



Best practice guidelines for coastal saltmarsh

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Cover photos: Saltmarsh: Lyndsay Holme; White-fronted chat: Jon Irvine

Published by:

Department of Environment and Climate Change NSW
59–61 Goulburn Street, Sydney
PO Box A290, Sydney South 1232
Phone: (02) 9995 5000 (switchboard)
Phone: 131 555 (information and publications requests)
TTY: (02) 9211 4723
Fax: (02) 9995 5999
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

DECC 2008/616

ISBN 978 1 74232 050 2

December 2008

Printed on environmentally sustainable stock

The Department of Environment and Climate Change NSW and Sydney Metropolitan Catchment Management Authority acknowledge the assistance of the Sydney Olympic Park Authority in preparing these guidelines.

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1 Introduction

Coastal saltmarsh is a mostly treeless floral community characterised by low succulent herbs and salt-tolerant grasses, rushes and sedges (DECC 2007). Coastal saltmarsh occurs in intertidal zones that are permanently or intermittently open to inundation by marine tides, frequently on the landward side of mangrove stands (DECC 2008a). It was listed in 2004 as an endangered ecological community under the *Threatened Species Conservation Act 1995* (NSW) in the NSW North Coast, Sydney Basin and South East Corner bioregions.

The Sydney Metropolitan Catchment Management Authority and Department of Environment and Climate Change NSW (DECC) have identified the need to produce best practice guidelines for coastal saltmarsh, and Sydney Olympic Park has been chosen as a demonstration site for the management of this endangered ecological community. These guidelines outline the innovative management of saltmarsh at Sydney Olympic Park and other sites to provide a technical guide applicable to the management of other saltmarsh communities. They provide practical guidance to bush regenerators, volunteers and the community.

1.1 Sydney Olympic Park

Sydney Olympic Park is home to approximately 20 hectares of coastal saltmarsh, comprising the largest remaining stands on Parramatta River and the second largest in the Sydney Basin bioregion. Coastal saltmarsh at Sydney Olympic Park forms part of a rare example of complete zonation from estuarine waters through to mangroves, saltmarsh, casuarinas and Cumberland Plain woodland.

Sydney Olympic Park's coastal saltmarsh supports one of only two remaining Sydney populations of the white-fronted chat (*Epthianura albifrons*). It also contains the largest Sydney population of narrow-leafed wilsonia (*Wilsonia backhousei*), a threatened plant that is listed as vulnerable under the *Threatened Species Conservation Act 1995* (NSW).

The largest stands of coastal saltmarsh at Sydney Olympic Park are protected in Newington Nature Reserve, which was gazetted in 2000 after formerly being part of a naval armaments depot on Parramatta River. Other stands of coastal saltmarsh are at Badu Mangroves in Bicentennial Park, along the banks of Haslams Creek, and adjacent to the River Walk along Parramatta River.

Management issues associated with coastal saltmarsh at Sydney Olympic Park include invasion by weeds, particularly spiny rush (*Juncus acutus*), encroachment of mangroves, and maintenance of appropriate tidal regimes.

2 Coastal saltmarsh

Coastal saltmarsh habitat and distribution are largely controlled by high and mean tides, because saltmarsh occurs in intertidal zones that are intermittently inundated by salt water, and is commonly found on the landward side of mangroves (DEC 2005a). In most areas saltmarsh is not inundated daily by tides, but relies on king or spring tides (Johns 2006). Characteristic vascular plant species of coastal saltmarsh include *Baumea juncea*, knobby club rush (*Ficinia nodosa*), sea rush (*Juncus kraussii*), creeping brookweed (*Samolus repens*), samphire or beaded glasswort (*Sarcocornia quinqueflora*), swampweed (*Selliera radicans*), saltwater couch (*Sporobolus virginicus*), austral seablite (*Suaeda australis*), streaked arrowgrass (*Triglochin striata*) and prickly couch (*Zoysia macrantha*) (DECC 2007, 2008a).

Many species of fauna use saltmarsh as habitat for foraging, breeding and roosting. Terrestrial fauna such as birds, insects, mammals, and aquatic fauna such as crabs, molluscs and fish use saltmarsh at different stages of the tide. Fish which frequent saltmarsh during high and spring tides consume organic films that cover saltmarsh, the periodically abundant crab larvae, and larger prey (Mazumder et al. 2006). High saltmarsh concentrations of zooplankton, predominantly crab and gastropod larvae, provide an important source of food for estuarine fish that may not venture into the saltmarsh (Mazumder et al. 2008). Shorebirds often feed in saltmarsh as it provides a good source of invertebrates at low tide. Bats have also been known to forage for insects in saltmarsh.

Coastal saltmarsh has not always been highly regarded as an ecological community. In the past, substantial areas of saltmarsh have been infilled for development. Tidal flows have been altered by artificial structures, such as seawalls, threatening saltmarsh communities. The discharge of stormwater in coastal areas alters salinity regimes, increases nutrient levels and facilitates the spread of introduced species.

At Sydney Olympic Park, large areas of saltmarsh grow in highly modified habitats of past land reclamation, rubbish dumping and chemical pollution (Kelleway et al. 2007). Although saltmarsh has been known to colonise disturbed areas, such as seawalls and occasionally the land behind seawalls, such instances are rare, and human modification generally poses the major threat.

Photo: Sydney Olympic Park Authority



Coastal saltmarsh



3 Guidelines for bushland managers and regenerators

Coastal saltmarsh is affected by a combination of threats, including clearing and modifying of vegetation, weeds, altered fire and hydrological regimes, predation from introduced pests, disease, climate change and stormwater.

Successful best practice methods implemented at Sydney Olympic Park to manage coastal saltmarsh include:

- weed management
- native vegetation management
- planting
- fauna management
- hydrology management
- access management and community awareness
- planning
- monitoring.

These and other best practice methods are described below. In selecting sites for saltmarsh rehabilitation, priority needs to be directed towards locations where saltmarsh has a chance to respond to sea level rise (see section 3.8).

A section 132 licence should be obtained under the *National Parks and Wildlife Act 1979* before undertaking any works in endangered ecological communities, such as coastal saltmarsh.

3.1 Weed management

Saltmarsh species are extremely sensitive to changes in elevation, even a few centimetres. It is, therefore, very important that weed removal techniques used in saltmarsh have minimal impacts on soil topography. General bush regeneration strategies focus on areas that are relatively free of weeds, and then work towards areas of high weed infestation. Bush regeneration works at a pace that allows native vegetation time to establish. There are three phases of a weed control program: primary, consolidation and maintenance.

Phase 1: Primary. The bulk of the weeds are removed in a staged approach section by section.

Phase 2: Consolidation. Weed removal causes an increase in soil disturbance and available resources which promotes germination of both native and weed seeds. Follow-up weeding must be undertaken to prevent weeds outcompeting native seedlings (Buchanan 1989).

Phase 3: Maintenance. Generally, as regenerating natives become established, the need for maintenance lessens. However, many areas of saltmarsh are surrounded by established subdivisions and invasion of weeds from neighbouring areas is ongoing. In particular, weeds can be spread through rivers and streams from infested areas in upper catchments to areas in lower catchments. Consequently, ongoing maintenance will be required for most saltmarsh areas.

These are the special work practices that are applied to weed management in saltmarsh at Sydney Olympic Park.

- Ensure tools and boots are washed and dried prior to moving between saltmarsh sites to prevent introduction or transfer of weeds.
- Work in tidal areas only when they are not under water (low tide).
- Minimise trampling of saltmarsh. Try to walk on bare ground – where you must walk on saltmarsh, walk on non-succulent plants (such as saltwater couch, grasses and weeds).
- Vary access routes to avoid forming a track unless undertaking high-intensity primary works. In that case form a track to minimise widespread trampling of saltmarsh, as saltmarsh generally rehabilitates within 1–2 years if the track is not used. If there are several people working, everyone should take a different route to avoid concentrating impacts.
- Limit the number of people working in saltmarsh and ensure tools and equipment are not placed on succulents.
- Weed by hand if possible. Where required, apply herbicide either by painting it on leaves or by filling a hole drilled into the trunks of woody weeds. Spray application of herbicide should be limited to the primary treatment of mature spiny rush only.
- Lift and carry tools and bags of weeds or litter – do not drag them across saltmarsh.
- Remove all green waste from saltmarsh to avoid changes to elevation and hydrology.
- Avoid creating changes in soil elevation and hydrology.
- Provide induction training in ecologically sensitive work practices to staff and contractors (SOPA 2008).

Note: Those who use pesticides or herbicides in their business or as part of their occupation must be trained in how to use these chemicals – see www.environment.nsw.gov.au/pesticides. Courses include Farmcare, SmartTrain and Chemcert. For further information contact your local TAFE or Department of Primary Industries.

Introduced species

Common sources of weeds in coastal saltmarsh include stormwater outlets and vegetation dumping. Salt-tolerant exotic species can also invade saltmarsh from vehicle tyres, equipment and shoes that are not properly cleaned when travelling between sites. Vehicle tyres, equipment and shoes should be thoroughly washed to remove all traces of soil before moving from one saltmarsh site to another.

Spiny rush is an invasive exotic species which is often confused with the native sea rush (*Juncus kraussii*). The leaves and bracts of sea rush are not as sharp and pointed as those of spiny rush (Fairley and Moore 2000). Stands of spiny rush are also generally taller and the stems thicker (Kelleway et al. 2007).

Note: The spikes of spiny rush are hard and sharp and can be dangerous to the eyes; protective eyewear should be worn while working with this plant.

Trials in the removal of spiny rush at Sydney Olympic Park have shown that the application of raw salt on cut bases restricts the growth of the weed and significantly boosts the growth of saltmarsh (Paul and Young 2005).



Spiny rush was cut with a brush-cutter and fine crystals of raw salt were manually applied on the bases of cut plants (at 4 kg/m² of cut plant). Clearing spiny rush or applying glyphosate bioactive over the whole plant were also effective techniques in removing the weed, but discouraged saltmarsh growth. When these techniques were applied, extensive planting of saltmarsh helped the area to regenerate (Paul and Young 2005).

Although the application of salt was trialled as a method of removing spiny rush at Sydney Olympic Park, the preferred primary method of treating this weed is to brushcut mature plants to a height where stems form a continuous mat (generally 10–25 cm above ground), then brush off excess plant material and dirt and spot spray with glyphosate bioactive. After 4–6 weeks, regrowth is treated by chipping out or, alternatively, by cut and paint. As spiny rush seeds remain viable in the seedbank for many years, treated areas are maintained by manual removal (crowning) of seedlings at least twice per year to prevent re-establishment. Crowning involves inserting a knife into the ground near the plant and cutting around the roots. Sydney Olympic Park Authority has found that careful spot application of glyphosate is just as effective in removing spiny rush and more economical than using salt. Coastal saltmarsh has been quick to re-establish in areas treated in this way at Sydney Olympic Park.

Seasonal considerations are taken into account when treating spiny rush. Treatment is generally not undertaken between June and August, when spiny rush is not actively growing and sheltering fauna is less likely to be active and hence less able to move out of the area. Care is taken prior to treatment in warmer months to ensure that no birds are nesting in the area.



Photo: Sydney Olympic Park Authority



Before and after treatment for spiny rush at Sydney Olympic Park



Photo: Natalie Izquierdo

Bitou bush

Bitou bush (*Chrysanthemoides monilifera* ssp. *rotundata*) and boneseed (*Chrysanthemoides monilifera* ssp. *monilifera*) are listed as noxious weeds under the *Noxious Weeds Act 1993* and are weeds of national significance (Australian Government 2008). The 'invasion of native plant communities by bitou bush and boneseed' is listed as a key threatening process under the *Threatened Species Conservation Act 1995*, and narrow-leaved wilsonia has been identified as a species being most at risk from invasion (DECC 2008b). Both bitou bush and boneseed show a level of salt tolerance and are invasive weeds that have been found on brackish saltmarsh margins. The bitou bush threat abatement



Pennywort growing in saltmarsh

plan describes the most successful methods in management and control of bitou bush and boneseed (DEC 2006).

Pennywort (*Hydrocotyle bonariensis*) is a saltmarsh weed at some locations. It is generally a fringing species, rather than a dominant part of saltmarsh communities (Kelleway et al. 2007). Hand removal of pennywort is a time consuming but effective method. When weeded by hand every piece of pennywort must be collected as it is able to regrow from root and stem fragments. If the pennywort is not completely removed and natives regenerate, it is difficult and time consuming to remove it from between regenerating plants.

Alligator weed (*Alternanthera philoxeroides*) is listed as a noxious weed under the *Noxious Weeds Act 1993*. It inhabits freshwater wetlands, but has been found in saltmarsh. If you suspect you have alligator weed on your property contact your local council or DECC to help control this species – a coordinated approach to the removal of this weed is most effective. The use of herbicides and annual removal of alligator weed can be effective in small infestations, but fragments are inevitably left behind and can create new infestations downstream.

Other exotic species found in saltmarsh include coastal morning glory (*Ipomoea cairica*) and salt daisy (*Aster subulatus*), which are usually found in the upper marsh and are best removed by hand. Other species at Sydney Olympic Park, including buffalo grass (*Stenotaphrum secundatum*) and common couch (*Cynodon dactylon*), are both time consuming to remove by hand. Where possible, increasing the frequency of tidal inundation is likely to be effective in controlling these weeds. Where this is not possible, application of salt by hand may be an effective alternative.

3.2 Native vegetation management

The grey mangrove (*Avicennia marina*) is known to colonise saltmarsh habitats in NSW. Although mangroves diminish in height and vigour with elevation, their habitat range can overlap with that of saltmarsh for a substantial portion of the upper tidal range (up to 30 metres at Kooragang Island) (Nelson 2006). The factors driving mangrove encroachment on saltmarsh are still unclear. It is believed that mangrove incursion on



Saltmarsh regrowth after mangrove removal - the same plot at time of removal and 18 months later



saltmarsh is primarily an outcome of increased tidal inundation, though other factors may contribute, including rainfall patterns, agricultural activities, and developments that have increased sediments and nutrients in intertidal areas (Johns 2006; Rogers et al. 2006).

Mangroves are protected under the *Fisheries Management Act 1994* (NSW). Any direct harm to mangrove trees or seedlings, including that associated with rehabilitation works in saltmarsh, will require a permit from the NSW Department of Primary Industries (DPI). Permit applications are assessed on a case-by-case basis, and for saltmarsh rehabilitation works will need to be accompanied by a vegetation management plan. Methods for mangrove removal, disposal and relocation of seedlings will be specified in the permit.

In accordance with DPI permit conditions, Sydney Olympic Park Authority currently removes mangroves encroaching on key saltmarsh habitats across the park. To ensure that there is no soil disturbance, mangrove trees and saplings over 50 cm tall or past the 12-leaf stage are cut and painted with herbicide; trunks are cut as close as possible to the base. Seedlings are hand-pulled. The saltmarsh is then maintained by annual hand-pulling of newly-germinated seedlings. All cut or pulled mangrove material is removed from saltmarsh areas and mulched or disposed of offsite (SOPA 2008). Where possible, mangroves removed from saltmarsh should be used in mangrove rehabilitation projects.

While encroaching mangroves can be removed from saltmarsh habitat, longer term management of this problem would involve mitigating the cause or, in the case of sea level rise, allow for the response of saltmarsh through appropriate monitoring and planning (section 3.8).

3.3 Planting

The regeneration of saltmarsh in cleared or degraded areas greatly depends on the site's surroundings. Saltmarsh is very slow to recover in areas where no existing saltmarsh species are nearby or where tidal flushing has been restricted. Where this occurs saltmarsh species cannot colonise the area through vegetative growth from neighbouring plants or rely on seed dispersal, as many saltmarsh species rely on the tide to disseminate seed. Where regeneration of saltmarsh is occurring in areas isolated from other saltmarsh communities, planting may be necessary to restore a viable saltmarsh community. A careful assessment should be made at sites where tidal flushing has been restricted and no saltmarsh species are present. These areas may no longer provide adequate saltmarsh habitat and therefore may not be suitable for rehabilitation.

Photo: Sydney Olympic Park Authority



Zonation of saltmarsh

Saltmarsh plant species often inhabit different zones within the saltmarsh habitat that have differences in elevation, inundation and therefore salinity. In some cases species may be zoned parallel to the shoreline and vary in elevation only by a few centimetres. The zones are commonly described as upper, middle and lower levels. The upper level is usually dominated by a border of rushes, such as sea rush, that separates terrestrial vegetation from the saltmarsh.

The middle saltmarsh is commonly dominated by species such as samphire and salt couch. Succulent inundation-tolerant species such as austral seablite dominate the lower marsh, and the seaward border is usually inhabited by mangroves. In many saltmarshes, however, such zonation may not be clear or present, and this makes regeneration very difficult.

In areas where zonation is evident, it is recommended that species are planted in their preferred zones to maximise planting success. Burchett et al. (1998) discusses the habitat preference of many saltmarsh species found at Sydney Olympic Park and in the Sydney region.



Photo: Sydney Olympic Park Authority

Seed collecting

Seed

Seed collection at Sydney Olympic Park is based on the following principles (SOPA 2008):

- Seed must be collected from multiple plants over as wide an area as possible, to maximise genetic diversity.
- Seed should only be collected from strong, healthy plants.
- Less than 20% of seed is to be collected from any one plant to allow for predation and natural regeneration at the donor site.

Seeds should only be collected from fruits that are close to maturity to ensure that viable seed is collected. Cotton or brown paper bags are good storage containers for fruits and/or seed. If seeds are to be stored, bags containing seed should be kept in a well ventilated location to avoid fungal contamination; exposing the seed bags to direct sunlight and/or heat should also be avoided (Hadlow 2004).

Rehabilitation

In 1998–99, 1.5 km of the concrete-lined Haslams Creek channel at Sydney Olympic Park was reconstructed and realigned to recreate a more natural, meandering streamline. This included shaping imported topsoil at an appropriate gradient along the banks of the creek to create potential saltmarsh habitat, and planting locally propagated saltmarsh species. These plantings largely failed, possibly due to unsuitable topsoil.

In 2004, the importation of new topsoil and subsequent replanting was trialled as a means of rehabilitating these areas. Results were encouraging with self-sustaining, healthy saltmarsh developed in trial plots. While this method would be feasible for a small area, it would have been too costly to apply it across the whole of the Haslams Creek site.

Subsequent trials were undertaken which involved various combinations of direct seeding, mulching and planting. Results from trial plots indicated that the most cost effective method was to incorporate mulch by ploughing it into the existing topsoil, and then direct seeding the site.

Results from a large part of the Haslams Creek site at which this method was employed in mid-2007 are encouraging, with many saltmarsh plants present and a fresh flush of newly germinated seedlings as at August 2008. This method has been extended to the remaining area of the Haslams Creek site.



Seagrass wrack (rotting vegetation washed ashore) applied to saltmarsh can, like mulch, reduce soil erosion. The experimental addition of seagrass wrack to bare sediment adjacent to saltmarsh rapidly increased cover and biomass of the dominant saltmarsh species, samphire. An increase in biomass of dominant plant species may reduce physical stress for small, establishing saltmarsh species and aid in regeneration (Chapman and Roberts 2004).

Transplanting

Transplanting saltmarsh species from natural healthy sites to degraded sites is a popular method used in saltmarsh regeneration. However, the impacts to the donor sites can be substantial; Species such as saltwater couch took 4–5 years to recover where 25 cm² had been removed from a donor site (Laegdsgaard 2002).

Where transplanting is implemented, saltmarsh species and elevation should be carefully considered. Pioneer species, such as samphire, translocated from areas frequently inundated by the tide should be used (Laegdsgaard 2002). Samphire took 14 to 17 months to recover from 25 cm² plots when taken from the lower marsh where conditions were most favourable for the species. The favourable habitat of species being translocated should be considered when they are taken from the donor site and planted at new locations. Species planted at preferred elevations within the saltmarsh are likely to regenerate faster than those planted at unfavourable elevations.

When transplanting saltmarsh, the presence of fertile topsoil is the most significant factor in the success and establishment of plants; streaked arrowgrass, saltwater couch and samphire all achieved substantial cover in under four years when transplanted to areas with abundant topsoil (Nelson 2006).

The use of plugs to transplant saltmarsh should only be undertaken by professional bush regenerators to ensure that the viability of the donor saltmarsh is not compromised. Where saltmarsh soil has a high clay content, plugs of plant material from the donor site should be collected using a robust implement, such as a soil corer or a posthole digger with straightened prongs of 10–20 cm diameter. When collecting saltmarsh on sandy soil, soil around the roots can fall away, leaving roots exposed and vulnerable to drying out; in this circumstance plugs should be handled with great care and packed closely in containers.

Transplanting saltmarsh species largely relies on the vegetative spread of saltmarsh clones via rhizomes or stolons. It is therefore important to try to collect plugs from a variety of individual plants over a large area of saltmarsh. Use the same implement to dig holes at the recipient site as that used to collect plugs.

At Sydney Olympic Park, transplanting is currently undertaken only when saltmarsh species are likely to be destroyed during infrastructure maintenance, such as seawall repairs. Incorporation of mulch into topsoil and direct seeding is the preferred method of rehabilitating saltmarsh.

Cuttings

Using plant cuttings to propagate saltmarsh species for regeneration has many advantages. Cuttings can be collected all year from donor sites with minimal impact on the saltmarsh. Shoot cuttings were used in 1998–99 at Sydney Olympic Park in attempts to establish saltmarsh along Haslams Creek (Burchett et al. 1998).

Propagation of saltmarsh plants from cuttings at Sydney Olympic Park encompassed the following techniques:

- For each species collected, new season tip and stem cuttings were taken from nearby saltmarsh stands. Cuttings collected in spring and summer were most successful.
- Cuttings were taken from a range of plants at the donor site to minimise impacts on individual plants and to maximise genetic diversity among the cuttings. Generally less than 20% of the parent plant should be taken for cuttings.
- The cuttings were washed in tap water to remove salt build-up, dipped in 1% sodium hypochlorite solution for surface sterilisation and rinsed in distilled water.

- Tip segments and sometimes two or three single-node segments from immediately behind the tips were used as cuttings for austral seablite, *Lampranthus tegens*, samphire, narrow-leafed wilsonia and black-seeded samphire (*Tecticornia pergranulata* subsp. *pergranulata*).
- Internode segments were used as cuttings for saltwater couch.
- The cut ends of all austral seablite, narrow-leafed wilsonia, black-seeded samphire and saltwater couch were dipped into root-promoting hormone gel.
- Cuttings were set in germination trays containing a 1:1 sand-peat mixture. The trays were then placed in a fogging tent in a glasshouse with bottom heat under a sand base at approximately 25°C.
- When root and shoot growth was established, the plants were acclimatised first by lifting the fogging tent flaps and lowering the level of fog, and then by placing the plants on the glasshouse bench.
- Individual plants were potted into small pots usually containing 3:2 sand and peat mixture.
- After approximately 10 days, the plants were watered with increasingly saline water over two weeks, to a final watering concentration of half-strength sea water, before being planted in saltmarsh habitat.
- Once in saltmarsh habitat the plants were watered with tap water two to three times a week for six weeks to survive the summer heat.



Photo: Nick Colman

Propagation from cuttings

Cuttings are no longer used at Sydney Olympic Park as the incorporation of mulch into topsoil and direct seeding is the preferred method of rehabilitating saltmarsh. Sydney Olympic Park Authority uses seeds rather than cuttings to regenerate saltmarsh because it is less time consuming and labour intensive as no planting or propagation is required.

3.4 Fauna management

It is important to consider fauna when planning work in saltmarsh communities – bird roosts and regular migratory visitors should be identified. Disturbance to feeding, nesting and roosting areas can cause parent birds to leave the nest, resulting in exposure of chicks or eggs. During their stay in Australia many migratory birds must rapidly build up their fat reserves before their return migration; loss of individuals may occur during migration if the birds have insufficient fat reserves. It is therefore important to plan works once migratory birds in the area have left for the year. A section 132 licence should be obtained under the *National Parks and Wildlife Act 1979* before undertaking any work in habitats used by threatened shorebirds.

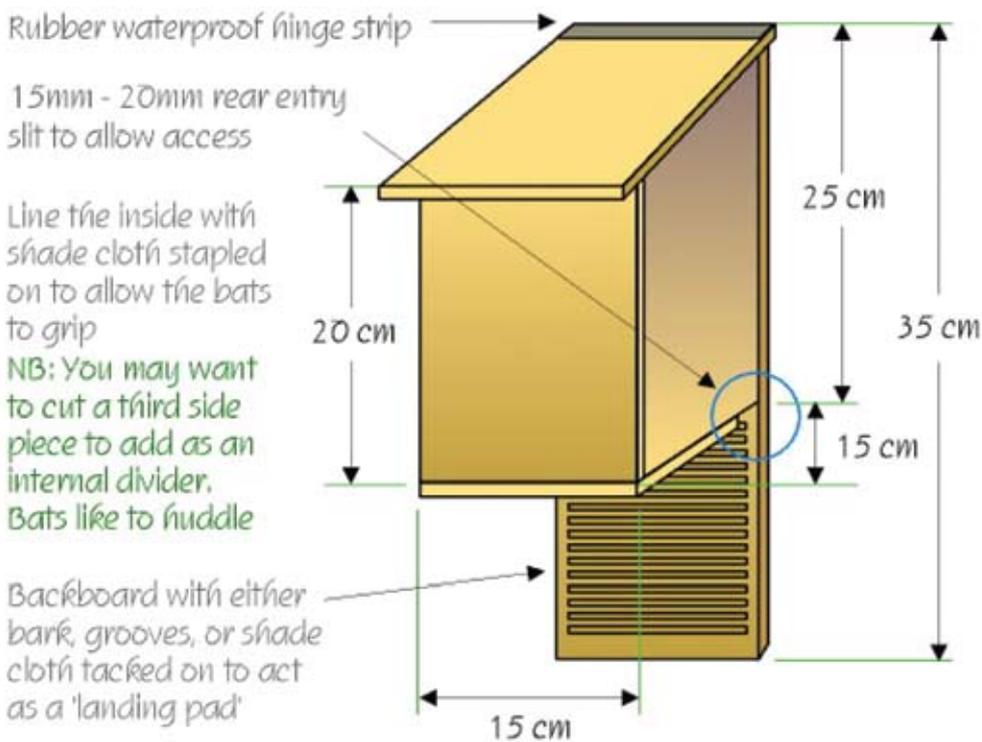
It is important to maintain tidal flows in saltmarsh to maintain a diversity of fauna. Many aquatic species such as crabs, molluscs and fish require occasional inundation and a clear passage from the shore. The management of mangroves is also important in maintaining saltmarsh fauna. The reduction of open saltmarsh areas can negatively impact bats and birds that would normally use the community to forage for insects (DECC 2008a). Maintaining natural tidal flows and a diversity of saltmarsh species is essential in attracting a range of fauna.

Litter floating in waterways can be deposited in saltmarshes by high and spring tides. Litter can smother saltmarsh and can also be a hazard to wildlife that forage and roost in saltmarshes. Litter should be systematically removed from saltmarsh areas on a regular basis. Saltmarsh communities should be inspected as soon as possible after storms, floods and spring tides to remove any accumulated litter.

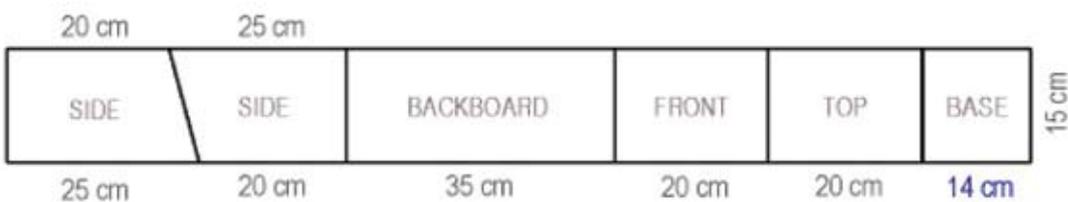


Some saltmarsh communities harbour large populations of the saltmarsh mosquito (*Aedes vigilax*). Encouraging insectivorous bats into saltmarsh communities could form the basis of a biological control mechanism for mosquitoes (Laegdsgaard et al. 2004). Insectivorous bats are largely reliant on suitable roosting areas during the day. If trees with hollows and artificial roosts, such as abandoned buildings, are not available close to a saltmarsh community, bats will have to travel elsewhere to shelter during the day. Installing roosting boxes for bats around saltmarsh communities is likely to increase the availability of roosting sites and encourage bats to remain in the area. When installing a roosting box always ensure cats, dogs and other predators cannot gain access to the box. Place it in a tree at least three metres above the ground. If introduced birds such as Indian mynas (*Acridotheres tristis*) colonise the roosting box, remove the eggs.

Microbat Roostbox



Roostbox pieces cut from a single plank



NB: Base is approximately 14 cm. Depending on the thickness of the wood used, you need to cut this piece to leave an entry slit of between 15 mm - 20 mm.

Design of a roosting box for insectivorous bats. (provided by Tweed Valley Wildlife Carers)

It is important that mosquitoes be regarded as a normal part of saltmarsh communities. A mosquito monitoring program between December and March should be undertaken before mosquito control occurs. Mosquito control involving changes to tidal flows should not be commenced in response to community complaints. Educational material promoting the use of personal insect repellents and avoiding saltmarshes during dusk and dawn should be promoted to minimise community exposure to mosquitoes (Webb and Russell 2006).

Maintaining tidal flows in saltmarsh can be an effective method to control mosquito populations. Tidal flushing increases access of fish to productive mosquito breeding habitats. Runnelling, the construction of shallow channels that connect pools within saltmarsh, can improve tidal flows throughout the saltmarsh without significantly affecting the hydrology. Runnelling can, however, increase mangrove encroachment into saltmarsh and reduce the habitat available for some crab species (Webb and Russell 2006). Where runnelling is undertaken a scrupulous monitoring program should be carried out to ensure the species composition and functioning of the saltmarsh are not significantly altered.

3.5 Hydrology management

Stormwater

The discharge of stormwater in saltmarsh communities alters salinity regimes, increases nutrient levels and facilitates the spread of introduced species (DECC 2008c). Long-term successful stormwater management requires that all water that flows onto the site be managed. High velocity stormwater can erode banks containing saltmarsh and introduce refuse such as silt, nutrients and weeds. Public education for residents adjacent and upstream is important to limit damaging substances entering stormwater. Saltmarsh communities can be particularly susceptible to common stormwater pollutants such as fertilisers and chlorinated water from swimming pools. It is important to liaise with and educate landholders adjacent and upstream to saltmarsh about water quality control within catchments containing saltmarsh communities.

Tidal flushing

Tidal flushing is an important component of saltmarsh habitats. A lack of tidal flushing can allow freshwater runoff to inundate the marsh for extended periods. Although natural flooding of saltmarsh can occur where there is tidal flushing, the length of time the marsh is inundated is increased where there is no flushing. Extended inundation of saltmarsh habitats can cause dieback of saltmarsh species and change the species composition of the marsh. Common reed (*Phragmites australis*) spreads rapidly to form extensive stands in tidally isolated saltmarshes and alters the landscape, hydrology, ecology and function of the entire community (Weinstein and Balleto 1999). Where the tide has been excluded from saltmarsh habitats for extended periods, vegetation will change to either freshwater or terrestrial communities.

Where saltmarsh rehabilitation is to be achieved through the removal of restriction to tidal flows, freshwater and terrestrial species should be left in place. Freshwater and terrestrial plant species will not survive the elevated salinity levels brought by the tide, but their dead root systems will help prevent erosion until the saltmarsh becomes established (Nelson 2006). Saltmarsh communities are extremely sensitive to changes in salinity and inundation by the tide. Sites where tidal flushing is being established require accurate monitoring and adaptation of management to ensure the site becomes suitable saltmarsh habitat. Regular tidal inundation of saltmarsh can encourage the growth of mangroves which can outcompete saltmarsh species.

Litter

Litter, which is deposited via waterways and large tides, is common in saltmarsh areas. Gross pollutant traps and/or floating booms can be installed to trap litter and other debris in stormwater. Gross pollutant traps and booms require regular inspection and cleaning, particularly after storms. Litter should be systematically removed from saltmarsh areas on a regular basis. Saltmarsh communities should be inspected as soon as possible after storms, floods and spring tides to inspect damage or deposition of sediment and remove any accumulated litter.



3.6 Access management and community awareness

Unrestricted access by walkers, bike riders, vehicles and grazing animals increases soil erosion and can change the topography and hydrology of saltmarsh flats.

Livestock grazing has been shown to substantially change the vegetation composition and structure of saltmarsh (Adam 1990). Stock trample and graze plants, exposing bare soil and acting as seed vectors which encourages weed growth. Stock can also change the species composition of saltmarsh through selective grazing (Laegdsgaard 2006) and should be excluded by fencing off saltmarsh environments and creating off-stream watering points.

Wheel ruts caused by recreational vehicles persist for many years in saltmarsh even after the exclusion of vehicles (DECC 2008a). Car tyres also act as vectors for seed distribution and can encourage the spread of weeds into saltmarshes. A change in the topography of saltmarsh caused by wheel ruts can result in a change in the species composition of the marsh. Waterlogged wheel ruts provide ideal conditions for the grey mangrove and help spread mangroves into saltmarsh. To prevent these impacts access points such as fire trails should be fenced and gated to prevent vehicle access to saltmarsh. Signage explaining the importance of the saltmarsh community and the legal implications of disturbing endangered ecological communities should be erected at closed access points. Regeneration of sites disturbed by vehicles may require infilling and levelling of deep wheel ruts to prevent mangrove incursion and maintain suitable saltmarsh habitat (Kelleway 2005).

Saltmarshes are sensitive to repeated pedestrian passage. Creating walking tracks within saltmarsh communities should be avoided; where this is not possible it is recommended that raised walkways such as boardwalks are constructed. Boardwalks must not alter the hydrology of saltmarsh habitats and should allow the free flow of water beneath them. Strategically planting stands of sea rush and swamp oak (*Casuarina glauca*) across access points can also help prevent unauthorised access (Kelleway 2005). Educational material such as signage explaining the importance of the saltmarsh community should be erected at closed access points to raise awareness of the conservation significance of the site. A saltmarsh community brochure is available at www.threatenedspecies.environment.nsw.gov.au/index.aspx.

At almost all saltmarsh communities some form of signage and/or fencing would assist to reduce the likelihood of disturbance. This may range from signage to notify people of the presence of threatened species to temporary closures and the fencing off of large areas around saltmarsh communities. Ideally, signage should indicate the reason for restrictions, as this increases compliance. Fences can be as simple as tomato stakes and string, but care should be taken to ensure that the fences are highly visible to prevent accidents. Small signs should also be placed at intervals along the fence as a second line of notification and to reinforce the message of why the area is being protected.

Where saltmarsh borders private land, educational programs highlighting the significance of the community should be undertaken. The mowing of saltmarsh and dumping of garden refuse is common near private land and has significant impacts on the community. Mowing saltmarsh will quickly change the species composition of the area, and destroy succulent species and the flowering stems of grasses (Laegdsgaard 2006).

The following community education messages should be advertised around saltmarsh communities:

- Do not walk on saltmarsh – stick to formal tracks.
- Never drive vehicles into saltmarsh habitats.
- Keep dogs on leads and out of saltmarsh.
- Pick up dogs faeces.
- Keep cats in at night.
- Do not remove plants or soil from saltmarsh.

- Do not plant trees or introduce soil into saltmarsh.
- Use green waste services provided by your local council.
- Do not dump waste in saltmarsh.

3.7 Planning

A rise in sea level associated with climate change will have a significant impact on the distribution of coastal saltmarsh (Adam 2002). As the frequency of tidal inundation increases, current locations of saltmarsh habitat may become more suited to mangrove or seagrass growth. Saltmarsh species will be forced to colonise upstream and upslope. Its movement will be restricted by the topography of areas it inhabits and the existence of artificial structures upslope. New developments directly upslope of saltmarsh should be avoided to ensure landward migration of the community is possible. Landward migration where grasslands exist directly behind saltmarsh is an ideal situation. Grazing pressures should be minimised in adjacent grasslands to allow for this process. As stormwater canal walls, sea walls and foreshore retaining walls behind saltmarsh come to the end of their practical life it is recommended that they either be removed and the bank revegetated (Kelleway et al. 2007), or new seawalls and retaining walls incorporate saltmarsh plantings.

The presence of the saltmarsh mosquito in some saltmarsh communities should also deter new developments close to saltmarsh. The saltmarsh mosquito is accepted as the major vector of Ross River and Barmah Forest disease in humans and is also known to carry dog heartworm. There are no specific treatments for Ross River and Barmah Forest disease and reducing mosquito bites is the best form of prevention (NSW ASVMP 2008). To avoid conflicts between health issues and biodiversity conservation, future developments should be avoided in close proximity to saltmarsh.

3.8 Monitoring

Monitoring of coastal saltmarsh communities is particularly important given the changes that are predicted to occur in the future with sea level rises and mangrove encroachment. As the management and regeneration of saltmarshes is poorly practiced in Australia, projects should be closely monitored to identify successful and unsuccessful techniques. Management of coastal saltmarsh must be adaptive. If monitoring indicates that the objectives of the project are not being met the project methods should be changed.

Monitoring involves observing the changes that take place before, during and after the rehabilitation work. Keeping comprehensive records provides information on the effectiveness of management practices, allowing land managers to determine if the natural vegetation is improving or declining (DEC 2005b). General monitoring techniques include the following.

- **Before and after photographs.** Photographs taken at permanent monitoring posts (star pickets) installed at the corner of 5 m x 5 m monitoring quadrats provide visual documentation of the vegetation regrowth if taken at regular time intervals.
- **Native plant and weed counts.** Periodically recording the diversity and abundance of weed and native plant species within each 5 m x 5 m quadrat, during pre- and post-treatment of weeds, provides a quantitative account of site conditions. The bush regeneration management practice employed should also be noted; this enables different techniques to be compared (McDonald et al. 2002).
- **Vegetation maps.** Mapping the area provides a visual representation of where the weed infestations occur, and also documents the type of regeneration works in a particular area.
- **Documenting and reporting.** Clearly specifying the desired ecological objectives and documenting the actions implemented provides a basis on which to evaluate progress, correct any mistakes and ensure ongoing success. Good data management also provides useful information for other groups about successful rehabilitation activities and guides future rehabilitation works.



4 Summary of threatening processes and their management

Threatening processes of coastal saltmarsh	Management
Inappropriate fire regimes	<ul style="list-style-type: none"> • Fire is not recommended as a management tool in coastal saltmarsh.
Weed invasion	<ul style="list-style-type: none"> • Hand weed where possible. Where required, use only paint or drill application of herbicide. Spray application of herbicide should be limited to a once off use during the primary treatment of mature spiny rush only. • Monitor pre- and post-regeneration. • Ensure tools and boots are washed and dried prior to moving between saltmarsh sites. • Work in tidal areas only when land is above water (low tide). • Minimise trampling of saltmarsh. • Avoid creating changes in soil elevation and hydrology.
Effects on fauna	<ul style="list-style-type: none"> • Avoid undertaking works during bird breeding seasons and during mid-winter (June–August inclusive) when plant growth is poor. • Maintain tidal flows. • Systematically remove litter from saltmarsh areas on a regular basis.
Stormwater	<ul style="list-style-type: none"> • Implement public education programs for residents to limit damaging substances going into stormwater. • Maintain tidal flows. • Install gross pollutant traps to trap litter and other debris entering saltmarsh. • Inspect saltmarsh communities after storms, flood events and spring tides to remove any accumulated litter.
Inappropriate access	<ul style="list-style-type: none"> • Restrict access by walkers, bike riders and vehicles by the use of signage and/or fencing. • Exclude grazing animals by fencing off saltmarsh and creating off-stream watering points. • Undertake educational programs highlighting the significance of the community where saltmarsh borders private land.

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