in 1973-74, the Westernport Bay Environmental Study. This provided baseline data on the mangrove and salt marsh vegetation of the whole bay. The study assessed and evaluated factors that affected the environmental viability of the bay, concluding that vegetation changes were either directly or indirectly linked to human activities. Few other studies were carried out during the 1970s. In the last 25 years, there have been very few follow-up studies, so little is known of any recent changes in the bay's mangrove-salt marsh vegetation.

Many studies suggest that in the course of succession mangroves are replaced by salt marsh (Bird 1971; Ashton 1972; Burton 1982; Mitchell & Adam 1989a; Saintilan 1999). *Avicennia marina* pneumatophores facilitate this process through trapping sediment, which enhances sediment build-up enabling seawards advance. A sediment terrace builds up which is then colonised by salt marsh. In contrast, recent studies in New South Wales and South Australia found mangroves moving landwards to replace the salt marsh (Burton 1982; Saintilan 1999). This process threatens salt marsh because agriculture and development restrict its landward retreat. Thus the seawards advance of mangroves is a common but not ubiquitous occurrence. Within one area there may be sections where mangroves are invading salt marsh and other sections where they are either static or advancing (Burton 1982). There is debate in the published literature over whether mangroves in Westernport Bay advance seawards or move landwards into the salt marsh.

The aim of this paper is to review the literature on mangrove and salt marsh vegetation in Westernport Bay. Studies of mangrove-salt marsh mapping and monitoring with quadrats are examined in Westernport Bay and other areas. This information will aid the design of future Westernport Bay mangrove-salt marsh studies.

MANGROVE-SALT MARSH MAPPING IN WESTERNPORT BAY

Old maps and aerial photographs of the Westernport region provide information on changes in the mangrove-salt marsh vegetation over time. They can be used to determine changes in the area cover and distribution of mangroves and saltmarshes.

George Smythe made the first accurate survey of Westernport Bay in 1842 (Shapiro 1975). Accuracy is judged through comparison of the spatial relationships between fixed points, such as headlands and hill summits on Smythe's map with modern surveys. In 1842 mangroves occurred almost continuously from Sandy Point in western Westernport Bay to the mouth of Bunyip River in the north. They also occurred at Red Bluff and around Pioneer Bay to Corinella. Mangroves grew in several bays along the east coast of Phillip Island, and on French Island along the north, west and south coasts. When Smythe drew his map, he included areas of the tall salt marsh shrub *Sclerostegia* with the mangroves. This error must be taken into account when comparing his map with later more accurate surveys. In 1865 Cox charted Westernport Bay, showing there were no great vegetation changes between 1842 and 1865. Any differences may be attributed to Smythe including some salt marsh with the mangrove. The two nineteenth century surveys can be used together as a reference point from which vegetation changes since the time of early settlers can be judged.

The first aerial photographs of Westernport Bay were taken in 1939. These show a decrease in the area occupied by mangroves since 1865, fragmentation of the mangroves and an increase in sandy beaches. Aerial photographs taken in 1973-74 show a further decrease in the area occupied by mangroves and further fragmentation. These vegetation changes are correlated either directly or indirectly with human activities (Shapiro 1975).

Sandy Point

The shoreline from Somers to Sandy Point has been modified since 1842, through erosion in some areas and sand deposition in others (Bird & Barson 1975). Longshore drift resulted in an eastwards advance of the Point. Between 1939 and 1972 new scrub-covered and grassy beach ridges were formed. Sand deposited in the mangrove-salt marsh habitat to the north caused decreased mangrove density. The marsh system was 600m wide at Sandy Point, which is unusually wide for Westernport Bay (Calder 1972). On the leeward side of Sandy Point, an immature salt marsh community was present with no mangroves (Champion 1974).

Stony Point

Prior to 1850, cattle were transported from Stony Point to Port Phillip Bay by boat. Early settlers cut a gap in the mangroves, to allow cattle to be loaded onto boats (Bird & Barson 1975). By 1884, mangroves were cleared for 200m on either side of Stony Point jetty. Erosion and sand deposition caused a further loss of mangroves by 1939. In 1952 a wall was built to halt cliff erosion and sandy drift, and by 1974 mangroves had regenerated.

Crib Point to Hastings

Prior to 1842, gaps were cut in the mangrove fringe to allow boat access at Crib Point, Hastings and Denhams Road to the north (Bird & Barson 1975). By 1974 these gaps had widened. Mangroves were depleted between Hastings and Crib Point due to a number of human-induced stresses (Calder 1975). An accidental discharge of distillate from an oil refinery damaged 0.6 hectares of salt marsh in 1968 (Calder 1975; Walsh & Connell 1975). Grazing cattle destroyed peat in the salt marsh, reducing its water-holding capacity (Calder 1975). Drains and embankments altered the natural drainage pattern, stunting some plants. Areas to the north of Hastings were reclaimed for industrial purposes.

By 1974, mangroves at Crib Point had not advanced either seawards or landwards (Clough & Attiwill 1974). In contrast, Clough (1975) concluded mangroves at Crib Point had spread into the salt marsh. Landward incursion of mangroves is unusual in Westernport Bay, where mangroves usually advance seawards. In the early 1990s, mangroves were absent from areas immediately north and south of Crib Point, including Woolleys Beach (Jaremovic *et al.* 1992), consistent with the human-induced damage to mangroves reported by Calder (1975).

At Hanns Inlet, vigorous salt marsh plants were found growing beneath the swamp paperbark behind the marsh, representing retrogression (Ashton 1972). At Denhams Road, sediment accretion was observed amongst pneumatophores on the seaward margin (Bird 1986), suggesting seaward advance of the mangroves.

Mangroves and salt marsh were damaged at Jack’s Beach during the 1970s and 1980s, due to commercial shipping activities and cattle grazing (Jaremovic *et al.* 1992). In 1992, the mangrove population at Jack's beach was mature and well established, having been stable for at least 50 years. There was no mangrove advance either seawards or landwards.

Sandstone Island

In 1842 Smythe mapped a continuous mangrove fringe along the north and west coasts of Sandstone Island (Bird 1974). By 1974 the mangroves were fragmented, with dead trees in areas of sand deposition. Patches of mangroves had developed on the eastern coast. By 1992, mangroves remained only on the northern coast of Sandstone Island. Salt marsh occurred on the landward side of the mangroves and on the western coast.

Yaringa

A boat harbour canal was excavated at Yaringa, through the salt marsh, mangroves and mudflats (Bird 1985). The canal was abandoned and recolonised by mangroves (Bird & Barson 1975). A second canal was built in 1967, bordered by levees of dredged materials. By 1974 mangroves had advanced on either side of the levees. The canal excavation did not cause sandy drift or erosion, and there was no mangrove dieback.

By 1971, mangroves close to the Yaringa boat harbour advanced seawards, succeeded by salt marsh (Bird 1971). Seaward advance of mangroves occurred in other areas of Westernport Bay, though there was no mangrove advance in many areas between 1966 and 1971. At Yaringa, muddy sediment and organic matter accumulated amongst the pneumatophores, building up sediment to a level in which mangrove seedlings could establish. In contrast, there was no seaward advance of mangroves south of Yaringa between 1970 and 1985, and no sustained mud accretion between 1967 and 1985 (Bird 1986).

Watsons Inlet and Cannons Creek

In 1972, the mangrove-salt marsh vegetation at Watsons Inlet was unusually wide at 780m (Calder 1972). Mangroves at Cannons creek did not advance either seawards or landwards (Clough & Attiwill 1974).

Blind Bight

In 1865 there was a continuous mangrove fringe around the future site of the Main Western Contour Drain in Blind Bight (Bird & Barson 1975). The drain was completed in 1938, and outflow from the Dalmore swamp diverted into it. By 1939 a gap had formed in the mangrove fringe, probably due to the massive influx of fresh water. By 1974, mangrove–salt marsh regeneration had occurred around the drain outlet. In 1975, a marina, swimming pool and car park were under construction in the Blind Bight mangrove zone (Calder 1975). At Tooradin, tidal scour was undercutting the seaward mangrove fringe in 1985 (Bird 1986).

The Inlets

The Koo-Wee-Rup swamp presented early settlers with an obstacle to overland travel (Gunson 1968). The land was also unsuitable for permanent settlement and agricultural development. Construction of a main drainage channel began in 1876, to divert water from the swamp into the bay via inlets between Tooradin and Yallock Creek. The Koo-Wee-Rup swamp was drained between 1870 and 1939 (Bird 1986). It is now an extensive area of channelled farmland. By 1939, mangrove-salt marsh vegetation at the inlets had died, due to a series of floods between 1893 and 1952 which caused salinity dilution around the inlets (Shapiro 1975). A reduced occurrence of floods between 1953 and 1974 returned salinity levels to normal and there was some mangrove regeneration.

Red Bluff and Stockyard Point

In the mid-nineteenth century the area from Red Bluff to Stockyard Point was used as a loading/unloading point for cattle and produce. Mangroves were cut down and burnt, to produce barilla ash for soap-making. Loss of mangroves occurred between 1842 and 1939. By 1974 a sand-ridge had built up, caused by sandy drift into the area. There was further mangrove decline associated with sand deposition. The salt marsh remained, but mangroves became sparsely distributed (Champion 1974).

Pioneer Bay

Early settlers cleared mangroves around Pioneer Bay in 1840. By 1974 there had been an extensive decrease in the area of mangroves. This was probably due to gaps being cut in the mangrove fringe to allow boat access. Only sparse mangroves remained, though the salt marsh remained (Champion 1974).

Bass River Mouth

Extensive salt marsh was recorded along the Bass River in 1962 (Bird & Barson 1975). In 1965 there were two areas of mangroves-one to the north and one to the south of the Bass River. By 1975, mangroves had advanced onto the muddy north shores of the River. Sand drifting in from the bay prevented mangrove spread onto the south shore. *Spartina angelica* was introduced to the area prior to 1974.

Observation Point, Phillip Island

In 1842 there were mangroves to the west and south of Observation Point (Bird & Barson 1975). By 1938 there were gaps in mangroves to the south, where a quarry and cattle landing were built. By 1974 there was extensive mangrove dieback on either side of the cattle landing. A gap was cut in the vegetation near the quarry, probably for boat access. By 1974, mangroves to the west had advanced seawards and were succeeded by saltmarsh.

Fairhaven, French Island

Mangroves were present at Fairhaven in 1842 (Bird & Barson 1975). Gaps were cut in the vegetation for boat access, and by 1974 sand had accumulated in the area, the mangroves had decreased and the salt marsh was eroded. There was a widening of the boat access gaps, and sandy drift prevented mangrove regeneration.

Scrub Point, French Island

There were continuous mangroves and salt marsh at Scrub Point in 1842 (Bird & Barson 1975). By 1865 there was a large gap in the vegetation. Gaps were cut for drainage channels, boat access, and to harvest mangrove wood for barilla ash production. There was a revival of mangroves by 1939. In 1974 there were different areas containing healthy, declining and dead mangroves. Dieback of mangroves was evident in 1985 (Bird 1986).

Spit Point, French Island (also known as Sandy Point)

In 1842 there was a mangrove fringe north of Spit Point (Bird & Barson 1975). These mangroves were possibly cut down and burnt to produce barilla ash in 1843-4 (Shapiro 1975). By 1974 there were only a few trees remaining in sandy mud in front of a sandy beach. Sandy drift into the area prevented regeneration. In 1842 Smythe recorded no mangroves to the south-west of Spit Point, however mangroves were present in 1865. This may either indicate regeneration, or error by Smythe.

Tortoise Head, French Island

This former island is separated from French Island by a channel. Between 1842 and 1974 mangroves advanced onto the channel shores (Bird & Barson 1975). In other areas mangroves declined. Mangroves were possibly replaced by saltmarsh in some areas.

Mangroves, and in some cases salt marshes, have also been recorded at Tyabb shore, River Point and along the north coast of French Island, Barrallier Island, Quaill Island, and Phillip Island between Newhaven and Rhyll (Champion 1974).

MANGROVE–SALT MARSH MONITORING IN WESTERNPORT BAY

In 1942, R.T.Patton carried out the first scientific monitoring of Westernport Bay salt marsh, though mangroves were not included. Salt marsh was particularly well-developed in the north and north-west of the bay. In some areas, such as Tooradin Pier, there was a clear junction between the salt marsh and mangrove, marked by a sharp drop in the soil surface. In other sectors, such as Bembroke and Hastings, the marsh was gradually sloped and the border between salt marsh and mangrove not well defined. A narrow bare zone commonly occurred between the saltmarsh and Ti-tree (*Melaleuca ericifolia*) zone. There was often a layer of salt on this bare zone during summer. A bare zone was also present in 1972 at Yaringa (Ashton 1972).

Four transects were taken across the marsh, between the mangrove and Ti-tree zones, at 3 widely separated places. Sixty $0.7m^2$ quadrats were sampled, 5.3 metres apart. Percentage occurrence was recorded for each species present, with each species assigned a frequency code as follows:

c=common
f=frequent
l.a.=locally abundant
m=marginal
o=occasional
r=rare
v.c.=very common
v.r.=very rare

Soil samples were collected across the width of the salt marsh during February. Though the marsh was densely populated with individuals, it was species-poor (26 species), a characteristic of pioneer communities. There was a dense ground-cover containing 4 genera of the family *Chenopodiaceae: Salicornia, Sclerostegia, Atriplex* and *Sueda. Atriplex* did not occur in a single quadrat, though it was sparsely distributed in

Westernport Bay. A number of species labelled ‘marginal’ occurred on the landward side of the marsh and were rarely found elsewhere in the marsh, increasing the total species recorded.

To the east of Tooradin, where the Toomuc and Cardinia Creeks entered the bay, the salt marsh ended on its landward side in grassland. *Mentha X rotundifolia* was much more common here than in other areas, and extended well into the marsh. The period of greatest floral activity was between November and February. During winter, water lay on the flat marsh, decreasing salt concentration.

Salt marsh along the coastline between Sandy Point and Blind Bight was studied during an investigation of Mornington Peninsula vegetation (Calder 1972). Twelve transects were located at randomly selected sites between Sandy Point and Blind Bight. Run across the width of the salt marsh, transects varied from 28.5 to 271.5m long. Transects extended from the *Melaleuca ericifolia* zone to the outermost occurrence of *Sclerostegia*, which usually corresponded with the inshore limit of mangroves. Species occurrence was recorded in 1.5m^2 quadrats. Percentage cover of species was visually estimated and recorded using a modified Braun Blanquet % cover index:

5=75-100% cover
4=50-75% cover
3=25-50% cover
2=5-25% cover
1=1-5% cover
+=<1% cover
0=present in immediate vicinity

Soil samples were taken from 90cm deep auger holes. In the field, horizon depth, soil texture, pH and depth of the water table was recorded.

The Westernport Bay Environmental Study in 1973-4 provided baseline data on the peripheral vegetation of Westernport Bay (Shapiro 1975). The seagrass, mangrove, salt marsh and *Melaleuca ericifolia* zones were studied using Zurich-Montpellier methodology. This system describes vegetation by grouping similar stands according to floristic similarity (Bridgewater 1971). Groups of vegetation stands are arranged in a hierarchical structure. The basic units of the Zurich-Montpellier hierarchy are termed 'Kennarten', or differential species. These species differentiate a unit of vegetation from similar units, but are not restricted to that unit. The two main phases involved are analysis (description) and synthesis (classification). Mangrove-salt marsh sampling was confined to well-developed vegetation, with fragmented systems omitted (Bridgewater 1975). 430 quadrats, each $5m^2$, were sampled from over 60 $1km^2$ square plots.

A classification scheme was devised based on that of de Smidt (Bridgewater 1975). The highest level in the classification is the complex, which comprises a group of communities. Within communities there may be sub-communities and variants. Nine major mangrove-salt marsh complexes were identified:

1. *Avicennia* complex – Mangrove zone
2. *Spartina* complex
3. *Salicornia* complex
4. *Sclerostegia* complex
5. *Suaeda* complex - Salt marsh zone
6. *Puccinellia* complex
7. *Juncus* complex
8. *Stipa* complex
9. *Schoenus* complex

Greatest diversity was found in the area from Tyabb to Tooradin and on the north coast of French Island. This area was classed as a high priority conservation zone due to its botanical importance. It contained the largest number of sub-communities, and populations of the more restricted species. 4 species that were widespread in this area did not occur anywhere else in Westernport Bay. Cattle grazing on French Island contributed to species richness.

Salt marsh vegetation of Westernport Bay was classified as highly diverse (Shapiro 1975), consistent with the pattern of high diversity in high latitude regions of Australia (Hutchings & Saenger 1987; Saintilan & Williams 1999). Mangrove-salt marsh vegetation of Westernport Bay was distributed as follows:

Avicennia complex

Avicennia marina community

The *Avicennia marina* community was distributed right around the bay, but was concentrated in the north-west arm and at the mouth of the Bass River.

Spartina complex

Spartina x. townsendii community

An introduced species, *Spartina* occurred at the mouth of the Bass River, the Main Drain outlet and possibly elsewhere. It usually grew amongst other species, often invading *Salicornia* communities.

Salicornia complex

Triglochin striata community

The *Triglochin striata* community occurred along creeks and on mudflats, apart from the *Schoenus nitens* sub-community which was found only on the west coast of French Island, where it grew on the inland side of the marsh.

Salicornia quinqueflora community

The *Salicornia quinqueflora* community was found directly behind *Avicennia*, though it sometimes occurred without any *Avicennia* present. Found growing on both the seaward and landward sides of the marsh, *Salicornia quinqueflora* usually occurred as a single species community. It was most common on the south-east coasts of Westernport Bay and French Island.

Sclerostegia complex

Sclerostegia-Puccinellia stricta community

Usually found on the landward side of the salt marsh, this was a transition community between *Sclerostegia* and *Puccinellia* communities.

Sclerostegia-Triglochin striata community

This community was found between *Salicornia* and *Sclerostegia* communities

Sclerostegia-Atriplex paludosa community

Found on drier, often raised areas, this community contained relatively few species.

Sclerostegia-Stipa teretifolia community

This community grew as patches amongst other *Sclerostegia* communities, in the driest and highest areas. Stipa was dominant or co-dominant.

Sclerostegia-Sueda australis community

This was a species–poor community. *Sclerostegia* usually covered more than 60% of the surface area.

Sueda complex

This complex was characterised by the absence of *Salicornia quinqueflora* and *Samolus repens*, which occurred in all other complexes.

Sueda australis community

The *Sueda australis* community occurred on strand lines, mainly in areas that lacked developed salt marsh. The *Atriplex prostrata* sub-community occurred where there was no salt marsh littoral fringe. The *Atriplex cineria/paludosa*? sub-community was found in the large saltings at the mouth of the Bass River.

Sclerostegia arbuscula community

Dominated by *S. arbuscula*, there were almost no other species present in this community. It occurred in three widely separated quadrats, in dry conditions, such as at Palmers Point on French Island, where there is a deep drain (Shapiro 1975).

Puccinellia complex

The *Puccinellia* complex was found on the landward side of the salt marsh, behind *Sclerostegia* communities.

Puccinellia stricta community

The *Puccinellia stricta* community was distributed bay-wide, with the largest populations at Rhyll, the mouth of the Bass River and the north coast of French Island. Abundances at Bass River and the north coast of French Island were due to cattle grazing. *Salicornia* was abundant. A *Parapholis incurva* sub-community was restricted to the mouth of the Bass River and the north coast of French Island.

Puccinellia-Triglochin striata community

The *Puccinellia-Triglochin striata* community occurred between the *Puccinellia stricta* community and pools containing the algae *Ruppia maritima* and *Lamporothamnium papulosum.*

Frankenia pauciflora community

This community was a transition between the *Salicornia* community and the *Schoenus-Cotula* community.

Disphyma australe community

Found in dry and often disturbed parts of the marsh, the *Disphyma australe* community often grew as a mosaic with other *Puccinellia* communities. *Puccinellia stricta* was absent. In areas of disturbance there was a *Plantago coronopus* sub-community.

Juncus complex

Juncus maritimus community

J. maritimus was dominant in this community. Boundaries between *Juncus* and other species were sharp. The *Juncus maritimus* community occurred on the sea side of *Sclerostegia*, and also on the far landward side of the marsh. In areas of freshwater flow, mesophytes grew in this community.

Stipa complex

Stipa teretifolia community

The *Stipa teretifolia* community grew only on dry sites. It was found on sandy banks around the bay and on sandy deposits amongst other salt marsh vegetation.

Shoenus-Cotula complex

Shoenus nitens-Cotula coronopifolia community

This was the most landward community of the salt marsh vegetation, and the most diverse, containing many species of grass and herbaceous plants. Cattle grazing restricted diversity, especially when it involved removal of the *Melaleuca* complex. Rabbit grazing seemed to prevent succession. There was a *Distichlis distichophylla* sub-community.

After the initial 2-year investigation, further studies of water and sediment movement in Westernport Bay continued, along with discussion on the relevance of these studies for environmental planning and development of management guidelines (Butcher 1979). The Westernport Bay Environmental Study 1973-74 became the Westernport Regional Environmental Study, one of three major environmental studies in Victoria. The project concluded in 1979.

A study of sites of botanical significance in the Westernport region included salt marsh but not mangrove (Opie *et al.* 1984a). Data from several previous studies was incorporated into the report, with quadrats 25, 90 or 1000 m^2. Data sources were from between 1972 and 1981. Data from all sources were collected using the same basic method. Quadrats were placed where they contained only one obvious vegetation type. All vascular plants present in each quadrat were recorded and assigned an estimate of abundance according to the Braun-Blanquet scale:

5=75-100% cover	(Any number of individuals)
4=50-75% cover	(Any number of individuals)
3=20-50% cover	(Any number of individuals)
2=5-20% cover	(Any number of individuals)
1=5% cover	(Any number of individuals)
+=5% cover	(Few individuals)

Data was collected on the height and cover of different layers in the vegetation, botanical landscape quality, surrounding disturbances, age of the stand, size of the vegetated area, any other features of biological interest, locality and altitude.

Mangrove-salt marsh vegetation was studied in the Bittern coastal wetland area (Jaremovic *et al.* 1992). 30m^2 quadrats were sampled at 8 sites, and the condition, composition and structure of the vegetation recorded. All species were assigned a cover/abundance value from a modified Braun-Blanquet scale:

5=75-100% cover	(Any number of individuals)
4=50-75% cover	(Any number of individuals)
3=20-50% cover	(Any number of individuals)
2=5-20% cover	(Any number of individuals)
1=<5% cover	(Any number of individuals)
+=<5% cover	(Few individuals)

Conservation status was assessed at the species and community levels. The categories were: endangered, vulnerable, rare and depleted. Four mangrove-salt marsh communities were identified in the Bittern coastal wetland area:

Mangrove community

This single-species (*Avicennia marina*) community occurred along the majority of the study area coastline, on the seaward side of salt marsh. It was absent from the areas immediately north and south of Crib Point and near Golden Point.

Sarcocornia community

Dominated by *Sarcocornia quinqueflora*, this community also contained *Triglochin striata* and *Sueda australis*. It commonly occurred immediately behind the mangrove zone and in depressions holding seawater.

Sclerostegia community

This Closed-heath to Low open-shrubland was dominated by *Sclerostegia arbuscula, Sarcocornia quinqueflora, Hemichroa petandra* and *Samolus repens. Distichlis distichophylla* and *Sueda australis* were often subdominants. It occurred landwards of the *Sarcocornia* community in areas of mud accretion

Mixed species salt marsh community

This herbland occurred landwards of the *Sclerostegia* community and was dominated by *Juncus kraussii* and *Sarcocornia quinqueflora*. Frequent subdominants were *Distichlis distichophylla*, *Selliera radicans* and *Samolus repens.*

A more detailed mangrove study was conducted at Jack's Beach, a population typical of the Bittern region (Jaremovic *et al.* 1992). There was a gap in the mangrove fringe where a jetty was built in the 1920s and used until the 1960s. The mangrove zone was 30m to 60m wide, extending north and south from the gap. Measures were made of tree density, height and trunk diameter at ground level. Density was measured from the gap to 100m southwards, using the method of point-centred quarters (Cottam & Curtis 1956). 12 points were randomly chosen, with a total of 48 mature trees. It was concluded that the Jack's Beach mangrove community was mature, well established and had been stable for at least 50 years. There was no advance either landwards or seawards.

A vegetation assessment of French Island State Park incorporated areas of mangrove and salt marsh (Vanderzee 1993). Eighteen wetland areas were sampled using 100m^2 quadrats. At each site, two quadrats were sampled- one in the wetland itself, and the other in the adjoining vegetation. All plant species present were recorded and assigned a Braun-Blanquet cover/abundance value:

5=75-100% cover
4=50-75% cover
3=25-50% cover
2=5-25% cover
1=5% cover
+=few individuals

Locality (longitude and latitude), altitude, water level and soil moisture was recorded. Sites were assigned a rating of botanical quality. Structural classification of a stand was made through estimation of the height and cover of the different vegetation layers. The degree of disturbance at a site was recorded through visual assessment of the landscape. Surrounding disturbances indicated the threats or potential threats posed to the vegetation. The size of the vegetated area indicated its degree of isolation. Maturity if the stand was estimated and any other features of biological interest were recorded.

MANGROVE-SALT MARSH MONITORING IN NEW SOUTH WALES

Mangrove-salt marsh vegetation was recently studied in NSW with quadrats (Clarke 1993; Clarke & Myerscough 1993; Zedler *et al.* 1995; Saintilan 1997). Mangrove-salt marsh studies in Jervis Bay revealed a community consisting of about 38 species, of which 5 were exotic (Clarke 1993). Six tidal inlets were sampled. Each was divided into 500m sections, and transects were randomly placed at right angles to the vegetation zones. Adjacent to each transect, 50 x 20m plots were established at low, mid and high tidal elevations in structurally similar vegetation. Four $5m^2$ quadrats were placed randomly within each plot. Floristic lists were compiled from the quadrats, transects and general observation of the areas. Presence/absence of species was recorded at 1m intervals along the transects. Cover of each species in the quadrats was estimated using the following classes:

5=81-100% cover
4=51-80% cover
3=21-50% cover
2=5-20% cover
1=less than 5% cover

To describe the mangrove community structure, *Avicennia marina* was divided into the following classes:

seedlings
shrubs <2m
shrubs 2-5m
single stemmed trees >5m
multi stemmed trees >5m

Degraded salt marsh scheduled for restoration was studied on the Hunter River (Zedler *et al.* 1995). Three transects were taken at Koorang Island, two of which were subject to heavy cattle grazing. One transect was established at Towra Point, a site which had not been grazed in recent years. Transects spanned from the most inland mangroves right across the salt marsh. Transects were located by measuring regular distances from a haphazardly chosen point. Relative elevations were surveyed at 1m intervals along each transect, and soil salinities were measured every 10m. 249 1m^2 quadrats were sampled at Koorang Island and 60 at Towra Point. Estimates of bare space and percent cover of each species were made, using seven classes (<0.5, 0.6-1, 2-5, 6-25, 26-50, 51-75, 76-100%).

SEDIMENT ELEVATION TABLE (SET)

A Sediment Elevation Table (SET), previously known as a Sediment Erosion Table, is a device for accurately measuring the elevation of the wetland sediment surface relative to a stationary point below the surface (Morris 1999). SETs provide a precise way of measuring rates of subsidence, sedimentation and erosion. This information may be used to forecast responses to environmental change, such as the predicted sea level rise associated with global warming. This will also lead to better management of coastal wetlands. Developed by Boumans and Day in 1993, a SET comprises a pipe sunk 3-6m into the marsh, with an attached levelling device (Cahoon *et al.* 1995). Pins at the end of the accurately levelled horizon arm are lowered to the sediment surface to measure elevation. The bottom of the SET pipe is the reference datum, which is assumed to be stable. Sampling platforms are located nearby to enable data collection without disturbance to the marsh.

Elevation change was measured with SETs in salt marshes in the southeastern United States (Cahoon *et al.* 1995). Subsurface data were placed 3-5m below the surface. At each site, seven sampling platforms were randomly placed in an area of the marsh with uniform vegetative cover and species composition. Three of these were randomly selected as SET stations. There were 36 pins at each SET station, totalling 108 pins at each site. Elevation measures were made over a 2-year period. It was found that significant subsidence occurred over the 2 years.

SETs overcome many of the limitations of other methods. They may be used in both intertidal and subtidal environments. SETs can be used to determine if the rate of subsidence and compaction exceeds the rate of sedimentation, which may be the case in areas where mangroves advance upon salt marsh. Subsidence may be the cause of wetland change in Corner Inlet, Victoria (Vanderzee 1988). This has applications for Westernport Bay, where mangrove incursion into salt marsh has been observed in some areas but not thoroughly investigated.

SUMMARY

The mangrove-salt marsh vegetation of Westernport Bay is of regional, national and international significance. Salt marsh in Westernport Bay is highly diverse, while there is only one mangrove species, *Avicennia marina*. Mangroves in Victoria are at their southern limit, with the most well developed communities occurring in Westernport Bay. The mangrove-salt marsh system plays an important role in stabilising the coastal system, nutrient cycling in the bay and providing wildlife habitat. Many changes have occurred in the salt marsh and mangrove area cover and distribution since European settlement in the early 1800s. The vast majority of these changes are either directly or indirectly related to human activities. Mangroves were cleared to create boat access, to produce barilla ash for soap production, and to reclaim land for industrial and port development. In turn, this exposed nearby mangroves and salt marsh to the damaging effects of tidal scour, erosion and increased sedimentation. Sandy deposits in areas once occupied by mangroves impeded their regeneration. Mangrove-salt marsh vegetation was also damaged through cattle grazing, the use of 4WD vehicles and decreased salinity associated with freshwater entering the bay from drained swamps.

The banded zones of salt marsh and mangrove in Westernport Bay represent a long-term successional sequence, with mangroves advancing seawards to be replaced by salt marsh. It is now recognised that this does not always occur. In some areas of New South Wales, salt marsh is threatened by the landward incursion of mangroves. This is a reversal of longer-term vegetation change (Saintilan & Williams 1999). Landward transgression of mangroves into salt marsh was recorded in some areas of Westernport Bay (Clough 1975; Bird & Barson 1975). No claims have yet been made that salt marsh is under threat from mangroves in Westernport Bay. It appears that the disappearance of mangroves is a more pressing issue, especially since this usually results in subsequent loss of salt marsh.

Sediment Elevation Tables provide an accurate and non-intrusive method for determining long-term changes in sediment levels. They may be used to determine if sediment surface subsidence and compaction outweighs sediment accretion in areas where mangroves invade salt marsh. On-going studies are needed in Westernport Bay, to determine what changes are occurring in sediment elevation and the distribution of

mangrove-salt marsh vegetation. Long-term quadrating of mangrove-salt marsh vegetation is required to monitor the diversity and overall health of this important ecosystem.

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APPENDIX I

Westernport Contacts

People with expertise relevant to mangrove-salt marsh research in Westernport Bay, their contact details and whether or not they were contacted as of June 2000.

Name		**Organisation**	**Contact Details**	**Contact Details**	**Contacted**	**Notes**
Robyn Adams		Deakin University				Field studies in westernport
Dr. Dave Ashton	Assoc. Prof. Botany	Department of Botany, La Trobe U	Tel: 9479 2217 or 9830 4209			Decades of studies on mangroves in Westernport Bay
Yvette Baker		Department of Defence				Environmental management and reports for Defence properties
Paul Barker	Land Victoria Archivis	NRE Archives	Tel: 9412 4615, Fax: 9412 4896	240 Victoria Pde, East Mel	*	NRE Ministry of Conservation Archived Files
Max Bartley		LaTrobe University	Tel:		*	Field studies in westernport
Juliet Bird	Assoc. Prof.	Department of Geography, Melb. Uni.				Wife of Eric Bird, who studied mangroves and salt marsh in Westernport Bay
Dr. Peter Bridgewater						siginificant studies on Westernport & mangoves
Winty Calder						researcher and published Peninsula Perspectives
Margaret Clayton		Monash University	Tel: 9905 4000			
Helen Cohn	Senior Librarian	National Herbaium of Victoria & R	Tel: 9252 2300	South Yarra	*	Publications including old original references & historical photos and slide collection
Peter Dann		Phillip Island Nature Park	Tel: 5956 8300 / 4 / 39, Fax: 5956 8394		*	Historical Photos
Astrid D'Silva		NRE Archives	Tel: 9412 4942	240 Victoria Pde, East Mel	*	
Bob Farquar		NRE Registry			*	NRE archive files
Adrian Goodrich		Land Victoria, Land Information G	Tel: 9269 4500, Fax: 9269 4539, Mob: 0412 379 150	2/121 Williams St, Melb.	*	Aerial photos of Westernport Bay
Carol Harris	Librarian	ARI Library	Tel: 9450 8604, Fax: 9450 8799	123 Brown St Heidelberg	*	Library search & access to publications
Sue Harris		City of Cardinia			*	Environmental responsibilities
Greg Jenkins		MAFRI	Tel: 525 80333, Mob: 0407 507 581			Recently mapped seagrasses in Port Phillip and Westernport Bay
Anne Lowry	Assoc. Prof Biol Sci.	RMIT				
Rosemary Mynard		Cranbourne Historical Society	Tel: 5998 3643	Tooradin		
Doug Newton	Manager, Westernport	EPA Marine Science Unit	Tel: 9695 2532, Fax: 9695 2690, Mob: 0412 234 964	40 City Rd, Southbank	*	
Tony Norton		NRS LIMS				NRE GIS information and files
Dr. Bob Parsons	Senior lecturer, Ecolog	Department of Botany, La Trobe U	Tel: 9479 2216, 9479 2217		*	Decades of studies on vegetation in Westernport Bay
Neville Rosengren						Geologist & soils expert
Scott Seymour		Melbourne Water	Tel: 9235 2127. Mob: 0402 002 463		*	
Barry Short		NRE Fire Protection				Forests Commission Collection of Information
Andy Stevens	Marine Projects Office	EPA Marine Science Unit	Tel: 9616 2359, Fax: 9628 5699/9614 3575	27 Francis St. Melb.	*	Studied seagrasses in Westernport Bay using aerial photos
Claire Turner	Historical Officer	Casey - Cardinia Library	Tel: 9704 7696	Narre Warren	*	Old photos of Westerport
Michael Vanderzee		NRE	Tel: 9637 8597			Studied mangroves in Corner Inlet
Joss Verstraelen		NRE		Nicholson St		Ministry of Conservation Files
David Westlake	Environmental Officer	City of Casey	tel: 9705 5200			
Phil Westwood	& Tim Ealey	Bass Valley friends group	Westwood” <bassbush@nex.net.au>	Corinella Community Centre		Involved in mangrove replanting near Corinella, Westernport Bay
John White		Land Victoria, Land Information G	Tel: 9269 4555, Fax: 9269 4501	2/121 Williams St, Melb.	*	Aerial photos of Westernport Bay
Anthea Whitelaw		Sth Gippsland Conservation Society	Tel: 5674 3738		*	Librarian-set up library at Bunurong Environment Centre (Inverloch, Anderson’s Inlet)
Ross Williamson		NRE Foster	Tel: 5682 2133			Anderson’s Inlet mangrove-salt marsh vegetation.
Dr. Jeff Yugovic	Consultant Botanist	Biosis	Tel: 9646 9242			Bay

APPENDIX II

Westernport Aerial Photos

Aerial photos of Westernport Bay located during the course of this review. Sheet 1 is a list provided by Andy Stevens of the Environment Protection Authority. Sheet 2 is a list provided by the Land Victoria Land Information Group. Sheet 3 is a list provided by the Phillip Island Nature Park (See Appendix I for contact details).

Westernport Aerial Photos

EPA

Begin Year	End Year	Title	Map
1973	1973	Adams Point Pr Col	7921
1973	1973	Adams Point Project B/W	7921
1978	1978	Cranbourne	7921
1981	1981	Cranbourne	7921
1981	1981	Cranbourne	7921
1983	1983	Cranbourne	7921
1983	1983	Cranbourne	7921
1987	1987	Cranbourne	7921
1973	1973	Fisherman Point Project B/W	7921
1973	1973	Fisherman Point Project Col	7921
1978	1978	Frankston	7921
1981	1981	Frankston	7921
1983	1983	Frankston	7921
1988	1988	Frankston	7921
1951	1951	Frankston Ptn/Melb Met	7921
1951	1951	Frankston Waarre Plantation	7921
1974	1974	Hastings Bight Project Set1Col	7921
1974	1974	Hastings Bight Project Set2B/W	7921
1973	1974	River Point (French Island) Pr Col	7921
1973	1974	River Point Pr (French Is) B/W	7921
1939	1939	Westernport/Woolamai	7921
1975	1975	Westernport	7921
1979	1979	Westernport	7921
1981	1981	Westernport	7921
1982	1982	Westernport	7921
1983	1983	Westernport	7921
1983	1983	Westernport	7921
1985	1985	Westernport	7921
1973	1974	Westernport Project Addn Runs (W	7921
1973	1973	Westernport Project B/W	7921
1973	1973	Westernport Project Col	7921
1960	1961	Port Phillip Bay Eastern Foreshores	7921
1957	0	Westernport	7921
1966	1966	Port Phillip Foreshore	7921
1967	1967	Melbourne Project	7921
1971	1971	Hastings Channel Project	7921
1973	1973	Westernport Project	7921
1965	1965	Warragul-Cape Patterson-Inverloch	7921
1977	1977	Western Port Foreshores	7921
1977	1977	Victorian Foreshores Project	7921
1984	1984	Nelson-Cape Patterson	7921
1977	1978	Westernport	7921
1980	1982	Frankston (Seaford)	7921
1950	1950	Somers	7921
1971	1971	Phillip Island	7921
1981	1981	Mornington Peninsula (1980 Project)	7921
1939	1939	Woolamai-Westernport	7921
1960	1960	Cowes	7921
1984	1984	Westernport Foreshores (Somers)	7921
1957	1957	Flinders Base Map (Somers)	7921

Land Victoria

Begin Year	End Year	Title	Project	Map	Runs	Reel	Film	Photos	Source
1939	1939	Cranbourne		3065		2703		6699-6713, 6719-6723, 6730-6744	VFRI, Queenscliff
1967	1967	Warragul J55-10/162-203			3&4		CAD37	201, 205, 210, 214	United Photo & Graphic Services
1970	1970	Melbourne Eastern Suburbs	832		3&4		2385	100, 103, 105, 107, 153, 158, 161	VicImage Melbourne
1975	1975	Woolamai Western Port Mapsheet			1		2964	90, 92, 93, 95, 97	VicImage Melbourne
1980	1980	Western Port 7921			7&8		3488	35, 37, 39, 41, 43, 45, 50, 52, 54, 56, 58	VicImage Melbourne
1983	1984	Western Port Seagrass Survey							Mosaics-held by VFRI, Queenscliff
1987	1987	Melbourne and Environs, QAS 2510c			29c			6791	Quasco (Victoria) P/L, Melbourne
1989	1989	Melbourne 89 Vic DPS	2004		40			98, 100, 102, 104, 105, 127, 129, 131	VicImage Melbourne
1994	1994	EPA Western Port Survey						135-179	Quasco (Victoria) P/L, Melbourne

Phillip Island Nature Park & NarreWarren Library

Year	Title	Source	Details
1944	Churchill Island	Phillip Island Nature Park	Height 4200ft. Scale 1:6000.Russ Evans. Donated by Arthur Evans, 21/03/97, Tel: 0359 522 421
c.1960s	Return to Churchill Island	Phillip Island Nature Park	Lower resolution
c.1960s	Return to Churchill Island	Phillip Island Nature Park	Higher resolution
1947	Korumburra A3 or 869 A3 Zone 7	Narre Warren Library	Aerial survey of Victoria. Dept. of Lands & Survey. Astrada Airways. Mosaic prepared by comparison of cadastral survey. Central Plan Office. CPO Neg no. 19018

APPENDIX III

SET References

A list of references on SETs, provided by Kerrylee Rogers, Australian Catholic University.

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APPENDIX IV

Mangrove References

A complete list of references relevant to mangroves and salt marshes, in Westernport Bay, elsewhere in Australia and the world. Each reference is flagged with whether or not it is cited in the review, and additional information on its contents.

Reference	Cited	Westernport Bay	Other location	Not yet received	SETS	Methodology	Aerial Photos/Maps	Data
Adam, P. & Hutchings, P. 1987. The saltmarshes and mangroves of Jervis Bay. *Wetlands (Australia)* **6(2):** 58-64.			NSW					
Adam, P. 1994. Saltmarsh and mangrove. *Australian vegetation* (ed. By R.H. Groves), 2nd edition, pp395 – 435. Cambridge University Press. Cambridge.			AUST					
Adam, P. 1998. Australian saltmarshes: a review. *Wetlands for the future: International Wetlands Conference*. Gleneagles Publishing. Adelaide. South Australia.			AUST					
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	Dave Ashton		
Geography Dept. Melb. University	Julliet Bird (to contact Eric Bird)		
Sth Gippsland Conservation Society	Anthea Whitelaw	5674 3738	*
NRE Foster: Anderson's Inlet	Ross Williamson	5682 2133	