Fish Habitat Guideline FHG 002

RESTORATION OF FISH HABITATS

Fisheries guidelines for marine areas

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Executive summary

DPI Fisheries Group has a statutory responsibility in the protection of marine plants and maintenance of fish habitats. Marine plants are protected under Section 123 of the *Fisheries Act 1994*. As such, permits are required where disturbance to marine plants is likely. Under the *Fisheries Act 1994* restoration of a disturbed fish habitat may be ordered, with restoration costs to be met by the perpetrator of the damage.

For any proposed wetland restoration, DPI Fisheries Group's preferred position is natural restoration of the site. Where this is not feasible, the site may be improved to allow natural regeneration or assisted revegetation to occur. This Fish Habitat Guideline provides information necessary for the restoration of marine wetland areas for fisheries purposes. The purpose of the guideline is to assist the preparation of rehabilitation plans that restore degraded fisheries habitats. Community groups, government agencies, researchers or developers may coordinate these proposals.

As awareness of the importance of marine wetlands increases, it is necessary to ensure that these are protected or restored where possible. When developing a restoration plan, referral to this document and listed references is recommended. Local DPI Fisheries staff should also be consulted in regard to the details of any restoration plan.

This document briefly outlines the importance, values and functions of marine wetland areas, as well as the responsibilities of DPI Fisheries in relation to administration of the *Fisheries Act 1994*. The main body of the document involves an 11 Step plan for use in development of restoration plans. This plan highlights the importance of outlining the entire project prior to commencement of works, the documentation of results following works and the instigation of an ongoing management plan following works.

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1.0 Introduction

1.1 The importance of wetland habitats to fisheries

The critical role of wetlands in providing nursery, feeding and spawning areas for fisheries resources is widely recognised and has lead to the realisation that wetland environments are fundamental to sustaining many commercial, recreational and traditional fisheries species.

In this document, wetlands are defined as:

> *'…areas featuring permanent or periodic/ intermittent inundation, whether natural or artificial, static or flowing, fresh, brackish or saline, including areas of marine water, the depth of which at low tide does not exceed six metres.'*

This definition is based on that adopted during the Convention on Wetlands of International Importance (Ramsar Convention 1971). Wetlands include billabongs, marshes, swamps, lakes, mud flats, mangrove forests, and shallow seagrass beds. Wetlands are important habitats in all aquatic areas, from freshwater streams through brackish estuaries to shallow marine sites. Floodplains, riparian vegetation, supralittoral marine flats, rocky shores and reef tops also contribute to fisheries productivity in wetland habitats. The main focus of this document, however, will be on marine and estuarine wetlands particularly those associated with mangroves, seagrasses and saltmarshes.

Disturbed marine wetland habitats may require restoration to maintain the fisheries values of an area. Restoration has been defined as the process of returning a site to an agreed pre-existing condition and implies a final objective to return all aspects of the previous system (Sheppard and McKinnon 1997). In real terms however, this objective may not be totally achievable. It may be more appropriate to rehabilitate a site to a level where natural succession will continue the recovery process. For fisheries purposes, a major aim of restoration of marine areas is to improve the site to maximise the fisheries values of the habitat.

Prior to restoration works being undertaken, natural regeneration of disturbed sites should be monitored to determine whether restoration should be assisted, and appropriate enhancement works undertaken. Restoration or rehabilitation may be appropriate where natural regeneration is slow or unsuccessful. Department of Primary Industries (DPI) Fisheries favours natural regeneration of wetlands, as this removes the possibility of impacting upon undisturbed areas during restoration works.

1.2 Fisheries Act and responsibilities

The Queensland *Fisheries Act 1994* and *Fisheries Regulation 1995* provide for the '*management, use, development and protection of fisheries resources and fish habitats and the management of aquaculture activities, and for related purposes*'. This *Act* encompasses Queensland waters, including marine, estuarine and freshwater. Fish and fish habitats are managed under the provisions of the *Act*. It operates specifically in the protection of marine plants, the declaration of Fish Habitat Areas, provisions for waterway barrier works and fishways, and the restoration of damaged or destroyed fish habitats. The legislation provides for the granting of certain approvals to allow works to be undertaken in fish habitats and also to stop works that appear to degrade fish habitats. Individual applications are assessed by DPI and decisions to issue approvals are based on the type of works proposed and likely impacts. Support may be given for proposals where the impacts of works are minimal, where works are for fisheries purposes and/or community benefit and appropriate mitigation measures are carried out to counter any authorised loss of fish habitat. Refer to current Fish Habitat Management Operational Policies (FHMOP 001, 002, 003, 004) and the *Fisheries Act 1994* for further information.

Where the fisheries values of an area have been compromised by the unlawful outletting or placement of polluting matter (e.g. litter, soil, a noxious substance or other matter), DPI may issue a 'Restoration Notice', under Sections 124 or 125 of the *Fisheries Act 1994*. A Restoration Notice may be issued to a person who is suspected, on reasonable grounds, to be responsible for the placement or outletting of polluting matter on land, in waters, on marine plants or in fish habitat if it is considered that the polluting matter has (or may):

- prevented fishing activities
- an adverse effect on the quality or productive capacity of a fishery or fish stocks
- an adverse effect on the quality or integrity of a fish habitat.

Where a Restoration Notice is issued, the recipient must cover the costs of restoration works.

1.3 Fisheries values and functions of wetlands

Fisheries values and functions of wetlands include:

- supporting the diversity and abundance of fisheries resources by providing a diversity of habitats;
- playing a key role in the productivity of fisheries resources by providing critical habitat and/or refuges for many species of economic or community importance;
- providing vital fish breeding and feeding grounds and sites for commercial, indigenous and recreational fishing;
- assisting in improving water quality by stripping nutrients and intercepting sediments.

1.3.1 Key fisheries values of tidal wetlands

Tidal wetlands, such as mangrove, seagrass and saltmarsh communities, have important roles in fisheries production. The fisheries values of tidal wetlands as habitats for post-larval or juvenile commercial, recreational or indigenous fisheries species have been demonstrated (Coles et al. 1987; Connolly 1994; Haywood et al. 1995). In dense mangrove areas, extensive root systems may protect juveniles from predation or other factors. The high primary and secondary productivities of wetland habitats support the wetland food chain.

Tidal wetlands of importance to fisheries have been declared as Fish Habitat Areas (FHA) for increased protection of their fisheries values. Over 80 FHAs have been declared under fisheries legislation throughout coastal Queensland, from Currumbin Creek to the Gulf of Carpentaria. FHAs are declared to enhance existing and future fishing activities and to protect the habitats upon which fish and other aquatic fauna depend. All legal forms of taking fish are allowed in declared FHAs. Activities causing major impacts on these protected habitats are restricted.

The importance of marine plants to fisheries production is recognised under the *Fisheries Act 1994* where all marine plants are protected against destruction, damage or removal. Marine plants, as defined under the *Fisheries Act 1994*, include:

'*a plant (a tidal plant) that usually grows on, or adjacent to, tidal land, whether it is living, dead, standing or fallen; material of a tidal plant, or other plant material on tidal land; and a plant, or material of a plant prescribed under a regulation or management plan to be a marine plant*.' Typically, marine plants include seagrasses, mangroves, saltmarsh species and *Melaleuca* spp. adjacent to tidal lands.

1.3.2 Economic values – fisheries production

Determination of the economic values of wetland habitats is inherently difficult. However, estimates have been drawn from the direct commercial value of faunal species that spend part or all of their life cycle within wetland habitats. Within Moreton Bay, in southern Queensland, the mangrove (*Avicennia*) habitat was valued at $8380 per hectare in 1988 (Morton 1990). This value was calculated from the catch of marketable fish. It should be noted that this figure constitutes an underestimate of the value of certain mangrove wetlands, as the presence of juvenile and non-marketable fish or invertebrates was not taken into account.

The economic value of wetlands may also be calculated by estimating the value of their function in waste and stormwater treatment as well as the tourism and conservation values of wetlands. An economic evaluation of coastal wetlands and its limitations from a fisheries perspective, are given by Blamey (1992).

1.3.3 An overview of marine wetland functions

This section provides a brief overview of the different functions performed by marine areas.

Water quality control

Marine plants provide a structural barrier that slows the rate of water flow from the land, allowing deposition of solids and absorption of nutrients. The removal of suspended solids improves water quality and clarity. Wetland habitats may also reduce nutrient levels in nutrient rich waterways. Mangrove wetlands also have the potential to remove heavy metals from waterways (Tam and Wong 1994).

A combination of sediment type, plant species and littoral fauna, coupled with flow dynamics of riverine systems and tidal inundation duration, contribute to the nutrient scrubbing efficiency of mangrove communities. Benthic fauna that create sub surface drainage channels and depressions may promote significant sediment reworking and soil aeration, thus assisting waterway pollutant removal (Clough et al. 1983).

Buffer zones

Tidal wetlands may act as buffers at the land and sea interface and have an important function in coastal protection. Wetlands may trap sediments, thereby reducing siltation of waterways, inshore waters and reef areas. Wetland vegetation can also protect the shoreline from wave action and storm surges by reducing the energy of waves, currents or other erosive forces, while simultaneously holding the bottom sediment in place with plant roots. These functions help to stabilise shorelines and reduce erosion.

While tidal wetlands may act as buffers, wetland habitats should also be buffered from impacts associated with development. A recommended buffer (or transitional area) between wetlands and development typically consists of a band of non-tidal vegetation, preferably natural habitat.

Pest control

Wetlands have values in the provision of habitat for birds and other species that may act to control insect pests, either within the wetland itself, or in adjacent land. Tidal influence may also reduce weed infestation along waterways.

1.3.4 Links with freshwater and constructed wetlands

Freshwater wetlands have similar functions to those of tidal wetlands, i.e. as providers of fish habitats. These wetlands also provide food, shelter and spawning areas for many fisheries species. Species such as barramundi, jungle perch, eels, mangrove jack and mullet spend part of their life cycle in freshwater habitats. Freshwater aquatic plants, waterway banks and other microhabitats such as snags and riffle zones all contribute to habitat diversity, which is important in supporting fish diversity.

Freshwater wetlands may also interact with mangrove areas at the upper tidal range, where both habitat types act to buffer against drastic salinity changes, nutrient loads, flood surge and erosion. Transitional vegetation species (e.g. *Melaleuca* spp.) may occur in tidal areas of lower salinity.

Aquatic plants within freshwater wetlands are important in the removal/reduction of excess nutrients and heavy metals (e.g. lead, copper, cadmium and zinc) (Crites et al. 1997). Aquatic plants, and associated microbial film, can also reduce water-borne nutrient loads from effluent discharged through constructed wetlands. The removal of excess nutrients, particularly nitrogen and phosphorus, can prevent excess weed growth. The removal of heavy metals from waterways may reduce impacts of pollutants on fisheries resources.

1.3.5 Conservation value of wetlands

A number of species of wetland fauna, such as Mary River cod (*Maccullochella peelii*) and silver perch (*Bidyanus bidyanus*), are listed as threatened by the World Conservation Union (formerly IUCN – the International Union for the Conservation of Nature). Conservation of wetland habitats is vital for the conservation of threatened fish species.

Wetland habitats worldwide have been set aside as important habitats for a variety of flora and fauna. The importance of the wetland habitat, particularly for wading and migratory birds, was established during the *Convention on Wetlands of International Importance Especially as Waterfowl Habitat*. The working title of the convention and subsequent agreement is the 'Ramsar Convention'. There are four recognised Ramsar sites within Queensland. Three of these are marine wetlands: Moreton Bay, Bowling Green Bay, and Shoalwater and Corio Bays. Currawinya Lakes is Queensland's only freshwater wetland currently listed as a Ramsar site.
Under the Ramsar Convention, categories for identifying wetlands of international importance have recently been expanded to include specific criteria based on fish. A wetland may therefore be considered to have a high conservation value if 'it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values' or if 'it is an important

source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend'.

1.4 Overview of wetland species in Queensland

1.4.1 Wetland flora: seagrasses, mangroves and saltmarsh species

The vegetation associations of tidal wetland ecosystems can be classed into three main categories: seagrasses, mangroves and saltmarshes.

Seagrasses
Seagrasses are submergent marine grasses and cannot survive long periods of exposure. Seagrasses tend to dominate the seaward edge of the tidal zone but may occur at depths up to 40 metres.

Seagrass beds are habitats for prawn, mollusc and fish species of economic and indigenous importance. A number of fisheries species depend on seagrass beds for some part of their life-cycle, including prawns (particularly tiger prawns) and fish (e.g. whiting, garfish and flathead) (Coles et al. 1985, 1993).

Seagrasses form one of the most productive plant communities (Fonseca 1993), largely due to their very high rate of biomass production. They provide food for bacteria and microscopic animals at the base of the food web. Seagrass roots and rhizomes effectively bind sediments. Seagrass beds also baffle sediments as leaf material slows current flows around the plant and allows material in the water column to fall out of suspension. These actions of baffling and binding are beneficial in reducing inshore erosion from wind and wave action within the tidal zone. Fifteen seagrass species (and one undescribed species) occur in Queensland (Lanyon 1986, Lee Long et al. 1997). These species and their Queensland distributions are listed in Appendix 1. Where known, their tolerances of different environmental conditions are also listed.

Mangroves
'Mangrove' is a generic term applied to trees, shrubs, palms or ground ferns, generally exceeding a half metre in height and normally growing in tidal conditions (Duke 1992). Mangrove ecosystems form important and widespread habitats along the Queensland coast. A number of fisheries species of economic or indigenous importance depend on mangrove habitats for some part of their life cycle. Species of commercial importance include penaeid prawns (particularly banana prawns) (Vance 1996), mud crabs (Williams 1997), bream, trevally and bait fish such as anchovies and herring (Robertson and Alongi 1996).

There are over 40 mangrove species known to occur in Queensland. These are listed in Appendix 1. All species occur in northern Queensland, reducing to nine species in south-east Queensland (Duke 1992). Physiological tolerance limits for different species determine their distribution within the tidal zone, and along the Queensland coast.

Zonation (distinct vegetation bands of dominant mangrove species running parallel to the tide line) is apparent throughout all mangrove habitats in Queensland. The species composition and size of each zone varies according to:

- position in the tidal zone
- position in an estuary (upstream or downstream)
- location of the habitat within Queensland (tropical or subtropical)
- the available gene pool (species present)
- frequency of tidal inundation (related to height above mean sea level and the elevation of the tidal zone)
- volume and frequency of freshwater runoff; and
- extent of tidal range (Claridge and Burnett 1993).

Saltmarshes

Saltmarshes are intertidal plant communities dominated by herbs and low shrubs, such as samphires and saltcouches. In Queensland, while saltmarshes cover an extensive area, they generally exhibit poor species diversity and are often dominated by a single species (Adam 1996). Saltmarshes are often associated with claypan areas and occur on the landward side of the mangrove zone (Hyland and Butler 1989). Saltmarsh vegetation is more tolerant of fluctuations in salinity, temperature and desiccation than mangroves. The halophytic ability of saltmarsh plants is at the expense of growth — most saltmarsh vegetation is small and slow growing.

While Australian saltmarsh habitats have few permanent creeks and pans (Adam 1996), they provide fish habitats on a tidal basis. Fish have been recorded as far as 500 m from deeper water channels on saltmarshes in Moreton Bay (Connolly 1997). Little research, however, has been conducted on northern Australian saltmarshes and there is limited information on their distribution and extent (Adam 1996) and fish species utilisation (Morton et al. 1988).

While bream, whiting, mullet, garfish and silver biddies have been recorded in Queensland's saltmarshes (Connolly 1997), fish species of direct commercial importance are generally found there in lower abundance than those of indirect commercial importance. Non-commercial species, recorded in saltmarshes, such as perchlets and hardyheads, are often prey items for commercial species, and so play an important role in the food web. Tropical saltmarsh flats also play a major role in release of nutrients in the Gulf of Carpentaria, which may be related to prawn production (Ridd et al. 1998).

1.4.2 Wetland fauna

The broad assemblage of tidal wetland habitats is vital to the ongoing sustainability of many economically and indigenously important fisheries species. Molluscs, insects, crustaceans and other invertebrates as well as reptile, bird and mammal species form either fisheries prey or at death, detritus, thereby contributing to the wetland food web.

In regard to fisheries species, planktonic larvae or post-larvae are typically swept into estuarine mangrove and seagrass habitats following offshore spawning. The reduction of current flow, caused by vegetation, allows these planktonic larvae and other suspended material to settle out of the water column. Individuals may move to or remain in seagrass beds as juveniles, or move upstream to freshwater.

The richness and diversity of wetland fauna has often been attributed to the high primary productivity of seagrass beds; the large surface area of attachment for encrusting fauna; and the shelter provided by physical structure of the vegetation. These characteristics support the ‘nursery’ role for which wetland habitats have been well documented in the scientific literature (Coles et al. 1987, 1993; Connolly 1994; Vance 1996). Correlations have been made between the numbers of larval and juvenile commercial prawns and fish in inshore habitats and the local and offshore fisheries catch.

1.5 Marine habitat successional development

Successional development regulates the species richness and diversity of a community at any particular time, in response to environmental conditions. In wetland systems, certain species (‘pioneers’) are more likely to colonise a new site than others. When colonising a new area, ‘pioneer’ species may either dominate, preventing the colonisation of further species, or they may create an environment that is more suitable for other species to colonise.

In Queensland’s mangrove habitats, the grey mangrove (*Avicennia marina*) or the red mangrove (*Rhizophora apiculata*) are often the colonising species. After *Avicennia* or *Rhizophora* create a suitable, relatively stable environment, including shade and shelter, other species, such as the orange mangrove (*Bruguiera* spp.) may establish. In north Queensland, *Halodule uninervis* was the first seagrass species observed to colonise intertidal and shallow subtidal areas following cyclonic disturbance. Paddle weed (*Halophila ovalis*) has been found to be important in colonising deeper subtidal areas (Poiner et al. 1989).

Where artificial restoration is planned for a site, the desired endpoint of successional development of the community is a major consideration when selecting suitable species for revegetation programs.

2.0 Scope

This document provides guidelines for restoration or rehabilitation of disturbed or degraded marine areas (particularly mangrove, seagrass and saltmarsh areas), for fisheries purposes. This document should be consulted during the planning stages of restoration projects. Expert advice will be required to assess the needs of each project on a case-by-case basis.

Restoration and rehabilitation are generally defined separately. As defined earlier, ‘restoration’ involves returning the site to an agreed pre-existing condition and implies a final objective to return all aspects of the previous system (Sheppard and McKinnon 1997). ‘Rehabilitation’ involves returning the site to a state where natural succession can continue the recovery process and allow fisheries values of the site to be returned. While restoration and rehabilitation have the above definitions, from here on, only the term ‘restoration’ will be used, as the preferred objective is to return the pre-existing fisheries values to the site.

3.0 Guidelines for restoration of marine areas

Projects seeking to restore marine areas for the benefit of fisheries resources will vary in complexity in accordance with restoration objectives, available resources and site characteristics. Restoration may be required where historical, existing or potential stresses degrade wetlands and reduce fisheries productivity. Restoration may also be required to partially compensate or offset losses of fish habitat following development, or to restore remnant and/or rare communities on the basis of biodiversity and relative abundance.

The following eleven (11) step plan is recommended for the restoration of marine areas. The checklist, provided in Appendix 3, should also be consulted.

Step 1. Identify site
Step 2. Identify baseline conditions and degrading factors
Step 3. Set restoration objectives and criteria for 'success'
Step 4. Determine resource allocation
Step 5. Determine and obtain relevant permits / approvals
Step 6. Formulate restoration plan
Step 7. Develop revegetation strategy (where necessary)
Step 8. Implement plan
Step 9. Assess and monitor site
Step 10. Report results
Step 11. Maintain restored site

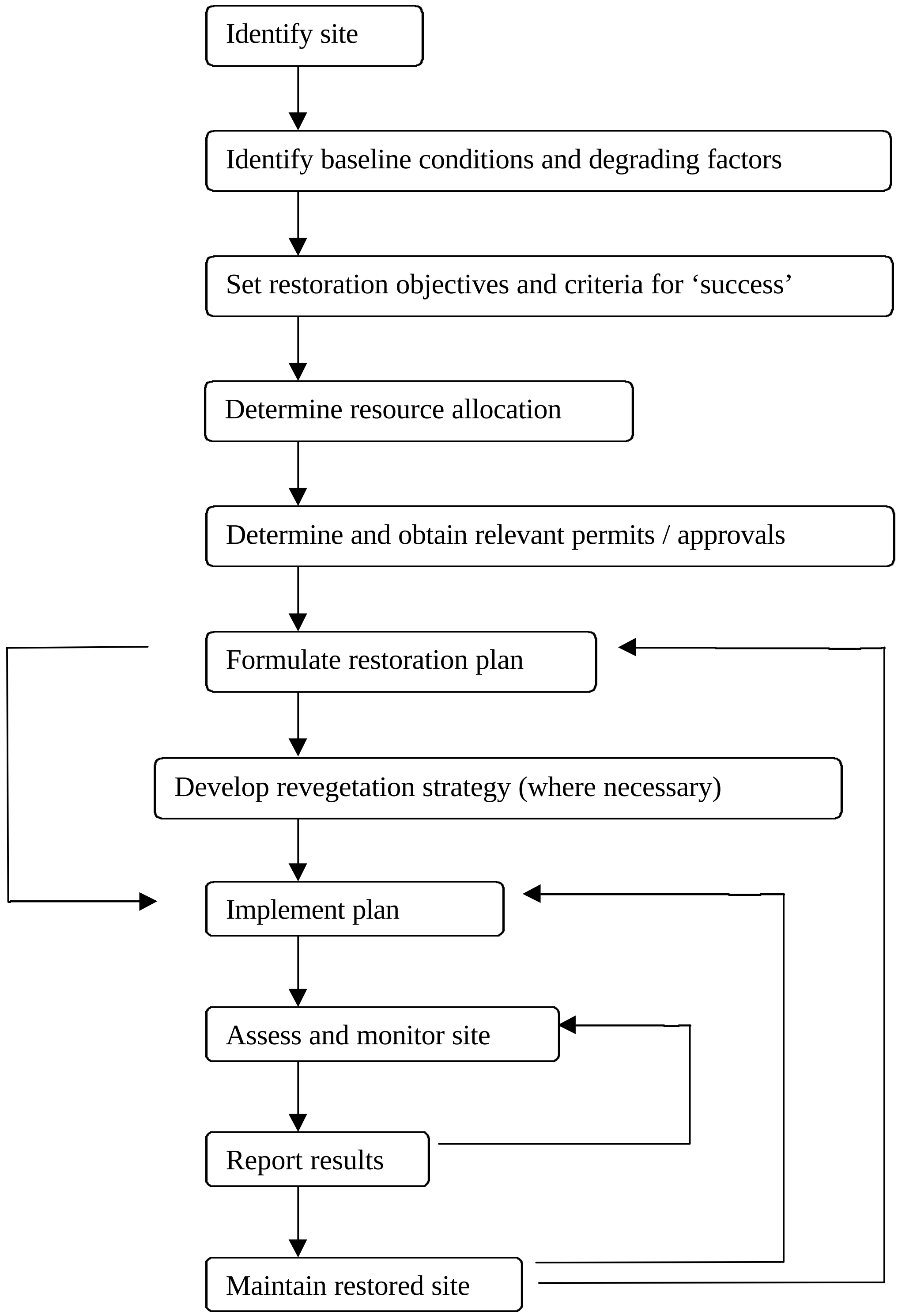

Figure 1: Flow chart of steps toward restoration of marine areas.

Step 1 Identify site

Site selection is a fundamental step in the process of wetland restoration and will be a major determinant of a successful project.

The following site attributes should be considered to determine the relative restoration potential of a site:

- Type and extent of habitat degradation.
- Occurrence of marine plants at the site prior to disturbance.
- Ease of access (particularly if machinery is needed).
- Availability of sufficient land (tenure, zoning etc.).
- Likelihood of issue of permits or approvals.
- Level of community concern over the site.
- Potential for exposure of acid sulfate soils (ASS) during restoration.
- Potential availability of plant material for revegetation (if required).
- Potential for erosion control following restoration.
- Potential for future colonisation by flora and fauna.
- Suitability of physical factors at the site for restoration (e.g. tidal range, hydrology, freshwater input, wind speed, wind direction, water depth and position of protective headlands or reefs) (restoration has been shown to be more successful in low energy environments).
- Potential for the site to counterbalance past, current or proposed fish habitat loss
- Potential for the site to counterbalance past or existing stresses where these affect fisheries resources or activities.
- Potential for preservation/restoration of unique or critical fisheries qualities (e.g. spawning or nursery sites, connectivity, habitat diversity).
- Potential to cause undesirable changes to existing habitat conditions (e.g. creating conditions conducive to mosquito breeding or weed invasion).

Public awareness of the site and of the proposed restoration project will help in further promotion of the project and its likely benefits. Such awareness may generate greater support and may lead to a greater success rate due to an increase in available resources.

Step 2 Identify baseline conditions and degrading factors

In the early stages of developing a restoration plan, it is necessary to establish baseline parameters/conditions for the site. This information will enable before/ after comparisons to be made with regard to the progress and success of a restoration project. Documentation of baseline parameters includes identification of physical markers at the site and should include flora and fauna surveys. Mapping of the intertidal profile is important to identify spatial and depositional changes over time. Identification of species, size and condition of individual plants at the site, incorporating plant tagging, is an important step in determining change and progress at a site over time, particularly for long-term monitoring of the site. This information will help to determine whether restoration is warranted at a site.

Before works start, the cause of habitat decline should be identified and, where possible, eliminated. Degrading factors may include:

- weed invasion
- excess sedimentation
- rubbish accumulation
- erosion
- habitat loss (e.g. vegetation loss, loss of structural complexity)
- driftwood and other floating debris
- stormwater inputs / freshwater inputs
- discharges/leachates (e.g. from ASS or contaminants)
- lack or restriction of tidal influence.

Successful restoration is unlikely if degrading factors continue to affect and place added stress on a site. The provision of continued protection of a site from degrading factors should be an integral part of the restoration project. If the degrading factors cannot be removed, or if there will be ongoing intermittent impacts (e.g. regular maintenance dredging), major restoration works at a site are not recommended.

Step 3 Set restoration objectives and criteria for ‘success’

It is necessary to determine whether the major objective of restoration is to return the site to a pre-disturbance condition or return the site to a stage where natural processes can achieve restoration goals.

Removal of a degrading factor(s) including rubbish and weed removal, and erosion and sediment control, are considered ‘minor’ restoration techniques, while revegetation, habitat enhancement and a number of water quality control techniques are considered to be ‘major’ restoration techniques.

When setting restoration objectives, it is necessary to consider when the restoration project will be completed and will be viewed as a ‘success’. When aiming to restore fisheries values, a project should only be considered successful when the restored area is colonised by fauna that were present or used the habitat prior to disturbance. The creation of an area that is a functional habitat for juvenile prawns, or as a feeding ground for commercially important fish species, are examples of beneficial outcomes of fish habitat-focused restoration projects.

The proposed extent of restoration efforts must be clearly defined prior to the start of the project. The principles of ecologically sustainable development should be considered when planning a restoration project. Works must be carried out in a way so that the biodiversity and the ecological processes on which fisheries resources depend are maintained.

Available techniques to achieve restoration objectives may include:

- *Rubbish removal and weed control*

Timely removal of rubbish and control of excessive weed growth may improve the fisheries values of a site, by increasing the available area for fish use, as well as visually improving a disturbed habitat. These controls may also potentially increase water retention times thereby improving water quality. It is important that erosion problems are not created by excessive removal of weed growth. Control techniques may be conducted mechanically or by hand and include weeding, mulching, mowing / slashing and only where necessary, poison.

- *Erosion and sediment control*

Erosion and sediment control may include modification of the profile and banks of a wetland through recontouring (introduction of berms and batters), placement of geotextiles, mulching, hydromulching and selective revegetation. Creation of pools, stilling basins, meanders and riffles may also help erosion and sediment control.

- *Water quality improvement*

There are a number of techniques to improve the water quality of a wetland. Alterations to hydrology include improved tidal flushing, increased freshwater movement, management of tide or flood gates, removal of bunds and the reduction of the size of drains. The control of stormwater is important and may include the installation of gross pollutant traps, sumps, energy dissipation devices and natural or chemical treatment of stormwater runoff. Management of leachates may include neutralisation, burial, reflooding or removal of the material in question, or diversion of flow from contaminated areas.

- *Revegetation*

Revegetation, using endemic plant species, is likely to enhance the fisheries values and water quality of a disturbed wetland. Riparian vegetation is likely to stabilise the banks and so reduce erosion. Shading of waterways is likely to reduce instream and bank growth of exotic plants. Revegetation techniques for mangrove, seagrass and saltmarsh areas are described in detail in Step 7.

- *Habitat enhancement*

The creation of pools and riffles enhances the fisheries value of the habitat, by increasing habitat diversity and so promoting biological diversity. This involves the provision of shelters and spawning and feeding habitats. Fish habitats may also be enhanced through the provision of aquatic vegetation, snags, overhangs and rocks, which add to habitat diversity.

Where creation of an artificial wetland is the desired objective, it is important that there is access to the site for maintenance. There should also be a high degree of flexibility in the system to cater for all flow regimes, i.e. to allow for tidal fluctuation and periods of flood.

Step 4 Determine resource allocation

Following site identification and costing of the restoration project, it is important that the necessary funding is available for the long term completion of the project. Funding will be required for a number of purposes including labour, expertise, materials and equipment, maintenance and monitoring and will depend on the extent of restoration effort taking place. Assistance in kind or monetary support may be sought from government agencies, community groups, private industry groups, fund raising, or other sources. Assistance may include provision of materials, equipment, advice, labour or funds. Availability of resources should be considered when planning the scope of the project, including restoration techniques and future monitoring of the site.

Step 5 Determine and obtain relevant permits/approvals

Prior to commencement of works, ensure that current statutory approvals are obtained. Refer to Appendix 3 for a list of relevant legislation and a list of relevant State departments administering activities. In situations where protected marine plants may be impacted (for collection, planting or removal), a Permit under Section 51 of the *Fisheries Act 1994* will be required.

Step 6 Formulate restoration plan

Restoration of marine areas is undertaken or overseen by DPI Fisheries to return fisheries values to a site. Restoration may only require the removal of the degrading factor(s). The site may then be allowed to restore naturally. Where removal of degrading factors is not sufficient to return the fisheries values of the site, alteration of the hydrology and profile of the site or revegetation may be required. When formulating a restoration plan, it is important that all stages are documented and all aspects of the project are considered prior to project commencement, including a future monitoring and maintenance schedule.

1. Plan removal of degrading factors

As described above, before successful restoration works can commence, degrading factors which influence habitat decline must be identified and, where possible, eliminated. Ease and effectiveness of removal of degrading factors will determine the extent of restoration works required to achieve restoration objectives.

2. Plan strategy to return the previous hydrology and profile of the site

Following a disturbance, it may be necessary to return the hydrology and tidal profile of the site to pre-disturbance conditions. Such modifications will enhance the likelihood of successful natural restoration. Altering the bed and bank profile aims to prevent or limit bank erosion, eliminate areas of poor drainage and ensure that the tidal range is suitable for establishing marine plants, either through natural colonisation or by planting of selected species. Altering the profile also restores appropriate levels of drainage and ponding for the tidal cycle. If major disturbance of the current tidal profile is required for restoration, it is important that testing for potential acid sulfate soils (PASS) is conducted and mitigation/contingency measures are put in place. During preparation of the site, it is important that the existing vegetation (unless identified as weeds) is not disturbed. When re-profiling a site, it is important to maintain some level of variation in microtopography at the site.

To aid tidal exchange to and from saltmarsh – claypan areas, landform modifications such as runnelling (creation of shallow spoon-shaped channels) may be considered as appropriate. This may ensure that excess ponding does not occur and create breeding grounds for mosquitoes. Refer to FHMOP 003 for more details on insect pest control in coastal wetlands.

3. Determine whether revegetation is required

If, after a pre-determined period of time, there is little natural revegetation at the site or if there is little capacity at the site for natural re-seeding, aided or active revegetation of the site, or of part of the site, may be required. A threshold should be set for the length of time and/or extent of regrowth that will lead to the commencement of aided revegetation. After this threshold has been exceeded, revegetation of a site may be considered.

Step 7 Develop revegetation strategy (where necessary)

The following steps outline components of a planting strategy that may be developed to restore disturbed marine areas.

It may be appropriate to conduct the revegetation program over three years, to observe whether the initial revegetation facilitates natural colonisation of the site, in turn decreasing the amount of assisted revegetation required to achieve restoration goals.

1. Prepare site

Following modification of the habitat profile and returning the hydrology of the site to pre-disturbance conditions, as described in Step 6, further modifications may be required to prepare the site for planting (e.g. loosening compacted soils).

2. Select species

Following the decision to revegetate a site, species need to be carefully selected for planting. The respective merits of planting of a mixed community versus a monoculture should be considered. Mixed planting may enable a diverse system to develop more quickly, while a monoculture may stabilise the site faster. It may be possible to plant a monoculture of colonising species initially, to stabilise the site, and plant other species subsequently. Alternately, natural succession may be allowed to act on the site. The fisheries benefit of a mixed community compared with that of a monoculture is, as yet, not known. Comparison of the plant structure of adjacent communities will assist in deciding whether a mixed or monospecific community should be established.

Species often use a number of basic life strategies that need to be taken into account when selecting species for a restoration project. Stress tolerant species are those that can exploit conditions of high stress and low disturbance, such as the mangroves *Rhizophora, Ceriops, Avicennia, Acanthus, Aegiceras, Bruguiera, Heritiera littoralis,* and *Cynometra iripa* (Saenger 1996). Disturbance tolerant species are those that can exploit conditions of low stress and high disturbance, such as, *Excoecaria, Lumnitzera, Xylocarpus* and *Osbornia* (Saenger 1996).

Species may be selected according to their suitability to the site’s environment, their maintenance requirements and their benefit to the overall ecology of the site. Environmental factors that may influence the suitability of species for a site include:

- salinity
- turbidity
- soil characteristics (density, pH, texture, composition, nutrients)
- tidal profile
- tidal height and range
- inundation frequency
- hydrology (wave action, current)
- quantity and quality of runoff

- local species distribution and abundance
- water quality (nitrogen, phosphorus, chlorophyll a, turbidity)
- proximity to freshwater source and frequency of freshwater inundation.

When selecting a species, consideration should be given to any legal or other restrictions on the use of a species. All marine plants are protected in Queensland, therefore, legislative requirements must be met in the use of marine plants.

There must be a sufficient source of stock that will suit the available propagation methods. For example, some seagrass species rely on vegetative propagation and rarely germinate from seed. In contrast, other seagrass species will readily germinate from seed but do not produce a rhizome for at least two years (West et al. 1990). A high growth rate will assist in the maintenance of vegetation on site and the development of the site into a complex system.

Species to be planted should either exist in neighbouring wetlands or have been recorded at the site prior to disturbance. Environmental tolerances and preferred conditions for Queensland's mangrove, seagrass and saltmarsh species are detailed in Appendix 1. Advice may be sought from DPI on the preferred species to be used in an area.

3. Develop propagation and stock management techniques, incorporating collection, care and storage of plant materials

Determine the quantity of plant material needed / desired plant spacing
To determine the quantity of material required for revegetation of a site, it is necessary to establish the planting density based on the desired plant spacing. When planning the spacing of plants it is advisable to plant equal to or more than the desired post-planting density to allow for potential mortality. Use of a grid system will ensure even planting. Planting density will influence the growth pattern of marine plants and is also likely to alter the patterns of use of the habitat by fisheries species. In some habitats, greater mangrove or seagrass density leads to high faunal abundance.

A preliminary cost – benefit analysis can help determine the quantity of material required for planting. It is important to consider the cost per propagule, the desired outcome, the most successful type of propagule, the level of protection offered by more dense planting and the impact of removal of propagules on the donor habitat.

Optimum spacing of **seagrass** planting units will differ with the location of the restoration site, whether it is in a tropical or sub-tropical area. In general, seagrass planting densities may be between 0.5 to 2.0 planting units per metre (m), with greater success appearing to result from denser plantings. However, the more dense the planting, the more expensive the operation. Details on seagrass row spacings are given in a number of papers, as listed by Fonseca (1993).

Mangroves have been successfully planted at a variety of spacings, depending on the area, topography and available funds. Mangroves have been planted at intervals of between 0.7 and 5 metres (Harty 1997; Duke et al. 1997; FRC 1997) along transects. It may be necessary to consult with documents in the reference list for details on individual projects.

Determine source of plant material
Genetic hybridisation and disease need to be considered when translocating material between sites. For this reason, it is preferable that the plant donor site is close to the restoration site. It has been suggested (Harty 1997) that the donor site should not be further than 1.5 kilometres

away from the transplant site to ensure minimum risk of alteration of the gene pool, and to enable the benefits of species' adaptations to local conditions to be maximised. It may be possible to remove plant material from the actual restoration site prior to disturbance, and to hold it in a nursery situation until the disturbance has been removed.

Prior to planting, it is important that any collected plant material is checked for disease.

Timing of seed/seedling collection

The species to be planted and the method of planting will determine the optimum time of year for planting of seeds and seedlings at the site. To assist with this decision, the flowering and fruiting periods for mangroves and seagrasses are included in Appendix 1. Where the preferred time for collection of propagating material (e.g. seeds, seedlings, plants) does not coincide with the optimum time for planting, nursery holding of material may be required. When collecting seeds/seedlings, it is necessary to consider the impact of the works on the donor site.

Nursery development

A nursery to hold stock may be required to ensure material is planted at optimum growth stage and season. When the need for restoration of marine areas increases, it may be necessary to establish permanent mangrove nurseries to hold and supply a stock of seedlings for restoration, as required. Mangrove nurseries have been developed in Queensland for specific restoration projects (e.g. DPI Northern Fisheries Centre (Cairns), AIMS, DPI Forestry (Beerburrum)). These facilities are small-scale, and generally for research purposes. No large-scale nurseries for marine plants have been established in Queensland at this stage.

Where nursery development is required, reference to guidelines for the accreditation of production nurseries (NIAA 1994) will be useful. These guidelines include details on crop hygiene (root disease prevention; disease, pest and weed control), regulatory requirements, crop management practices (nutritional and environmental control) and site appearance. Careful practices in the nursery environment will help to reduce the likelihood of transfer of disease and maintain plants in optimum condition.

Mangroves may be grown in a variety of nursery conditions. Plants that have been grown under conditions similar to those found at the restoration site have better survival rates when planted at the site.

Details of nursery holding techniques

Nursery holding techniques will be influenced by the planting method to be used.

Peat moss Jiffy pots have been shown to be a successful method of storing mangrove seedlings (Duke et al. 1997). Plants may be kept moist in ponds of brackish water with added nutrients. Prior to planting, the salinity of the pond water should be increased to that of the restoration site. When using peat moss Jiffy pots, seedlings may be considered ready for planting when roots have developed, and prior to their emergence from the pots. Root damage to seedlings has been correlated with increased mortality following planting at the restoration site (Duke et al. 1997).

The soil medium in which nursery seedlings are grown should be the same soil into which they will eventually be planted. This allows for nursery plants to become adapted to the soil type at the site and if there is a limiting factor associated with the soil at the site, it will be identified and any remedial measures may be taken.

Methods of Planting

The methods outlined below may assist with selecting planting techniques for revegetation of marine habitats. Following the determination of the species for planting, it will be necessary to determine the optimum planting method on a species and case specific basis.

Mangroves

Mangroves can be planted successfully at a number of stages, depending on the species: as seeds; as newly germinated propagules; as seedlings, having developed some root structure and/or some leaf growth; and, as larger plants.

Seeds.—may be used to revegetate a site, however survival and success rates are generally lower than for nursery reared seeds, germinated propagules and transplanted seedlings. Seeds may be collected and raised in a nursery until at a suitable height or level of leaf growth.

Germinated propagules.—have a higher rate of success than planting of seeds. Germinated propagules may be collected directly from the tree, from the litter under mangrove trees, from beach wrack, or may be removed from the sediment as newly rooted young seedlings.

Seedlings.—have been successfully transplanted. Mangrove seedlings may either be planted in pots (usually following nursery holding), or as plugs in natural sediment. Survival of transplanted seedlings is often greater than for transplanted seeds, although the planting costs are often greater. Seedlings may be planted at varying heights. Plantings of seedlings between 15 and 50 cm high have been successful.

Where seedlings are to be held for a period of time, it may be necessary to store them in peat moss Jiffy pots or plastic/poly bags. These allow transport of seedlings with limited damage to the seedling roots. Peat moss Jiffy pots may be planted directly into the sediment at the transplant site. Individual holes are required in the sediment at the transplant site to allow spreading of roots. The depth of the holes needs to be sufficient to allow the top surface of sediment in the pot to be buried with local sediment, to minimise loss of sediment during rising and falling tides.

Larger plants.—mangroves taller than 1m in height have been successfully transplanted in some instances. However, the cost of such relocation will often be prohibitive. Large plants may be more suitable to stabilise a site and provide dense mangrove cover in a shorter period of time (Saenger 1996).

Tips

- While planting mangrove seedlings, care must be taken not to damage the roots. Increased mortality of seedlings has been associated with root damage.
- The use of growth stimulants, such as fertilisers or auxins, on seedlings may increase the amount of root growth per seedling and may enhance survival.
- The larger the root mass at planting, the better the chances for survival
- Devices to provide shelter and shade to newly planted seedlings may reduce the effects of desiccation through heat stress. Protective devices may also be required to reduce the impacts of driftwood which may lodge on mangrove seedlings.

For more information on transplanting mangroves refer to:
- Field (1996)
- Thorhaug (1990)
- Duke, Dalhaus and Clough (1997)
- Quinn and Beumer (1984)
- State Pollution Control Commission

Seagrasses

Seagrasses are generally transplanted rather than grown from seed. Before seagrass material is transplanted, it is important to ensure that each planting unit has fragments of actively growing rhizomes to enhance vegetative growth of the plants.

Success rates for transplanting seagrasses have been highly variable. Restoration has been successful in a number of small-scale projects, however, there has been no consistent success for large-scale seagrass restoration. The methods involved in transplanting seagrasses are both time consuming and costly. Disturbance of the donor site, during removal of plants, and the restoration site, during planting, may cause more damage than would be repaired through the transplantation process. In a number of cases, transplanted seagrass grows but there is no lateral spread, which means there is no increase in the seagrass area. For these reasons, transplantation of seagrass is not recommended as a major component of restoration of degraded marine habitats. However, a number of planting methods are outlined below, in case favourable conditions for seagrass restoration are encountered.

Seeds.—have been successfully planted. However these projects often involved specific methods, which could not be replicated on a large-scale (e.g. collection of seeds by hand using SCUBA and separation of seeds from the fruit pod). More often, attempts at revegetation of seagrass beds using seeds has been unsuccessful due to limited germination from viable seeds and the length of time required for rhizome production in some species. The suitability of species to be planted from seed is highly species dependent.

Planting seagrass directly into the sediment will require an anchoring mechanism to reduce the chance of the seedlings being washed away. ‘Plugs’ and ‘staples’ are used to transplant seagrasses, and may be used in the nursery development of seagrasses, if required.

Plug method.—requires that plugs of seagrass and sediment be removed using a core tube, which is inserted into the sediment. When the tube is in place, a stopper is placed in the top to create a vacuum seal. When the tube is removed from the sediment, the sediment plug is also removed. At the transplant site, the core containing the sediment plug is placed into a pre-dug hole and after release of the stopper, the sediment plug slides into the substrate. Plug sizes can vary from 10 cm diameter to over 20 cm x 20 cm. As this method transfers leaf blades, roots, rhizomes and sediment the disturbance to individual plants can be minimised. It is important, however, that an apical meristem is included in the plug to ensure lateral spread.

Staple method.—involves removal of intact seagrass plants from which sediment is shaken and washed from the roots and rhizomes (these complete shoots are referred to as ‘sprigs’). The root and rhizome portion of approximately 15–30 sprigs is placed under the bridge of a metal “staple”, with the leaf material above the staple. The plants are attached to the staple with twist ties or nylon cable ties. The planting unit is inserted into the sediment to a depth just covering the bridge of the staple. The planting unit may be pushed into the sediment at the transplant site, or placed into a pre-dug hole.

Mechanical planting.—planting of seagrass has been developed in Western Australia (Paling et al. 1997) using a mechanical prototype. Mechanical transplanting of sods of seagrass has been demonstrated, with survival between 75 and 95%. Large-scale transplanting would only be feasible where the seagrass at the donor site will be destroyed, due to the impact of removal of large areas of seagrass.

Tips

- When planting seagrasses, placement of slow release fertiliser (such as Osmocote) into the pre-dug hole at the restoration site may be beneficial (regulation of the nutrient composition of the fertiliser may be required).
- It is important that any sprigs prepared for transplanting contain rhizomes with apical meristems to enable spread of the seagrass.
- Transplanting methods involving removal of sediment from the seagrass shoots allows the roots to be checked to ensure they have apical meristems.
- Sprigs of seagrass for transplanting may occasionally be collected from beach wrack although there may be little root/rhizome. This will reduce the impact on the donor site.

For more information on transplanting seagrasses refer to:

- Kirkman (1989)
- Fonseca (1993)
- McLennan and Sumpton (1997)
- Thorhaug (1990)
- Luck (1990)

Saltmarsh species

Little, if any, research has been conducted on transplanting methods for northern Australian saltmarsh species. There is a variety of species of saltmarsh plants, and transplanting, rather than planting from seed, may be the more appropriate method for saltmarsh revegetation.

Whole plants.—may be transplanted as, due to their growth form, it is often possible to transplant entire saltmarsh plants, either with sediment still attached to the root systems, or following the washing of all sediment from the root system of the plants.

Cuttings.—may be taken from vegetative material of saltmarsh species that naturally root from nodes or may develop roots from vegetative fragments. These cuttings may be placed into the substrata of the site to be restored.

Seeds.—may be collected from a variety of saltmarsh plants. However, the success, reliability and viability of revegetation using seeds are variable. It may be possible to collect the seeds of saltmarsh plants for nursery rearing.

Tips

- The use of fertilisers may be beneficial at sites that are typically nutrient poor, to allow plants to become established.

- Germination and seedling establishment of many saltmarsh plants may be dependent on a period of reduced salinity (Calder 1981).

For information on planting saltmarsh species refer to:
- Adam (1990)
- Romanowski (1998)
- Zedler (1988)

Timing of planting

Timing of planting needs to be considered on a case by case basis depending on the species to be planted and the location of the restoration site within Queensland. However, the timing of planting of wetland species is crucial to ensure that plants are not washed away through water and wave action immediately following planting.

The developmental stage of the transplanted material is an important determinant of the timing of planting for successful colonisation of the site. The level of root growth on the individual plants and also the position in the tidal zone for planting need to be considered in the planning process. In northern Queensland, autumn is recommended as a suitable time for planting mangroves. Root growth is generally higher during winter months, so planting in autumn may allow development of root structure prior to the wet season, to reduce the chance of material being dislodged and plants being washed away. In southern Queensland, autumn is not recommended for planting seagrasses as growth is often minimal in winter and so may increase the chance of mortality. Planting in spring is suggested as plants may grow and establish prior to the extremes of summer.

For saltmarsh species, many show maximum germination in freshwater and are dependent on a period of reduced salinity for seed germination and seedling establishment (Calder 1981). Therefore, when transplanting saltmarsh species, particularly by seed, it is important to consider the option of reducing salinity levels in the surface soil.

Different plant species will have different requirements throughout the State. Consideration of localised natural colonisation processes and their timing may assist in identifying the most appropriate period for restoration works.

Protection devices

As part of a planting strategy for mangroves, it may be necessary to install devices to reduce the potential risk of damage to transplanted material from water and wave action (including tidal movement) and herbivores. Anecdotal evidence indicates that sediment disturbance during planting may attract fish and other fauna. Subsequent active foraging in newly disturbed sediment may dislodge freshly planted material. Examples of protection devices include PVC piping and mesh netting.

PVC piping may be used for protection of mangrove seedlings. Lengths of PVC piping may be placed over individual seedlings to protect them from wave and wind erosion and scouring from driftwood and other such impacts. For larger seedlings, PVC pipes may be arranged in a pyramid structure, attached together at the apex, and pushed into the sediment. These pyramids may be placed around seedlings and act in the same way as mangrove stilt roots (e.g. *Rhizophora* spp.) to prevent damage from driftwood scouring and to reduce the water flow and erosion around the seedlings. Such devices may be allowed to remain at a site for a number of years. It is likely that they would not be necessary following one to two years of growth.

For seagrass, mesh netting has been used to stabilise sediment and reduce herbivory. Mesh that is sensitive to UV light breaks down and therefore does not require removal, as does PVC piping. Mesh netting may however become clogged with algae, which will prevent rapid breakdown and instead cause shading of seagrass sites.

Step 8 Implement plan

Following the development of a detailed restoration plan, it is necessary to implement the process. It is important to follow the details of the plan and keep within an agreed time frame to increase the likelihood of a successful project. A record of all stages of the process should be maintained. This will aid in reporting the results at a later stage.

Step 9 Assess and monitor site

Following planting, it is necessary to monitor survival and growth of the transplanted plants and also to ensure that they are not being overtaken by weed species. If problems occur following planting, troubleshooting mechanisms should be undertaken.

1. Monitor survival

If survival of transplants is low, it may indicate the presence of a degrading factor not previously identified or considered at the site. It will be necessary to identify and, where possible, remove the degrading factor.

Where mortality is high, a second planting may be necessary. A threshold level may be determined prior to commencement of the study to evaluate whether further planting should be undertaken, e.g. approximately 50% mortality.

2. Monitor growth

High growth rates may provide additional area and protection for the planting of further seedlings. It may be necessary to remove some plants to allow full canopy development.

It is important for the long term success of a restoration project that both growth and survival are monitored regularly for at least a year following planting and then monitored annually.

3. Troubleshoot problems – modify plan where necessary

Troubleshooting of potential problems is another follow up step of the restoration process. Table 1 summarises potential problems with restored wetlands and potential corrective measures.

Table 1. Summary of potential problems following restoration and corrective measures that may be undertaken. (adapted from Table 24–2 Kadlec and Knight 1996)

Problem	Corrective Measure
Water stress (water levels too low) or flood stress (water levels too high)	Where possible, manipulate the water levels to increase or decrease flow

Macronutrient (N P K) and micronutrient stress (Fe, Mg, Mo etc.)	Fertilise as required
Dissolved oxygen stress: organic loading; ammonia loading; smothering (sludge or solids); tight soils	Reduce input of oxygen demanding substances; lower water levels; reduce input of solids (mineral solids and sludge)
Pathogens/herbivores	Tolerate without chemical controls as much as possible

Step 10 Report results

Following implementation of a Restoration Plan, it is important that the techniques/methods and outcomes are documented. This should be undertaken, even when restoration is not successful, to assist with potential information gathering for future projects, particularly if problems can be documented.

Where marine plants are used in the restoration project, development of a report on the project and an outline for the long-term monitoring of the site may form part of the conditions of Permit. The report should be sent to DPI, Fisheries. Where possible, a copy will be lodged in the Fisheries Library to allow access to the information for further restoration projects.

Step 11 Maintain restored site

After completion of restoration works and a period of monitoring of the site, it is important to maintain the restored values of the site into the future. It will be necessary to reassess the steps of the restoration project periodically (at pre-determined periods) to ensure long-term success. Following assessment of the site, repetition of a number of the steps in the project may be required.

4.0 Glossary

Acid sulfate soils (ASS): Soil and sediment containing iron sulfides (principally iron pyrite) or containing acidic products of the oxidation of sulfides. When exposed to air, oxidation of sulfides occurs. When the soil's capacity to neutralise the acidity is exceeded, sulfuric acid is produced (QASSIT 1997).

Apical meristem: The growing tip of a plant, an area of rapidly dividing cells.

Declared Fish Habitat Area: An area declared under the *Fisheries Act 1994* to be a Fish Habitat Area.

Ecologically Sustainable Development (ESD): Development carried out in a way that maintains biodiversity and the ecological processes on which fisheries resources depend; and that maintains and improves the total quality of present and future life. (*Fisheries Act 1994* S.25)

Endemic: Belonging to or native to a given geographic region, not introduced.

Exotic plant: Not native to an area (introduced from elsewhere).

Fisheries Group: Refers to the Department of Primary Industries, Queensland, Fisheries Group.

Fish habitat: Includes land, waters and plants associated with the life cycle of fish, and includes land and waters not presently occupied by fisheries resources (*Fisheries Act* S.4)

Fisheries resources: Includes fish or marine plants (*Fisheries Act 1994* S.4)

Halophytic: Salt loving or salt tolerant. Halophytic plants are capable of maintaining normal growth under conditions of high salinity.

Hypersaline: Very high salinity environment. Hypersaline waters have a salinity in excess of 35‰. Only halophytic plants will be successful in a hypersaline environment.

Littoral: Of, on or near the shore, particularly the intertidal zone.

Marine plant: A plant (a tidal plant) that usually grows on, or adjacent to, tidal land, whether it is living, dead, standing or fallen; material of a tidal plant, or other plant material on tidal land and a plant, or material of a plant prescribed under a management plan or regulation to be a marine plant. A marine plant does not include a declared plant under the *Rural Lands Protection Act 1985* (*Fisheries Act 1994* S.8).

Typically, a marine plant includes mangroves, seagrasses, saltmarsh plants, algae and *Melaleuca* spp. adjacent to tidal lands.

Planting unit: Plant material in a form that is suitable for use in revegetation of a site. A planting unit may include an individual core, plug, staple or peat pot.

Propagule: Any part of a plant capable of growing into a new organism; the unit of dispersal.

Rehabilitation: Returning a site to a state where natural succession can continue the recovery process and allow fisheries values of the site to be returned.

Restoration: Returning a site to an agreed pre-existing condition – implies a final objective to return all aspects of the previous system.

Riparian vegetation: Vegetation growing on the bank of a watercourse.

Tidal land: Includes reefs, shoals, mudflats and sandbanks and other land permanently or periodically submerged by waters subject to tidal influence (*Fisheries Act 1994* S.4).

Waterway: Includes a river, creek, stream, watercourse or inlet of the sea (*Fisheries Act 1994* S.4).

Wetland: Areas featuring permanent or periodic/intermittent inundation, whether natural or artificial, static or flowing, fresh, brackish or saline, including areas of marine water the depth of which at low tide does not exceed six metres. Examples include billabongs, marshes, swamps, lakes, mud flats, mangrove forests and shallow seagrass beds.

5.0 Acronyms

AIMS	Australian Institute of Marine Science
ASS	Acid sulfate soils
DEH	Department of Environment and Heritage, Queensland
DNR	Department of Natural Resources, Queensland
DPI	Department of Primary Industries, Queensland
ESD	Ecologically Sustainable Development
FHA	declared Fish Habitat Area
FHMOP 001	Fish Habitat Management Operational Policy 001 (see Couchman et al. 1996)
FHMOP 002	Fish Habitat Management Operational Policy 002 (see Zeller and Beumer 1996)
FHMOP 003	Fish Habitat Management Operational Policy 003 (see White and Beumer 1996)
FHMOP 004	Fish Habitat Management Operational Policy 004 (see Hopkins and White 1998)
IUCN	World Conservation Union (formerly the International Union for the Conservation of Nature)
NIAA	Nursery Industry Association of Australia
PASS	Potential acid sulfate soils
QASSIT	Queensland Acid Sulfate Soils Investigation Team
S.	Section

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Appendix 1 Queensland's mangrove, seagrass and saltmarsh species

The details provided in this appendix are listed as a guide only. Further advice should be sought from local literature and from regional Fisheries staff.

Mangrove flora of Queensland

Species (common name)	Queensland distribution	Flowering period	Fruiting period	Sowing material	Max Ht	Salinity tolerance	Estuary pos[n]	Tidal pos[n]	Comments
Acanthus ebractiatus	Escape River, tip of Cape York	Sep–Dec ?	Jan–Feb ?	Seed	2 m		I	MH	
Acanthus ilicifolius (holly leafed mangrove)	North of Rockhampton	Sep–Dec	Jan–Feb	Seed	2 m	Low	IU	MH	May dominate after clearing of mangrove areas
Acrostichum speciosum (mangrove fern)	All Qld	-	-		2 m	V. low	I	H	Dominates in cleared/disturbed areas. Common in undisturbed areas under freshwater influence.
Aegialitis annulata (club mangrove)	North of Tin Can Bay	Nov–Mar	Jan–May	Propagule	3 m	V. high	D	MH	In sandy or rocky environments
Aegiceras corniculatum (river mangrove)	All Qld	Jun–Sep	Dec–Mar	Propagule	5 m	Wide	IU	L	Upstream in rivers
Avicennia marina (grey (or white) mangrove)	All Qld	Spring	summer/ autumn		30 m	V. wide	DI	LMH	Most widely distributed mangrove in Australia
Barringtonia asiatica (freshwater mangrove)	North Qld				20 m			H	Often on beaches in north Queensland
Barringtonia racemosa (Freshwater mangrove)	North of Townsville	Aug, Oct–Jan	Dec, Feb–Mar		10 m	Low		H	
Bruguiera cylindrica (orange mangrove)	North of Cairns	June	*c.* Nov	Propagule	20 m	Low	DI	M	
Bruguiera exaristata (orange mangrove)	North of Rockhampton	Sep–Oct	Feb–Mar	Propagule	25 m	Low	IU	H	
Bruguiera gymnorrhiza (large leaf orange mangrove)	All Qld	Jan–Aug	Jan–Jul	Propagule	30 m	Low	DI	MH	
Bruguiera parviflora (small leaf orange mangrove)	North of Mackay	Aug–Oct	Jan–Feb	Propagule	25 m	Low	DI	M	Yellow–green leaf colour
Bruguiera sexangula (orange mangrove)	North of Townsville	Aug–Dec	Aug–Sep	Propagule	30 m	Low	IU	MH	

Species (common name)	Queensland distribution	Flowering period	Fruiting period	Sowing material	Max Ht	Salinity tolerance	Estuary pos[n]	Tidal pos[n]	Comments
Camptostemom schultzii (Kapok mangrove)	North of Cooktown	Spring	Mar–Apr?	Propagule	25 m	High	DI	LM	More characteristic of open rocky shores than estuarine mangroves
Ceriops decandra (yellow mangrove)	North of Townsville	Sep–Mar	Dec–May	Propagule	10 m	High	I	MH	
Ceriops tagal (yellow (or spurred) mangrove)	All Qld	Nov–Mar	Dec–May	Propagule	10 m	High	DI	MH	
Clerodendrum inerme (mangrove vine)								H?	
Crinum pedunculatum (mangrove lily)	Tropical Qld	Nov–Jan	Feb–Mar					H	
Cynometra iripa (wrinkle pod mangrove)	North of Mackay	Sep–Feb Mar–Aug	Mar–Nov Dec–Feb	Pod	5 m	Med	IU	H	Prefers shade, only produces seed in years of high rain, slow growing
Derris trifoliata (derris vine)	North of Mackay				15 m			H?	Widespread vine on mangroves, may be climber or shrub
Diospyros littoralis	North of Cairns	Nov?	?	Seed	25 m		IU	MH	
Dolichandrone spathacea	North of Cooktown	*c.* Sep	Nov	Seed	20 m		U	M	
Excoecaria agallocha (milky (blind-your-eye) mangrove)	All Qld	Nov–Feb	Jan–Mar	Seed	15 m	Low	DIU	MH	Has milky sap which may damage human eyes. Prefers sandy areas with freshwater input.
Heritiera littoralis (looking glass mangrove)	North of Rockhampton	Nov–Mar	Sep–Dec	Seed	30 m	V. low	I	H	
Hibiscus tiliaceus (native hibiscus/cotton tree)	All Qld	Oct–Jan	Feb–Apr		15 m			H	NQ – flowers and fruits all year round
Lumnitzera littorea (black mangrove)	North of Townsville	Nov–Feb	Feb–Mar	Propagule	8 m	Low	I	M	
Lumnitzera racemosa (black mangrove)	All Qld	Nov–Feb	Feb–Mar	Propagule	8 m	Wide	D	MH	
Lumnitzera x rosea (black mangrove (a hybrid))	North of Townsville	Nov–Feb	Mar	Propagule	8 m		I	H	A hybrid of *L. littorea* and *L. racemosa*
Nypa fruticans (mangrove palm)	North of Townsville	Nov	Dec–Mar	Seed	9 m	Low	U	LMH	Found upstream in low salinities and calm water

Species (common name)	Queensland distribution	Flowering period	Fruiting period	Sowing material	Max Ht	Salinity tolerance	Estuary pos^{n}	Tidal pos^{n}	Comments
Osbornia octodonta (myrtle mangrove)	North of Bundaberg	Dec–Feb	Feb–Mar	Seed	5 m	High	D	MH	Crushed leaves have distinctive eucalypt smell. Does not occur in areas of frequent freshwater inundation.
Pemphis acidula (pemphis)	North of Bundaberg	All year	All year	Seed			D	H	
Rhizophora apiculata (tall stilted mangrove)	North of Rockhampton	Apr–May	Feb Apr–Oct	Propagule	25 m	Wide	I	M	In less saline areas than *R. stylosa*
Rhizophora mucronata (red mangrove)	North of Townsville	Oct–Dec	Jan–Mar	Propagule			IU	LM	
Rhizophora stylosa (red mangrove)	All Qld	Feb–Apr	All year	Propagule	20 m	High	D	LM	
Rhizophora x lamarckii (red mangrove)	North of Rockhampton	Aug–Dec	Jan–Mar	Propagule	25 m		DI	M	Hybrid of *R. apiculata* and *R. stylosa*
Scyphiphora hydrophyllacea (yamstick mangrove)	North of Rockhampton	Oct	Feb–Mar		5 m	High	I	H	Intolerant of shady areas
Sonneratia alba (pornupan mangrove/mangrove apple)	North of Rockhampton	Oct–Dec	Nov–Mar	Seed	20 m	Wide	D	L	Mostly 4–5 metres high
Sonneratia x gulngai (white flower mangrove apple)	North of Townsville	Oct–Dec	Nov–Mar	Seed	15 m	Wide	I	LM	Hybrid
Sonneratia caseolaris (mangrove apple)	North of Townsville	Sep–Jan, Mar	Nov–Mar, Jun-Aug	Seed	15 m	Wide	U	L	
Sonneratia lanceolata (red flower mangrove apple)	North of Cooktown	Oct–Dec?	Nov–Mar?	Seed	15 m	Wide	U	L	Least common of *Sonneratia* spp.
Xylocarpus granatum (cannonball mangrove)	North of Rockhampton	Dec–Jan	Jun–Sep	Seed	25 m		I	MH	
Xylocarpus moluccensis (cedar mangrove)	North of Gladstone	Sep–Oct	Dec–Feb	Seed	20 m		I	MH	Related to the red cedar tree of tropical rainforests. Pneumatophores may grow very tall

Abbreviations: Salinity tolerance: V = very, Med = medium; pos^{n}= position.; Estuary pos^{n}: D = downstream, I = intermediate, U = upstream; Tidal pos^{n}: L = low intertidal, M = medium intertidal, H = high intertidal; *c.*= *circa*

Sources: Duke et al. 1984, 1998; Field 1996; Lovelock 1989; Tomlinson 1986; Claridge and Burnett (1993).

Seagrasses of Queensland

Species	Queensland distribution	Propagule production (for genera)	Current flow tolerance (knots)	Turbidity tolerance	Disturbance tolerance	Depth range (below MSL) (m)
Cymodocea rotundata	North of Repulse Bay	Jan–May	?	Low	Low	
Cymodocea serrulata	All Qld	Jan–May	Wide	Moderate	Low	
Enhalus acoroides	North of Townsville	All year?	?	Moderate	High	
Halodule pinifolia	North of Hervey Bay	Oct–Jan	High	Moderate	Moderate	0–7
Halodule uninervis	All Qld	Oct–Jan	0–2	Low	Moderate	0–14
Halophila capricorni	Great Barrier Reef region	Sept–Jan	Low	Low	Low	
Halophila decipiens	All Qld	Spring & Summer	Low (0–1)	Wide	Low	3–5
Halophila ovalis	All Qld	Spring & Summer	Wide once established (0–1)	Wide	Moderate	0–14
Halophila ovata	North of Great Sandy Strait	Spring & Summer	(0–1)	Moderate	Moderate	Intertidal
Halophila spinulosa	All Qld	Spring	(0–4)	Moderate	Moderate	3–14
Halophila tricostata	North of Whitsundays	Spring	Low	Wide	Low	
Halophila sp (undescribed)	Shoalwater Bay	Spring & Summer ?	High	Moderate	High	
Syringodium isoetifolium	All Qld	Oct–Nov	0–1	Low	Low	0–14
Thalassia hemprichii	North of Great Sandy Strait	Jul–Nov	Moderate	Low	High	
Thalassodendron ciliatum	North of Cape Weymouth	Oct–Dec?	Moderate	Low	?	
Zostera capricorni	South of Cape Tribulation	Aug–Dec	Moderate	Wide	High	0–7.5

Abbreviation: MSL = mean sea level
Sources: Lanyon 1986; Larkum et al. 1989; Lee Long et al. 1993, 1996 and 1997.

Saltmarsh vegetation of Queensland

Saltmarsh families: Poaceae (grasses), Cyperaceae (sedges), Juncaceae (rushes), Chenopodiaceae (succulents), Frankeniaceae (sea heaths), Plumbaginaceae (sea lavenders), Aizoaceae (succulents, including pigface).

Species	Qld Distribution	Flowering period	Growth form	Comments
Caprobrotus edulis (pigface)	Southern Qld	Late summer to winter	Succulent creeper	Native to South Africa, useful stabiliser for sandy foredunes.
Caprobrotus glaucescens (pigface)	Southern Qld	Late summer to winter	Succulent creeper	Useful stabiliser for sandy foredunes
Enchylaena tomentosa var. *glabra* (ruby salt bush)	Found in southern Qld. Northern distribution?	Flowers and fruits most of the year	Succulent	Shrub up to 1.5 m tall
Halosarcia halocnemoides (samphire)	Found in southern Qld. Northern distribution?	Usually summer	Shrubs with succulent 'leaf' structures	Grows to 50cm, found in saltmarshes in littoral areas
Halosarcia indica (*Salicornia indica*) (samphire)	Found in southern Qld. Northern distribution?		Shrubs with succulent 'leaf' structures	Grows to 50cm, found in saltmarshes in littoral areas
Halosarcia pergranulata (samphire)	Found in southern Qld. Northern distribution?	Usually summer	Shrubs with succulent 'leaf' structures	found in saltmarshes in littoral areas
Isolepis cernua (isolepis (sedge))			Small tufted herb	Grows to 20cm
Isolepis nodosa (isolepis (sedge))		Summer	Densely tufted perennial	Grows to 80cm
Portulaca oleracea (purslane/pigweed)		Summer	Succulent creeper	Yellow flowers
Portulaca pilosa (purslane/pigweed)		Summer	Succulent creeper	Purple flowers
Sarcocornia quinqueflora (beadweed, tree samphire)	All Qld	Spring to summer	Succulent	*Sarcocornia* appears more tolerant of high salinities than *Sporobolus*.

Species	Qld Distribution	Flowering period	Growth form	Comments
Sesuvium portulacastrum (sea purslane)	All Qld	Spring and summer (flowers most of the year)	Succulent	Grows to 20cm, found in sandy areas and saltmarshes along beaches
Sporobolus virginicus (saltwater couch/ sand couch)	All Qld		Grass	Grows to 40cm Generally high competitive ability (compared with other saltmarsh species). Found in drier areas of saltmarsh and those under freshwater influence.
Suaeda arbusculoides (samphire or jelly bean plant)	All Qld	Mainly in summer	Succulent	Common in saline areas, grows to 30cm
Suaeda australis (saltbush / samphire bush)	All Qld	Spring to summer	Succulent	Grows to 80cm
Tecticornia australasica	Gulf of Carpentaria		Samphire	Grows to 40cm
Triglochin striatum (streaked arrow-grass)	All Qld		Emergent narrow leaved	Perennial, inhabits tidal and freshwater swamps or on muddy creek banks. Found in wetter parts of saltmarsh.

Sources: Carolin and Clarke 1991; Dowling (personal communication); Romanowski 1998; Stanley and Ross (1983).

Appendix 2 Fisheries Information Leaflet

WETLANDS: INFORMATION ABOUT RESTORING WETLANDS OF FISHERIES IMPORTANCE

What is a wetland?

Wetlands* are areas featuring permanent or periodic/intermittent inundation, whether natural or artificial, static or flowing, fresh, brackish or saline, including areas of marine water the depth of which at low tide does not exceed six metres. Examples include billabongs, marshes, swamps, lakes, mud flats, mangrove forests and shallow seagrass beds.

Why are wetlands important to fisheries?

Wetlands are important habitats for many species of commercial, recreational and traditional fisheries importance. 75% of the commercial fisheries species targeted in Queensland are dependent on tidal wetlands for at least part of their life cycle. The juveniles of these species use wetlands as ‘nursery’ grounds, while adults use wetlands as spawning and feeding grounds.

Why restore a wetland?

Increased development in coastal areas puts pressure on the marine environment and has the potential to cause a decline in fisheries productivity. Protection and restoration of wetland habitats is critical to maintenance of productive fisheries. Well-informed wetland restoration projects, which result in the provision of good quality habitat, can contribute to Queensland’s commercial, recreational and traditional fisheries.

Is there always a need to restore a wetland?

Restoration, through active revegetation, may not be the best option for a damaged wetland. Wetlands are sensitive environments and in some instances, the damage to the vegetation donor site will be greater than the benefits gained at the restoration site. Wetland restoration is only of benefit where there is no net loss of wetland habitat following completion of works. In many cases, if removal of the degrading factor/s is undertaken, natural processes may act to restore a degraded wetland.

Have guidelines for wetland restoration been developed?

Issues to be considered when planning a wetland rehabilitation project are outlined in a “Wetland Rehabilitation” brochure produced by Fisheries Group of Queensland Department of Primary Industries (QDPI). Copies may be obtained from the contact address below. Detailed guidelines and Fisheries Group recommendations on restoration of wetlands for fisheries purposes may be obtained from QDPI.

Will a Fisheries Permit be required to restore a wetland?

If the wetland to be restored is in a tidal area and marine plants (as defined below) will be impacted (removed, damaged or destroyed), a permit under the *Fisheries Act 1994* will be required.

What is a marine plant?

* This wetlands definition is based on that used in the *Convention on Wetlands of International Importance* (or Ramsar Convention).

A marine plant is defined under the *Fisheries Act 1994* as: a plant that usually grows on, or adjacent to, tidal land, whether it is living or dead, standing or fallen. The definition includes material of a tidal plant or other plant material found on tidal land.

Marine plants include mangroves, seagrasses, saltcouch and samphire species. In certain areas, species of *Melaleuca, Casuarina* and *Hibiscus* may also occur on or adjacent to tidal lands and fall under the definition of marine plants.

Suggested reading:

Brisbane City Council (1997) *Integrated Manual for Waterways, Wetlands and Open Drains* Planning Section, Brisbane City Council.

Clarke, A. & Johns, L. (1997) *Cairns Waterway and Wetland Rehabilitation Guide* Northern Fisheries Centre, Queensland Department of Primary Industries, 87pp.

Hopkins, E, White, M. & Clarke, A. (1998*) Restoration of Fish Habitats: Fisheries Guidelines for Marine Areas*, Department of Primary Industries, Queensland, Fish Habitat Guideline FHG 002, 44pp.

For further information contact:

Queensland Department of Primary Industries

Fisheries Group (Head office)
GPO Box 3129
Brisbane Qld 4001

or

Southern Fisheries Centre
PO Box 76
Deception Bay Qld 4508

Northern Fisheries Centre
PO Box 5396
Cairns Qld 4870

Appendix 3 Restoration checklist

Checklist	YES
Step 1 Identify site	
• Location	
• Tenure (e.g. freehold/lease/state land) and existing land use	
• Conservation status (e.g. Fish Habitat Area, National/Marine Park etc.)	
Step 2 Identify baseline conditions and degrading factors	
• Weed invasion	
• Excess sedimentation	
• Turbidity	
• Habitat loss	
• Reduced visual amenity	
• Erosive influences	
• Slumping	
• Scouring	
• Stormwater inputs	
• Stormwater pipe present	
• Stormwater pollutants visible	
• Discharges/leachates	
• Identifiable source	
• Can discharge be stopped?	
Step 3 Set restoration objectives and criteria for "success"	
• Rubbish removal and weed control	
• Erosion and sediment control, reprofiling	
• Water quality improvement	
• Revegetation (natural or enhanced)	
• Habitat creation	
Step 4 Determine resource allocation	
• Funding source (grant, fund raising, sponsored)	
• Determine project costing	
• Assisting body (Councils, landholders, other interest groups, community groups)	
• Nature of assistance (materials, equipment, advice, labour)	
Step 5 Determine and obtain relevant Permits/Approvals	
• Department of Primary Industries	
• Marine Plant Permit (e.g. collection, translocation)	
• Fish Habitat Area Permit	
• Department of Environment and Heritage	
• Works below High Water Mark	
• Works within a Marine Park	
• Department of Natural Resources	
• Local Councils	

Step 6 Formulate restoration plan

- Plan removal of degrading factors
    - Weed control
        - Weeding
        - Mowing/slashing
        - Mulching
    - Rubbish removal
        - By hand
        - Machine
    - Erosion and sediment control
        - Reprofiling of sediment
    - Water quality improvement
        - Increase tidal flushing
        - Management of tide/flood gates
        - Gross pollutant traps
    - Discharges/Leachate
        - Stop
        - Treatment (e.g. Neutralise)
        - Burial
        - Reflooding
        - Removal of material

Step 7 Develop revegetation strategy (where necessary)

- Prepare site
- Select species
- Develop propagation and stock management techniques
- Determine quantity of material and desired plant spacing
- Determine source of plant material
- Determine timing of propagule collection
- Determine nursery holding techniques, where necessary
- Determine methods of planting
- Determine timing of planting
- Develop protection devices for seedlings, if necessary

Step 8 Implement plan

Step 9 Assess and monitor site

- Monitor plant survival
- Monitor plant growth
- Troubleshoot problems

Step 10 Report results

Step 11 Maintain restored site

Appendix 4 Relevant legislation

The following is a list of Queensland legislation that may be applicable to restoration of marine habitats. Authorisation under any number of these Acts may be required prior to commencement of restoration works. This list is not exhaustive and permits/approvals may be required under more than one Act for a single operation. Application does not ensure issue of a permit/approval.

Department of Primary Industries, Fisheries Group

Fisheries Act 1994

A Permit under Section 51 of the *Fisheries Act 1994* will be required where works:

- are likely to impact on marine plants (as defined in the glossary)
- are proposed in a declared Fish Habitat Area
- may impede the movement of fish (e.g. waterway barrier works).

Department of Environment and Heritage

Harbours Act 1955, as preserved under the *Transport Infrastructure Act 1994*
Marine Parks Act 1982
Environment Protection Act 1994
Coastal Protection and Management Act 1995
Nature Conservation Act 1992
Canals Act 1958

Department of Natural Resources

Land Act 1994
Rural Lands Protection Act 1985
Water Resources Act 1989
Native Title Act 1993

Department of Local Government and Planning

Integrated Planning Act 1997

Department of Transport

Transport Infrastructure Act 1994
Transport Operations (Marine Safety) Act 1994
Transport Operations (Marine Pollution) Act 1995

Appendix 5 Acid sulfate soils

The presence of acid sulfate soils (ASS) and potential acid sulfate soils (PASS) is an important environmental consideration in the development and restoration of marine areas. ASS include soil and sediment containing iron sulfides (principally iron pyrite) or containing acidic products of the oxidation of sulfides. When exposed to air, sulfides oxidise. Sulfuric acid is produced when the capacity of the soil to neutralise the acidity is exceeded. ASS or PASS occur predominantly in coastal lowlands with elevations generally below 5 m Australian Height Datum (AHD) (QASSIT 1997).

During wetland restoration and in a number of developmental activities relating to marine areas, it is possible that disturbance of soil will expose ASS and PASS. The exposure of ASS leads to an increase in the likelihood of acidic runoff into waterways. Acidic runoff has been known to cause fish diseases and mass fish kills, as well as destroying aquatic vegetation (Sammut and Lines-Kelly 1996).

In all cases of proposed soil disturbance within wetland habitats, it is important that testing for ASS is conducted prior to commencement of works to minimise the likelihood of fish kills and allow mitigation measures to be in place. Refer to the Sampling and Analysis Procedure for Lowland Acid Sulfate Soils in Queensland (QASSIT 1997) for details on soil testing.

Appendix 6 Case studies

Wallum Creek, North Stradbroke Island

Location of wetland
An area of approximately 20 hectares of mangroves growing in Wallum Creek, near Amity Point on North Stradbroke Island in Moreton Bay, east of Brisbane.

Vegetation at site prior to disturbance
Mangroves dominated the original community. Mangrove species present at the site include: *Avicennia marina, Rhizophora stylosa, Ceriops tagal, Aegiceras corniculatum* and *Bruguiera gymnorrhiza*.

Threatening process
The mangroves of the original community were killed or severely stressed in late 1978, following the inundation of tidal wetlands with brackish water for a period of approximately six months. The water was retained over the site following the construction of a bund across the creek to create a water source for nearby sand mining operations. The bund wall prevented tidal flow upstream and retained brackish water over the upstream intertidal area. It is likely that the continued submergence of the mangrove pneumatophores and prop roots caused the plants to die from lack of oxygen. No substrate damage occurred at the site.

Method of control of threatening process
The bund wall was removed from the creek in early 1979, allowing tidal flow to be restored to the site.

Restoration methods undertaken
The recovery of the affected area was monitored at two sites. One of the plots was planted with *Avicennia marina* seedlings (approximately 20cm tall) at 1 m spacings. The number of seedlings planted at the site was not documented. The seedlings used in the transplanting process were obtained from local stock downstream of the bund wall. The second site was left to revegetate naturally.

Success of restoration project
Avicennia marina recolonised both sites and was the dominant species by late 1983. Other mangrove species were also recorded following natural regeneration. The newly colonised mangroves grew well at both sites and the transplanted mangroves appear to have similar growth rates to that of the naturally regenerated plants. Natural revegetation at the site has been successful. However, it is likely that it will take more than 20 years before the mangrove community resembles the height and species composition of the pre-disturbance community.

The site is still monitored regularly.

References
Quinn, R. and Beumer, J. (1984) Wallum Creek – A study of the regeneration of mangroves In: *Focus on Stradbroke*, Boolarong Publications, Brisbane, pp 238–259.

Mourilyan Harbour

Location of wetland
Mourilyan Harbour is situated 60 kilometres south of Cairns.

Vegetation at site prior to disturbance
The two most common species of mangroves at the Mourilyan Harbour site were the red mangrove (*Rhizophora stylosa*) and grey mangrove (*Avicennia marina*).

Threatening process
Reclamation of the tidal wetland was proposed and undertaken. Prior to reclamation, a number of mangrove seedlings were removed from the disturbance area, in preparation for transplantation at another site.

Restoration methods undertaken
The affected site itself was not restored. However the objective was to have the fisheries values that it supported transferred, in part, to an adjacent site with relatively low fisheries value. Approximately 200 seedlings from the reclaimed site were transplanted at a nearby shallow sandy site in January 1997. The mangroves (80% red mangrove and 20% grey mangrove) were removed by hand from the reclamation site. Care was taken to leave the roots intact, as damage to mangrove roots has been shown to greatly increase mortality rates in transplanted mangroves. Relocation of most seedlings occurred within two hours. The seedlings were replanted by hand at a time when tidal inundation and rainfall patterns at the site were highest. The site was visited a month after planting to determine mortality rates.

Success of restoration project
This restoration project appears to have been successful. Survival rates have been high and the plants have established well. The site is being monitored biannually. After the transplanted seedlings established, an understorey of *Avicennia marina* seedlings developed. These seedlings are likely to have been transported on high tides following transplantation. The protection gained from the transplanted seedlings appears to have provided shelter for establishing the propagules and enhancing recruitment.

It is hoped that this study will assist future restoration projects by indicating expected success rates, appropriate timing and methodology of relocation and re-establishment times.

References
Clarke, A. and Johns, L. (in prep) *Mourilyan Harbour Rehabilitation Study*, QDPI.

Appendix 7 DPI Fisheries contacts

DPI Call Centre   13 25 23

Brisbane City

Department of Primary Industries, Fisheries Group
GPO Box 3129
BRISBANE QLD 4001

Phone: (07) 3225 2283
Fax: (07) 3229 8146

South Region   (NSW/Qld border to Sarina)

Southern Fisheries Centre
Department of Primary Industries
PO Box 76
(13 Beach Road)
DECEPTION BAY QLD 4508

Phone: (07) 3817 9500
Fax: (07) 3817 9555

North Region (Sarina to Qld/NT border)

Northern Fisheries Centre
Department of Primary Industries
PO Box 5396
(38-40 Tingira St, Portsmith)
CAIRNS QLD 4870

Phone: (07) 4035 0100
Fax: (07) 4035 1401