

Saltmarsh Restoration – Rebuilding habitat with a community partnership.

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Abstract

The recent listing of saltmarsh as an endangered ecological community in NSW has highlighted the need to protect and enhance these estuarine communities. Loss of saltmarsh due to both natural and human change, combined with greater knowledge of the function and value of these ecosystems has created challenges and opportunities for managers considering their rehabilitation and conservation. A recent project in the Tweed Estuary has shown that when the shared goal of committed stakeholders is the rehabilitation of a damaged saltmarsh ecosystem, then progress is definitely possible.

A strong and innovative partnership between local government, traditional owners, researchers and an NGO conservation group has provided the means for wetland restoration on the Fingal Peninsula. The major damage and continuing threat to saltmarsh at this site was the disturbance of sediment surfaces and the loss of vegetation structure caused by repeated vehicle traffic. Over the past twelve months the implementation of practical integrated management strategies, including different methods of saltmarsh restoration, have been tested to determine suitability and success in recreation of the saltmarsh vegetation structure.

Although it has been shown that long-term monitoring of rehabilitation sites is required for strong evidence of restoration of full saltmarsh functions, early indicators show the development of the ecosystem towards a nominated reference condition. At Fingal, measurements and monitoring of soil physical character, fauna and vegetation colonisation and algal community development are being used as indicators of the early development in the saltmarsh food web and progression towards soil stability after rehabilitation. This monitoring provides essential information to managers and allows adaptive restoration to occur, for long-term project success.

Keywords

Saltmarsh, wetland rehabilitation, community partnerships, monitoring.

The Fingal Peninsular Wetland Rehabilitation Project

Tom Alletson

INTRODUCTION

This paper is focused on aspects of the Fingal Peninsular Wetland Rehabilitation Project, a partnership formed between Tweed Shire Council, the Tweed Byron Local Aboriginal Land Council and Wetland Care Australia.

It is important to acknowledge the Land Council and its members, and the traditional custodians of Fingal and the Tweed Valley, the Bunjalung people, on whose land this project has taken place.

Fingal Peninsular, also known as Letitia Spit, is a narrow sand spit, which forms the eastern bank of the Tweed River near its mouth at Point Danger on the border between Queensland and NSW. The spit is sandwiched between the Pacific Ocean and the Tweed, and in the area in which this project is set, is approximately 300 metres wide. Kerosene Inlet and Sponsors Lagoon are both small tidal systems, which lie close to the Tweed Rivers mouth. Both of the lagoons have been affected by sand mining in the past. Despite this major disturbance, the peninsula has stabilised and supports excellent quality seagrass beds, mangrove forest and saltmarsh. The area is very important and in a broader landscape context as it is the first significant area of undeveloped coastal land between the NSW border and South Stradbroke Island, some 50 kilometres to the north.

One of the greatest threats to the Fingal Peninsula wetland at has been illegal use of recreational vehicles on the site and dumping of stolen cars. The mangrove foreshore and the slightly more elevated salt marsh zones have been used to access a number of fishing, camping and drinking spots. The relative remoteness and seclusion has made it a popular place to thrash, destroy and ignite vehicles.

BACKGROUND AND HISTORY OF THE PROJECT

Undertaking rehabilitation and enhancement works on the Fingal Peninsula wetlands had been an objective of the Tweed Shire Council's *Tweed River Committee* for many years, but had been stalled for a number of reasons.

Barriers to commencing work on the land included difficulties in getting plans approved by State Agencies and Council itself. Uncertainty existed about implementation and works arrangements and the working relationship between Tweed Shire and The Tweed Byron Land Council who have freehold title to the land.

The evolution of the Fingal Wetland Conservation Project removed the barriers.

In April 2003, a lapsed development application to undertake rehabilitation works in the wetlands was reactivated by the Tweed River Committee. Submitting this new application required consultation with the Land Council and other interested members of the Aboriginal community. The strong message from these meetings was that it would preferable for on-ground works undertaken on Aboriginal land to be done by Aboriginal people. This project was seen by all parties as an excellent opportunity to provide remuneration, skills and work experience to a number of young men in the local community who were presently undertaking training through a CDEP program.

This perspective was conveyed to the relevant Tweed Shire Council managers. While it was agreed that paid work for the Aboriginal community was a very worthy concept, there was uncertainty as to how to negotiate this outcome through the realities of Councils competitive tendering policy. At first assessment it was not considered possible to pay a private landholder to do improvement works on their own land without any kind of competitive tendering process, especially as a considerable investment of public monies would be invested. Envirofund grants are an investment of public

money on private land, but are part of a competitive and transparent selection process. This work was not being considered within the context of an external grants program, although it should be noted that the funding allocated to the project by the Tweed Council was contributed by the NSW State Government through the NSW Estuary Management Program.

Quite fortuitously, at the same time that negotiations were taking place between Tweed Shire Council and The Land Council, an initiative was being developed by Wetland Care Australia with assistance from NSW Fisheries, called the Fish Unlimited Project. Fish Unlimited was funded by Federal Government through the Sustainable Regions Program and aimed to undertake work on private land, generally agricultural land that would increase and enhance fish habitat. The follow on effect would be a positive difference to the regional economy through increased stocks for commercial and recreational fishing.

Two mechanisms were being promoted to assist landholders achieve better fish habitat management. These were:

- stewardship payments to offset the cost of changed land management practices, for example altered grazing regimes; or,
- minor works agreements, where farmers could be paid one off amounts to undertake works such as removing flood gates, fencing off wetlands or replanting riparian buffers.

Tweed Shire Council became a partner to the Fish Unlimited Project, and under this arrangement, was able to provide funds to Wetland Care Australia so they could enter into a *minor works agreement* with the Tweed Byron Local Aboriginal Land Council. A budget was allocated to Wetland Care Australia to contract the Land Council to employ a three-person team for three days a week to carry out on-ground rehabilitation works.

To maintain accountability by all partners, an independent site advisor was engaged by Council and Wetland Care Australia for Stages 1 and 2 of the project. This role included regular visits to the site to assist with technical aspects of bush regeneration, and to objectively assess the team's progress against pre-agreed work objectives. A monthly report on performance was submitted by the advisor prior to payment of invoices from the Land Council.

The Land Council was also a significant contributor to the project. They provided most of the tools necessary for on-ground work, a site compound to house equipment and a nursery, a vehicle, plus the important administrative services for the work team. An additional contribution from the Land Council was at least one extra day of labour per week to the project through the CDEP program.

Over the course of the project the arrangement between the parties has been able to provide significant on the job and formal training for the Land Councils Wetland Conservation Team Members in bush regeneration. The three Land Council Team members held a Certificate 1 in the TAFE course, *Conservation and Land Management* at project commencement. Over the course of the project, the Land Council supported them in continuing this study and all have now attained a Certificate 3. The team members have undertaken a significant amount of on the job training in weed identification and control, attained chemical user accreditation and been mentored in the logistical aspects of managing this style of project, including planning, preparation of grant applications and record keeping.

IMPLEMENTATION OF THE FINGAL WETLAND REHABILITATION PROJECT

The aim of the Fingal Wetland Rehabilitation Project has been to reverse ongoing neglect and abuse of Sponsors Lagoon and Kerosene Inlet and the terrestrial communities adjacent to them. These

tidal wetlands and swamp sclerophyll forests have suffered considerable disturbance from sand mining, followed by infestation with Bitou Bush, rubbish dumping and destruction by four wheel drive vehicles, stolen cars and more recently, trial bikes. The project objectives focused on preventing vehicle access and further site disturbance, and restoration of the saltmarsh vegetation community. The decision to focus on Saltmarsh was taken in recognition of the increasing scarcity of this habitat type in the Tweed Estuary, and reflected a growing interest in this vegetation type due to increased understanding of its productivity and value as a feeding ground for juvenile fish. In the Tweed, Saltmarsh is actually being invaded and colonised by mangroves.

PROJECT PLANNING

Planning for implementation of on ground works was a collaborative between the land Council work team, Tweed Council officers and Wetland Care Australia with involvement from the site advisor at all stages. Project works were divided into three stages over two years. For Stage 1 and 2 (2004), a three-person team was employed for twelve months at three days per week and for Stage 3 (2005) the three-person team worked for one day per week. A substantial part of this work involved weed control, installation of tracks and bollards, and on-going site maintenance.

The first task in the project was to remove all dumped cars and other rubbish, and attempt to prevent future vehicle access. Access prevention proved difficult. There have been continual cases of people going to extreme lengths to tear down gates and get back into regenerating areas. The area of Sponsors Lagoon was secured from four-wheel vehicle incursions reasonably quickly, however trail bikes have been more of a challenge.

One of the primary objectives of the project, in alliance with Fish Unlimited, is restoration of the Saltmarsh zones in Sponsors Lagoon that had been so obviously disturbed by vehicles. These areas were characterised by fragmented patches of remnant Saltmarsh dominated by three species of marsh plant, predominantly Saltcouch, or *Sporobolus virginicus*, with Sea Blite or *Suaeda australis* and Samphire or *Sarcocornia quinqueflora*. The Saltcouch patches were divided by eroded and compacted vehicle tracks. In some areas, the depressions caused by vehicles were as much as 300 mm lower than adjacent healthy growth of Saltcouch.

To restore the natural levels of the site, the patches of remnant saltmarsh were connected through filling and allowing natural regeneration to occur. Highly degraded saltmarsh sites were characterised by a depressed sediment level from erosion and compaction with no remaining saltmarsh vegetation. The surface of these sites was filled to achieve a level that corresponded with existing healthy growth in adjacent patches. Determining the line to which fill would be placed was undertaken using survey pegs and string line. Desired surface levels were set by placing the string at the height of adjacent areas of existing healthy saltmarsh.

It was predicted that in some areas of the site, through the exclusion of vehicles, would result in eventual recolonisation by mangroves rather than saltmarsh. It was also predicted that the lowest areas, which receive more frequent tidal inundation would be dominated by mangroves in the future. In an attempt to prevent mangrove incursion in areas where saltmarsh regeneration was desired, surface levels were raised to a higher level.

Suitable fill for the site was an importance factor in planning. Sand mining in the areas surrounding saltmarsh regeneration sites had left several piles of clean sand. This was subsequently used as fill in areas where existing surface levels were too low. This was an advantage to the project as it prevented the need to import fill for site works and removed the associated impacts of more heavy

vehicles traversing the site. It also avoided the problems associated with matching soil texture and finding uncontaminated material.

The first step taken in preparing fill sites was to strip back surface sediments so that the top soil could be used to inoculate the new surface and as such provide a source of silt, nutrients and the microfaunal assemblages that were already occupying this niche.

Filling was undertaken using a backhoe. After approximate string levels were achieved, levels were slightly overfilled, to allow for settlement and redistribution of sand due to wetting and tidal flow. The original surface sediment was respread by throwing it out in individual shovel loads onto the new sand surface, and then mixing it in as much as possible with a steel rake.

There was one site where mixing was not undertaken, and the different rates of recolonisation of various site treatments have been monitored through the research program. Further details are included below.

The next step in regenerating the main saltmarsh site was reintroduction of plant material, which was limited in this case to Salt Couch. Several methods were considered to replant Saltmarsh, including growing on small cuttings in a nursery, sowing stolons after treating them with a growth hormone and translocation of turves. The latter method refers to the technique of removing a spadeful of existing Salt Couch, roots and sediment included, and replanting it into the newly prepared surface. This was judged to be the technique that offered the greatest chance of success because it involved the least disturbance of the roots and therefore maximum chances of plant survival.

The disadvantage of this approach was that it placed the greatest demand on donor material, healthy salt couch, from within the immediate area. Extensive translocation was only undertaken at one site due to the demand for donor material and its relative scarcity. It was also recognised that removing a divot of salt couch created a site requiring natural recolonisation. Published literature and site observations suggest that this is not a rapid process. Each divot that was created was back filled with sand to the original level.

The area that was selected for regeneration using turves was approximately 0.4 hectare. In assessing the amount of donor salt marsh available it was determined that turves would be laid at approximately 1 per 1 metre square. Most of the turves planted were approximately 100mm by 100 mm.

Planting was undertaken at low tide using 1m quadrats made of PVC conduit. The conduit quadrats allowed accurate spacing and layout across the site for maximum use of donor material and future counting of success. Within each quadrat, turves were placed randomly so as not to create a rigid grid pattern.

In some areas where vehicle traffic had been eliminated for a period of approximately three months, surface elevations appeared to 'rise naturally'. This was not quantified or investigated in detail, however it was observed that the sites in question were recolonised by burrowing fauna in the period following vehicle exclusion. It is believed that the activity of benthic burrowing organisms was significant in aeration of the soil providing a raised surface and a suitable substrate for seedling germination.

Works are currently at Stage 3, which involves a considerable amount of maintenance on Stage 1 and 2 objectives, especially the continuing problem of unauthorised vehicle access. Recently trail bikes have discovered the site. Trail bike activity has occurred in areas showing high levels of

assisted and natural Saltmarsh regeneration and is regarded as a very severe threat to the long-term success of the project. The erection of barriers using star pickets and fencing has deterred the intrusions for the present time, but ongoing surveillance is needed.

Overall the site is appears to be returning to a functioning Saltmarsh. The research program will continue until 2007 and will assist in providing feedback on site development to the project managers. The project success to date is the result of strong collaboration between all the stakeholders with a focus on a common goal: the removal of threatening processes and the restoration of the saltmarsh vegetation at Fingal peninsula. The ongoing commitment by the project partners has culminated in a successful grant from the NSW Government Environmental Trust to undertake additional works within the area. This success by the Land Council has allowed the Tweed Shire Councils' investment in Stage 3 to be scaled back leaving the Land Council to manage the project for the future.

PROGRESS OF THE REHABILITATION WORKS ASSESSMENT AND MONITORING

Jo Green

INTRODUCTION TO SALTMARSH RESTORATION ASSESSMENT

As losses of saltmarsh in NSW have been high, degraded areas need to undergo rehabilitation and restoration in a scientific framework, in an attempt to regain past losses (Jordan III *et al.* 1987). Key indicators that a saltmarsh is becoming a functioning ecosystem are paramount to the rehabilitation efforts. Success can be measured by structural and functional parameters but clear statements of goals at the commencement of the project are essential. Algae are the first colonisers of the habitat mosaic and a key link in the food chain, so may be a useful indicator of the early success of rehabilitation programs. Long-term studies of all biota, particularly the vegetation structure and fauna colonisation of the sites, are required to determine if the goals of the restoration program have succeeded and to increase our limited knowledge of saltmarsh structure and function in a disturbed coastal landscape.

Ecological restoration is defined as the re establishment of a functioning wetland ecosystem similar to the original, to the extent possible given current scientific understanding (Bradshaw 1987; Zedler 2001). Wetland restoration aims to re-establish the physical, chemical and biological conditions at degraded wetland sites that still possess characteristic wetland features (Weinstein *et al.* 2001). The distinction between attempting to recreate the original as a 'carbon copy' and the creation of a functioning wetland that imitates the original is paramount to success of the restoration project. Rather than copying, ecological restoration actually seeks to imitate. The distinction between copying and imitation is explained by Jordan III *et al.*, (1987). Copying implies that the system is reproduced item by item. Imitation implies that the created system is not identical but similar in critical ways and can therefore function in a similar ecological way. It is a critical test of ecological theories to identify the essential similarities, resemblances and differences between systems and their functioning components (Jordan III *et al.* 1987).

Although the recognition of the need to restore and rehabilitate to reverse the impacts of degradation is now more widespread, the science of ecological restoration is still developing. Restoration is now recognised as a sub discipline within ecology (Chapman and Underwood 2000). However, much more research is needed in restoration ecology, particularly in the development of methodologies and assessments that can translate across habitats and biota (Chapman and Underwood 2000). Restoration assessment can provide managers with crucial information for decisions on future site management with solutions to ensure the success of the project.

At each restoration site, a reference wetland should be used for measuring change. A reference wetland is an existing wetland, close to the restoration sites with relatively little or no modification. The use of reference wetlands helps to identify goals for wetland restoration within an area; provides a template for restoration and rehabilitation and over time and parameters for wetland functions to be measured (Brinson and Rheinhardt 1996; Zedler 2001).

At Fingal, a research program has been developed to measure and understand the restoration process.

The research program seeks to provide information to assist in answering the following questions:

- What are suitable methods and parameters to measure the success of Australian saltmarsh restoration works;
- What changes have occurred to saltmarsh structure and function since restoration works and

- How can knowledge of saltmarsh and ecological restoration be improved by future research?

Preliminary results and parameters that show potential for ecological assessment in saltmarsh restoration sites are presented in this paper.

METHODS

During the planning phase, several different factors were identified as important to furthering the knowledge of saltmarsh restoration.

These factors were:

- the type of topsoil for rebuilding lost soil levels,
- the micro topographic levels were required for maximum saltmarsh vegetation development and
- whether planted or natural rehabilitation provides maximum structural development of vegetation.

Experimental Site Design

For the research program, eight treatment areas; two reference areas, four rehabilitation areas (two treatments) and two disturbed areas, were identified for assessment within the entire restoration location (Figure 1).

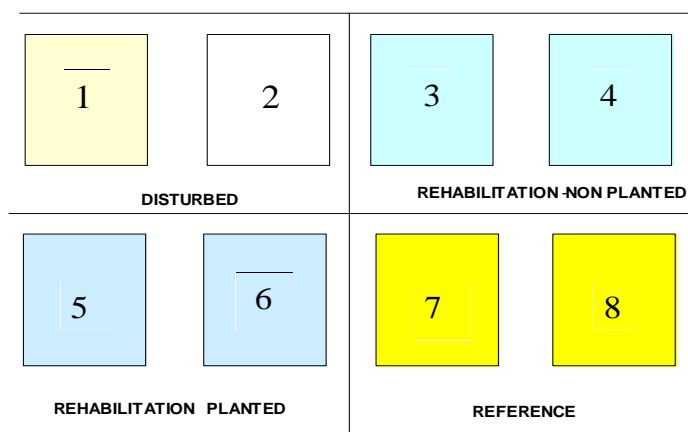


Figure 1 –Design for measurements of Fingal Restoration works. Sites 1 and 2 were labelled disturbed as some disturbance from authorised vehicles will continue. At Site 3 and 4 soils levels are raised but no planting. At Site 5 and 6, soil levels are raised and planted, Site 7 and 8 are reference sites or sites where little disturbance has occurred in the last ten years.

Within the four rehabilitation areas treatments were separated as:

- soil level restored to existing Saltcouch, soil bought in from local quarry, no planting (Site 3),
- soil level restored to existing Saltcouch, soil from site, existing topsoil retained and used as cover over soil excavated from on-site, no planting (Site 4).
- soil level restored to existing Saltcouch, planted with 150 mm x 150 mm Saltcouch turves at 1m x 1m spacings. soil for filling excavated from on-site (Site 5),
- soil level restored to existing Saltcouch, planted with smaller cuttings of Saltcouch at 1m x 1m spacings, soil for filling excavated from on-site (Site 6).

Vegetation Study.

The vegetation of each treatment area was recorded immediately after rehabilitation works were completed in July 2004 and then in autumn and spring each year. To measure vegetation, a fixed belt transect 50 m x 1m was set up within a permanent grid, 50m x 4m, at the respective treatment areas. An ordinal scale of percentage cover was used to record each species in 1 m x 1m quadrats along the transect, to a total of 50 quadrats. The cover scale had 5 classes, (0-1% =1, 2-10% =2, 11-30% =3, 31-60% =4, 61-100% =5).

Algal Study

Samples for soil algal colonisation were also collected from within the permanent grid (50 m x 4 m wide) within each treatment area. To study the colonisation by the two dominant algal groups, diatoms and Cyanobacteria, of the various treatment sites, six core samples, from the top 4 mm of sediment were collected monthly from each of the eight treatment areas, using randomly selected quadrats. In the laboratory, a sub sample of soil was taken for diatom processing using the standard methods of Chessman *et al* (2004). A similar sub sample was taken to view slides of fresh algae present at each site.

Soil Physical Factors – Salinity, Moisture, Particle Size and Organic Matter.

Soil pH and electrical conductivity (EC) was also tested using this same soil sample following the standard methods (Rayment and Higginson 1992). A separate sample from the same random quadrat was tested for soil moisture content using methods of Raymond and Higginson (1992). Soil texture was measured using the Hydrometer method for particle size analysis (Gee and Bauder 1986). Soil organic matter was measured as Loss on Ignition (LOI). Details and limitations of this method are discussed by CSIRO (2000).

Fauna Colonisation

Benthic burrowing organisms, particularly several species of saltmarsh snails and crabs were identified as key indicators of fauna colonisation in saltmarsh. Crab activity at each treatment site was recorded at the same time as vegetation cover, along the fixed transect following the methods of Breifuss (2003). Various methods for the study of saltmarsh snails are currently being tested and results are not presented in this report.

RESULTS AND DISCUSSION

Vegetation

Colonisation of the major species is shown at each site (Figure 2). The method used in this study, cover classes using an ordinal scale, can indicate important changes in the dominant vegetation over time and indicate disturbance features at a large scale. Minor change is not detected and a more detailed survey is required for measurements of seedling germination and establishment. The highest cover for lowest number of species was recorded at the reference sites, numbers 7 and 8, indicating the stability of a site with relatively little disturbance. Dominance by *S. virginicus* is common feature of saltmarsh at lower latitudes (Adam 1990). *Sporobolus virginicus*, or Salt Couch is the dominant species at the study site, with a general increase over the study time, at sites with no disturbance (Figure 2).

All sites are showing recovery of vegetation structure, even the disturbed sites where some authorised vehicle use will continue on a needs basis. The level of disturbance tolerated by saltmarsh vegetation is low as the plants grow relatively slowly under the extreme physical conditions (Zedler and Callaway 1999; Zedler 2001). The removal of disturbance, through the complete exclusion of vehicles on the restoration sites, is the main factor in the changes of vegetation cover shown in this study.

Bare soil (no plant cover) is recorded to show increasing plant cover over time in comparison to a reference level and also to note its importance as a habitat factor for crabs and molluscs. Bare soil provides a substrate for soil algae and consequently a feeding area for saltmarsh snails (Coles 1979; Breiffuss 2003; Armitage and Fong 2004). At the study site, the cover of bare soil changes little over most of the sites with the lowest bare soil level evident in the reference sites. Bare soil levels in relation to plant cover are still relatively high at the reference sites providing an important site characteristic to describe the Fingal saltmarsh. Comparisons between bare substrate, cover of individual plant species and fauna will provide more information on this habitat feature. This level of bare substrate will vary across different saltmarsh types but indicates a feature for measuring habitat worthy of further investigation.

Mangrove cover has increased slightly in the study area. Mangroves have increased in cover at one reference site, and two of the rehabilitated sites, both planted and non planted, but further long term monitoring is required to determine if mangroves will dominate over saltmarsh. Mangrove colonisation has been identified as a major concern for saltmarsh rehabilitation in the subtropics (Saintilan 2004). Mangrove encroachment has been mapped in the Tweed area, indicating the drop in the area of saltmarsh to increasing mangrove area (Rogers *et al.* 2003). The cover of each species of mangrove will continue to be monitored at Fingal.

The rush, *Juncus kraussii* was not recorded as increasing in cover on any site. This species is often found at higher soil levels in saltmarsh in extensive patches (Adam 1990). It is slower to colonise but provides important vegetation structure for air-breathing snails to avoid the high tide (pers obser). Although no taller grass-like species, such as *J. kraussii* or *Fimbristylis dichotoma* were planted at Fingal, some natural colonisation of *F. dichotoma* is evident. Further investigation of the importance of *Juncus* and other taller species as habitat may provide information on the need to include them in assisted restoration.

To determine whether natural regeneration or assisted regeneration through planting is the best method for saltmarsh restoration will require long term monitoring. At this stage in the rehabilitation there is only a small difference in cover, when measured over the entire site, between planted and non-planted sites. It is predicted that the planted sites will achieve a higher cover more quickly and that this cover will promote fauna colonisation, but monitoring is required to confirm this prediction. The non-planted sites, numbers 3 and 4, show an increase in cover of *S. virginicus* to similar levels of the planted sites (1-10%). This colonisation in unplanted sites is mainly from Saltcouch 'runners' moving into the sites from the edges. As Saltcouch appears to establish more quickly from vegetative material, such as runners from existing patches or planted turves, and not from seedlings, it would be expected that assisted regeneration will benefit site restoration where little Saltcouch remains. Overall the microtopographic levels, plus the moisture and salinity levels will facilitate the species composition.

Natural colonisation, predominantly *S. australis* and *S. quinqueflora* is apparent at all restoration sites, particularly Site 3, 4 and 5. A mass germination of seedlings was evident after the July flood at the time of the spring vegetation survey. As seedlings were very small the overall cover was not substantially changed in the current results. The establishment of seedlings will be seen in the autumn 2006 vegetation study. *S. australis* produces abundant seed and germinates readily in the bare soil with suitable moisture. The fast growth rates have been identified as useful in stabilising the sediments after initial level refilling (Alletson 2004). A closer investigation of germination times and moisture requirements will assist future restoration projects.

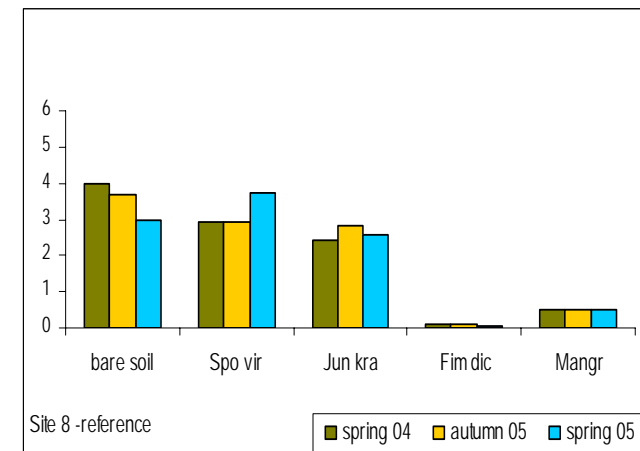
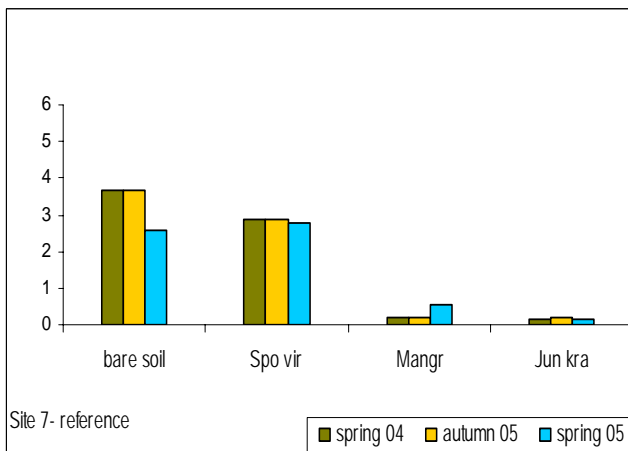
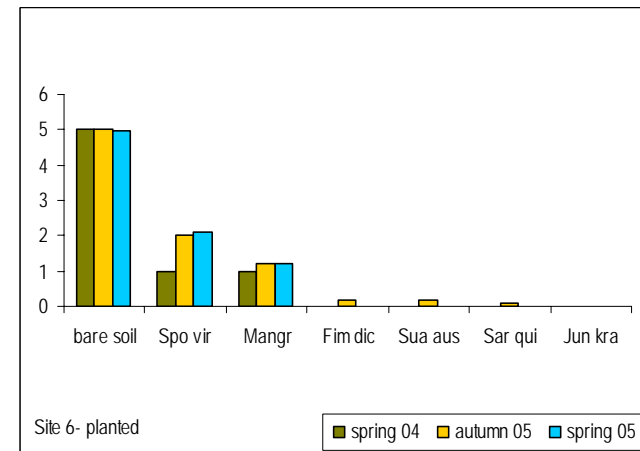
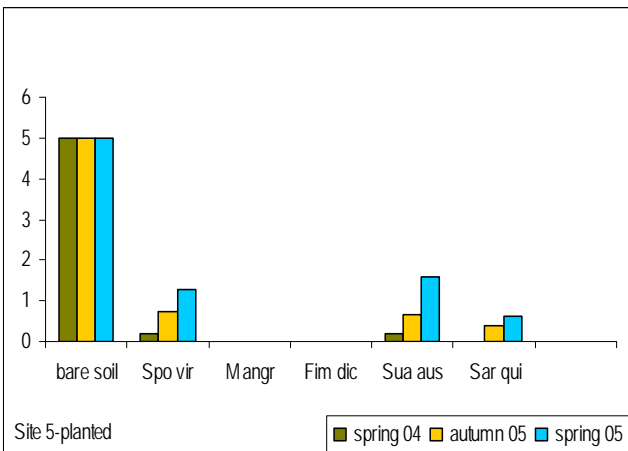
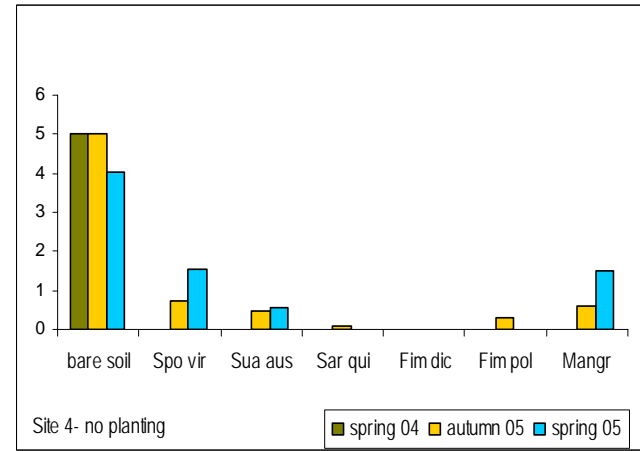
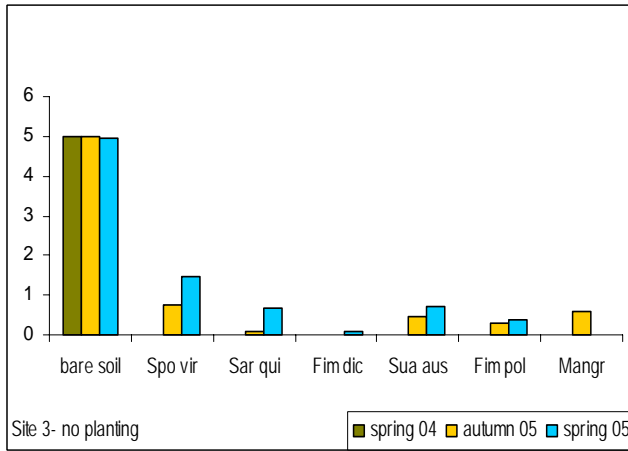
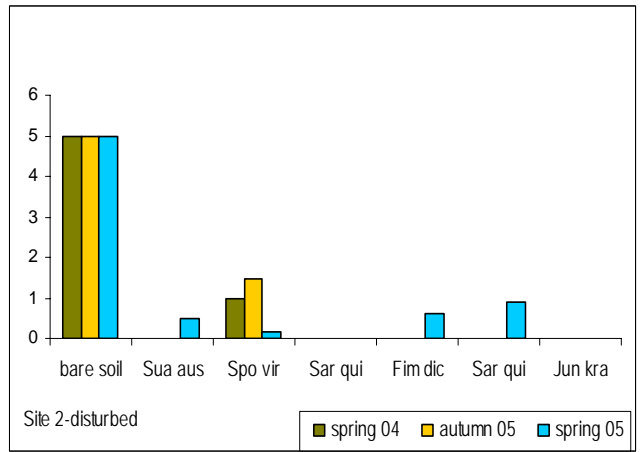
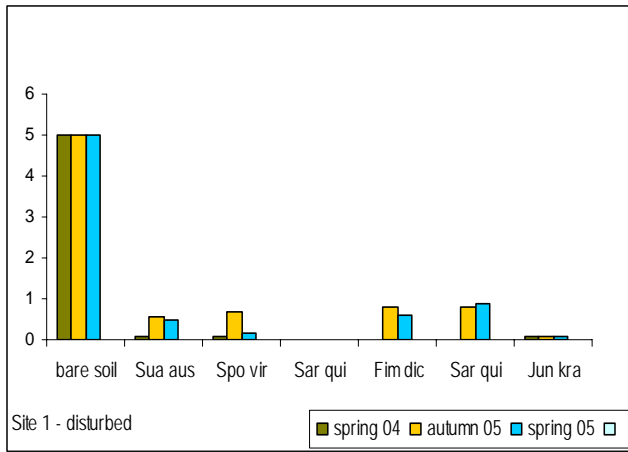


Figure 2(above): Sites 1-8 showing vegetation change from spring 2004- Spring 2005. (Legend: **Bare soil**, **Spovir** = *Sporobolus virginicus*, **Sarqui** = *Sarcocornia quinqueflora*, **Suaaus** = *Suaeda australis*, **Fimdic** = *Fimbristylus dichotoma*, **Mangr** = all Mangroves, **Junkra** = *Juncus kraussii*).

S. quinqueflora is increasing in cover through natural colonisation, at all sites except the reference areas, indicating competition as a factor in its long-term abundance on saltmarsh sites. *S. quinqueflora* is a dominant species in Australian saltmarsh especially in lower microtopographic areas, which may be too moist or too frequently inundated for the dominant Saltcouch (Adam 1990; Figueroa *et al.* 2003). Although it is not found in all the survey sites in the study area, it does exist in many areas on the Fingal saltmarsh with a large area on site 5 near the tidal inlet. This provides an important seed source for natural colonisation. The large germination event after the July flooding, indicates the importance of freshwater for the germination of this species. As competition with the dominant Saltcouch may also be a factor in its longer-term survival, measurements of vegetation cover over an extended period (10 to 20 years) will be required to record the change in dominants over time (Zedler and Callaway 1999; Craft *et al.* 2002; Dale 2004).

Frequency of vegetation measurements depends on the questions being asked. For overall change at Fingal the current frequency, spring and autumn or wet season, dry season, is adequate to show change, as seen in this study. More frequent measurements of vegetation change are required in the initial twelve months to show seedling germination rates and survival. These measurements should be correlated with moisture levels and salinity measurements.

Algal Study

Several species of algae, particularly diatoms, have been identified at all sites. Major species of diatoms include *Amphora coffeaeformis*, *Navicula cryptocephala* and *Nitzschia filiformis*. Although counts of the abundances of individual diatom species are extremely useful, to indicate any changes in conditions in the saltmarsh, the increase in total numbers of algal cells at a rehabilitation site has provided useful evidence of site recovery for this study. Diatoms secrete a mucilage called *extracellular polymeric substances* (EPS) as they move through silts and clays (Little 2000). EPS fills the space between the soil particles and coats the surface, which helps to bind the sand grains and creates resistance to erosion by water flow (Underwood *et al.* 2004). This function by diatoms can stabilise sediment before it can be removed by the tide. The role of algae in soil stabilisation provides an important reason to measure their abundance as an indicator of site recovery after restoration. Their relatively fast colonisation also provides a useful measure of change in response to other events.

The total mean abundance of diatoms per site for three replicates is illustrated in Figure 3. Year two (Y2) sites show a slight increase or are similar to the previous season, except for reference sites.

Algal abundance varied from season to season. In July 2005, a flood over the entire site appears to have affected abundances as seen by the lower reference site abundances in Figure 3. This lower level may be representative of lower levels across the entire study site. Further study will highlight the particular factors affecting diatom abundances but it is known that moisture and salinity affect individual species

Although algal abundance is increasing at all other sites, an increase at Site 6 may be linked to an increase in plant cover. In initial analysis, diatom numbers were extremely low at Site 6. This site has a higher microtopographic level than other sites and it is thought that this soil factor may have influenced or slowed the initial algal colonisation. An improvement in moisture levels and a corresponding fall in salinity, during the cooler months, March to July 2005, have promoted extensive growth in the vegetation, predominantly Saltcouch. An increase in fauna activity has also occurred at this site but this is further discussed below.

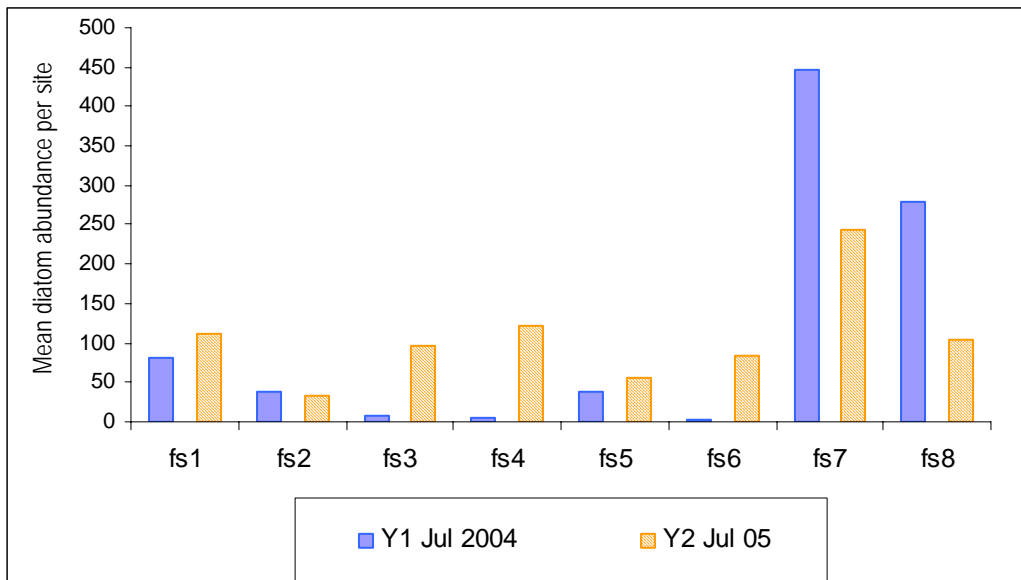


Figure 3: Graph of the relative abundance of algal diatom cells in July 2004 and in July 2005, one year from the completion rehabilitation works. (Fs1 and 2 disturbed sites, Fs3 and 4 no planting, FS 5 and 6 planted, Fs 7 and 8 reference).

The algal methods tested in this study have indicated several key results in the progress of restoration. Algal abundances have indicated that site 3 and 4 are recovering to levels close to reference condition (Figure 3). Site 5 and 6 are also showing signs of recovery but at a lower level. Little disturbance from vehicles was evident at Site 1 and 2 at the time of this sample collection, but vehicle use will be ongoing at these sites, so further monitoring will show if there is a negative change in diatom abundances after disturbance. Soil moisture levels may affect the algal abundance overall, but soil salinity may be a factor which affects individual diatom species. Further work is required to determine these trends.

Soil Physical Factors – Salinity, Moisture, Particle Size and Organic Matter

Particle size analysis indicated that overall the sites were predominantly fine sand (60–94%). The reference sites, 7 and 8 had a slightly different texture to the rest of the site, with a slightly higher coarse sand component. The only imported soil for filling was used at site 3. Grain size analysis indicated that the texture of the imported soil complemented the other sites very well, except for a slightly higher gravel component. The coarse texture of the study site, varying between 60–94% fine sand and 4–37% coarse sand, provides drainage and aerobic conditions. Under aerobic conditions decomposition rates are higher and organic matter doesn't accumulate in the soil (Zedler 2001). This indicates the importance of soil texture and its effect on most soil properties and it is recommended that soil grain size be measured pre-works and then yearly in a restoration project (Zedler 2001).

Soil salinity levels can change daily in different areas of the saltmarsh in response to extreme high tides and rainfall (Zedler 2001). Salinity levels at the study site are extremely variable even when not affected by rainfall events (Table 1). The lowest rainfall period was March, August and October, 2005 with a higher salinity level at these times as indicated by Sites 1, 4, 5, 6 and 7. The lowest salinity levels correspond to the high rainfall periods, July and September, 2005 (Table 1). Measurements of soil salinity and moisture levels, linked to rainfall data, are crucial for monitoring change in saltmarsh restoration projects. Measurements should be taken prior to works to record pre-planting conditions, especially if fill is imported (Zedler 2001). Lower soil salinity levels can indicate freshwater inputs to the site from various sources including rainfall, flooding or stormwater

drains and also periods where tidal inundation is the main factor controlling salinity and site moisture levels. Vegetation patterns and colonisation of a restoration site may be strongly influenced by the freshwater inputs.

Table 1: Rainfall data from March to October 2005 with corresponding soil salinity measurements (dS/m). Rainfall for the week prior (Rain wk prior) to soil sample collection (includes days from previous month) and total for the same month (month total) is shown with mean salinity levels from March 2005 to October 2005 at each site (Rainfall recorded at Coolangatta, Queensland)

	rain wk prior	month total (mm)	EC site							
			1	2	3	4	5	6	7	8
March	1.6	34.4	2.58	0.77	1.21	3.52	2.90	1.53	3.54	5.24
July	139.8	203.2	2.13	1.20	4.17	0.46	1.07	0.09	1.04	3.30
August	1	31.2	3.70	2.70	3.73	2.80	4.13	2.27	3.53	4.07
September	25.4	21.6	0.75	0.68	2.25	1.29	0.74	0.60	2.17	4.71
October	0	0	5.10	1.83	7.37	3.70	7.50	2.33	4.33	9.80

Rainfall records for the initial period (January 2004 –2005) indicate a relatively dry period for the establishment of the restoration works. As the Tweed region is a high rainfall area, mean annual rainfall of 2000 mm, it would be expected that freshwater inputs from rainfall events, might be a controlling factor in site restoration. High rainfall periods in 2005 have coincided with mass germination events of *S. quinqueflora* and *S. australis* by a change in plant cover (Figure 2).

Further detailed study of seedling germination rates on restoration sites is required. Measurements of other factors should be taken as often as practical to build a clear picture of physical change in the saltmarsh. Measurements should taken prior to any works to determine any extreme levels.

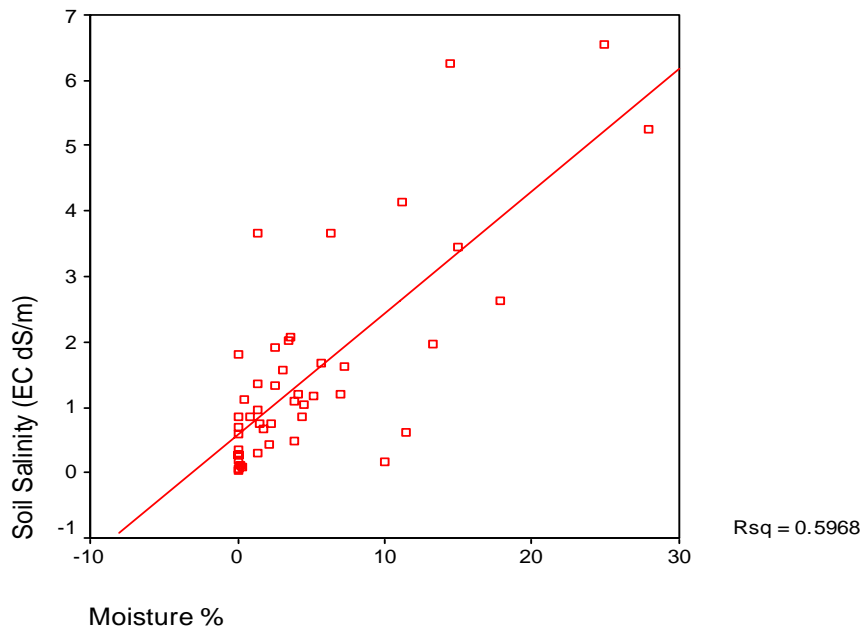


Figure 4: Graph indicating the relationship between soil moisture content and soil salinity, September 2005, measured as electrical conductivity (d/S m).

Soil Organic Matter, Moisture and Restoration

Soil Moisture level provides an indication of tidal inundation of the site and therefore will vary according to the tidal cycle. As the degree of tidal inundation will influence the vegetation structure, salinity levels and level of algal growth this is a relevant parameter for measuring change and progress of saltmarsh rehabilitation.

Measurements should be taken at a similar time within the tidal cycle to minimise this variability (Zedler 2001). At Fingal, to minimise variability, soil samples are collected at low tide in the first week of the month, following the new moon. All samples are taken at a similar time during the day from each site. The relationship between soil moisture levels and soil salinity for September is indicated in Figure 4. Variation in levels will occur with different seasons.

Soil organic matter was measured to determine the value for recording the progress of the restoration efforts. Soil organic matter accumulation is known as a useful indicator of accretion or changes in the soil levels and sediment deposition. Changes in soil organic matter may indicate changes in microtopographic levels and may correlate with vegetation change. Increasing soil organic matter will improve soil structure and nutrient cycling (Zedler 2001). A strong positive relationship between soil moisture levels and organic matter is shown in Figure 5, but levels of both are extremely low, 0-8%. These figures are similar to southern Californian saltmarsh soils, with high decomposition rates (Langis *et al.* 1991). Further investigation is required at the study site. Soil organic matter may be useful measure of change in the restoration site over a longer time scale, especially in saltmarsh with a different soil structure and higher organic matter levels.

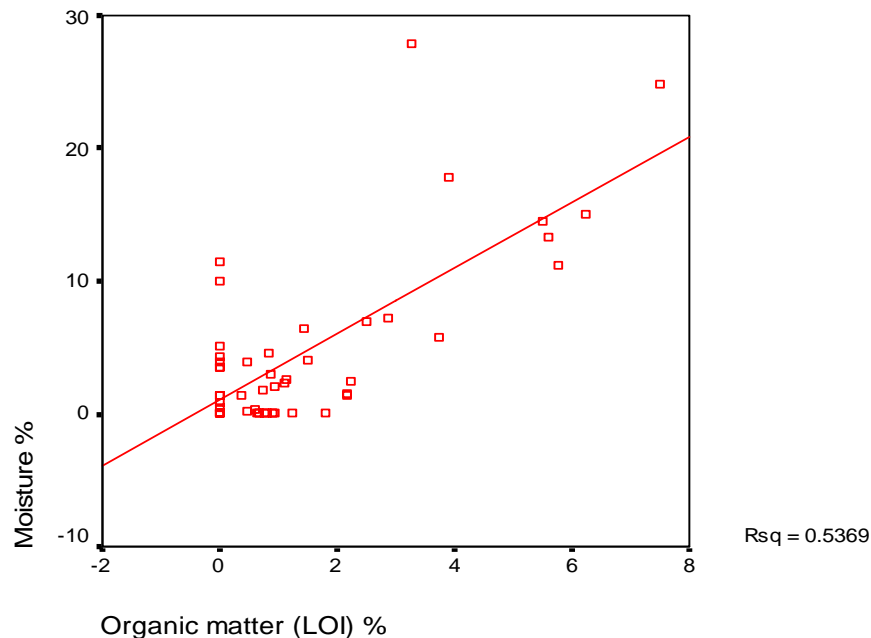


Figure 5: Graph showing relationship between moisture content in the soil and organic matter (measured as Loss on Ignition, LOI) for September 2005. Algal contribution to organic matter in saltmarsh is extremely high.

Fauna

The measurement of crab burrows may be a useful indicator of the longer-term development of the restoration site (Breitfuss 2003). One of the main indicator species in saltmarsh environments is *Helograpsus haswellianus*. This grapsid crab is usually found above the high tide level, in sheltered estuaries and in lower salinity areas of the river and usually avoids burrowing in waterlogged substrates (Richardson *et al.* 1998; Breitfuss 2003).

The use of crab burrows, as a measure of crab abundance in saltmarsh has been explored by Brietfuss (2003). Only fresh burrows are counted. These burrows are identified by the presence of lighter or fresh soil deposits around the entrance to the burrow, with sharp edges to the perimeter of the burrow. Tide, rainfall events and wind will remove the evidence of regular maintenance by the crabs, so older unused burrows are easy to distinguish. With consideration of species characteristics and site particulars the measurements of crabs burrows can provide a rapid assessment of fauna activity in the saltmarsh.

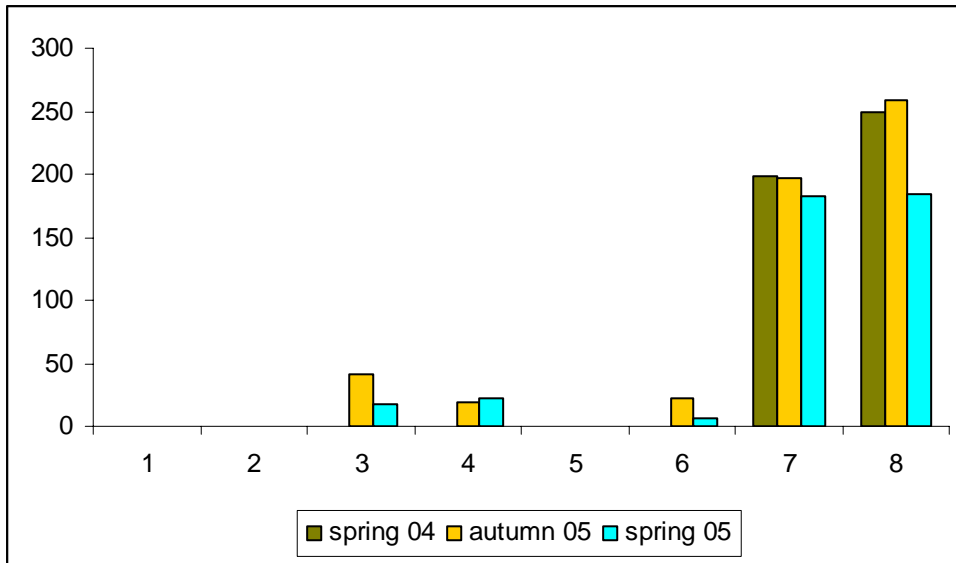


Figure 6: Graph of numbers of crab holes found at each site.

NB: Sites 1 and 2 are disturbed, sites 3 and 4 are Rehabilitation without planting, sites 5 and 6 are rehabilitation with planting and Sites 7 and 8 are reference.

At the study site the reference communities showed the highest development of crab holes as an indicator of the activity of benthic burrowing organisms. The non-planted sites also showed some crab activity. Further measurements will identify long-term change in the site. No crab holes were found within the study area at the two disturbed sites (1 and 2) or at the rehabilitation site 5. Crab activity was found outside the study sites but still within the restoration area, at different times throughout the assessment program. As crabs tend to like a firm substrate for their burrows, it may be expected that the crab activity will increase as the saltmarsh surface is stabilised through the establishment of plant roots and lack of disturbance. Long term monitoring of the sites is required to record this change.

CONCLUSION

The methods and parameters tested to date are showing the progress of restoration at the Fingal site. Initial and ongoing measurements of soil physical parameters, particle size for soil texture, salinity and moisture content for tidal inundation and effects on vegetation and algal growth are considered the most relevant for measuring the early stages of restoration. Long term measurements of fauna colonisation and vegetation cover are relevant for restoration at a longer time scale.

The major changes to the saltmarsh structure in the first twelve months since rehabilitation works are an increase in vegetation cover and algal abundance at all restoration sites. Fauna colonisation has occurred at a slower rate. The removal of disturbance to the sediment surface has been

paramount in the recovery of the site to date. Further measurements over time will verify these trends in change to saltmarsh structure and function

Much more research is required to measure the development of saltmarsh restoration with the inclusion other fauna types, such a benthic microfauna, terrestrial insects, birds and fish. For the purposes of short-term assessment of restoration efforts, algal abundance and vegetation cover indicate that the Fingal site is recovering from disturbance. On going research into saltmarsh restoration, particularly the time required for recovery, could provide important information for managers and planners, where losses of saltmarsh are unavoidable and restoration of sites is the only option.

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