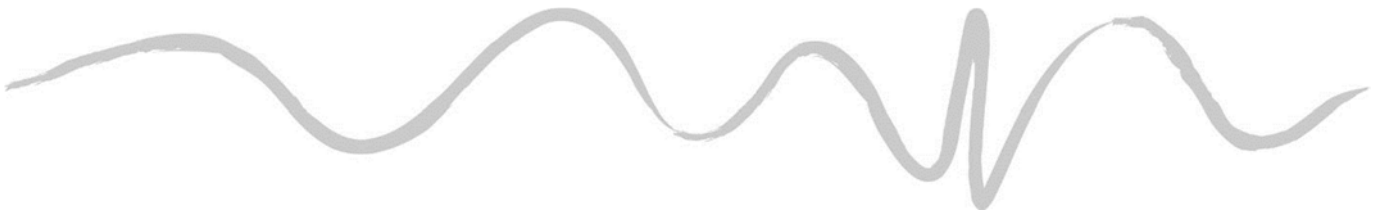
Environmental Management Plan

Pacific Pines, Lennox Head

EPBC 2007/3585



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Environmental Management Plan

Pacific Pines, Lennox Head

EPBC 2007/3585

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Executive Summary

This Environmental Management Plan (EMP) is prepared to support the approved Pacific Pines urban development. It addresses Condition 5 of the Approval.

The Approved Development

EPBC 2007/3585 was approved in 2011. It provides for a residential subdivision and associated amenities and infrastructure, including a central Conservation Zone.

A modification is currently proposed, primarily to increase the area proposed on the site for ecological conservation.

Hairy Joint Grass (HJG)

HJG is an annual grass, meaning that it completes its lifecycle within a single year. The species germinates from seed in late winter or spring, grows most actively during the summer wet season, flowers and sets seed in March and April, then dies off in May and June.

The primary habitat of HJG is lower slopes that remain damp or are fed by groundwater seepage during the wet season, (Benwell 2012). Nearly all known HJG populations occur on cleared grazing land in pasture dominated by exotic grasses and herbs (Benwell 2012). It is only rarely found in a natural habitat.

Studies by ECOS Environmental (2004) have shown that persistence of HJG in areas of cleared pasture is dependent on ongoing biomass removal by grazing stock and the maintenance of small gaps in ground layer vegetation suitable for HJG germination and establishment. In the absence of biomass removal, HJG is likely to be out-competed by vigorous exotic pasture species.

Studies have noted that HJG has declined when grazing animals are withdrawn. Experiments in areas of declining HJG population at Pottsville, where biomass removal was reintroduced in the form of slashing and mulch removal, resulted in a marked increase in HJG population (Ecos, 2004).

Updated survey / mapping was undertaken at the site in November 2011. Targeted surveys for HJG were undertaken within all areas representing potential habitat for the species. 3.56 ha of HJG were mapped as being present across the whole of the site, with 1.4 ha of HJG present within the Conservation Zone. A further 0.3 ha of HJG will be protected within a public reserve located in the north-west corner of the site, being land within a 100 m buffer to a mapped SEPP26 littoral rainforest area on adjoining land.

The Conservation Zone

The Conservation Zone covers an area of approximately 14.07 ha. When rehabilitated, the Conservation Zone will create a vegetated corridor for fauna and flora habitat that extends both east-west and north-south across a significant portion of the site.

It is heavily degraded, having been subjected to a combination of disturbances by way of vegetation clearance, cattle grazing and hydrological modification (e.g. drainage channels and dams). The following vegetation communities are present in the Conservation Zone:

Freshwater Wetlands	4.4
Littoral Rainforest	3.9
Swamp Sclerophyll Forest	0.3
Exotic-dominated grassland	7.0

HJG occupies 1.4 ha within the Conservation Zone, primarily around the fringes of the existing Freshwater Wetland community. Suitable habitat for the species has also mapped within the Conservation Zone, being areas that display some or all of the following characteristics:

- existing presence of HJG;
- on the margins, or just within the margins of, Freshwater Wetland EEC; and / or
- on a lower slope or within a soak.

As well as this existing suitable habitat, it is evident that there are also areas where there is potential habitat that is currently only slightly higher in elevation. In these areas of potential habitat, very minor habitat modification (i.e. scraping of ground less than 100mm depth) is likely to be sufficient to create suitable habitat conditions for the species.

In all, 3.85 ha of suitable HJG habitat is available within the Conservation Zone.

Conservation Zone Rehabilitation Strategy

To enhance the ecological values of the site, a comprehensive rehabilitation strategy will be implemented to create a mosaic of vegetation and habitat types forming an integrated suite of ecosystems within the Conservation Zone.

The focus of the compensation strategy will be to:

- facilitate the establishment of an integrated suite of ecosystems, representing the distribution pattern of EECs that are expected to have been present in this area pre-clearing;
- minimise maintenance inputs to this area by encouraging self-sustaining vegetation;
- enhance the inherent ecological values of the EECs and threatened species presently occupying this area; and
- ensure that a viable population of HJG persists within the Conservation Zone (ensuring a retention versus removal ratio of 2:1).

The management approach for discrete areas within the Conservation Zone consists of a combination of:

- Conservation and enhancement of:
  - mapped HJG (outside of Freshwater Wetland EEC);
  - existing Swamp Sclerophyll Forest EEC; and
  - existing Littoral Rainforest EEC.
- Freshwater Wetland EEC rehabilitation (including enhancement of mapped HJG and SSSR within this EEC);
- Revegetation of EECs:
  - Littoral Rainforest EEC revegetation incorporating HJG;
  - Swamp Sclerophyll Forest EEC revegetation;
  - Swamp Oak Forest EEC revegetation; and
  - Littoral Rainforest EEC revegetation.
- Translocation of threatened species:
  - recipient areas for translocated HJG; and
  - recipient areas for translocated SSSR.

Mapped HJG (outside of Freshwater Wetland EEC)

A number of areas within approximately 25 m outside of the boundary of the mapped Freshwater Wetland EEC contain extensive patches of HJG, which co-exists in these peripheral areas with exotic pasture grasses.

Some mapped areas support only light cover of HJG, while other areas support comparatively dense cover. Enhancement of this community will be achieved by:

- selective weed control of weedy pasture grasses during the non-growing season of HJG; and
- annual slashing / brush-cutting of grass in these areas following seeding of HJG to stimulate recruitment of HJG.

Freshwater Wetland EEC (including enhancement of HJG and SSSR)

Freshwater Wetland EEC covers an area of approximately 4.4 ha in the central section of the Conservation Zone. Existing vegetation comprises a range of wetland habitats, including reedland, sedgeland, areas of dense Swamp Ricegrass (*Leersia hexandra*) and substantial areas supporting HJG and SSSR.

Weed grasses are common in this community. The ongoing viability of the Freshwater Wetland EEC vegetation is challenged by removal of cattle and the probable proliferation of exotic grasses once grazing has ceased.

Rehabilitation of the Freshwater Wetland EEC will be achieved by:

- selective weed control of weedy pasture grasses during late winter (non-growing season of HJG);
- annual slashing / brush-cutting in target areas supporting HJG and SSSR during the dormant period, to stimulate threatened species seedling germination and vegetative spread; and
- supplementary planting of wetland species targeting areas that are not currently occupied by HJG or SSSR, and those areas in which weed treatment has occurred, and/ or where the overall diversity of wetland plants is low.

Biomass reduction enhancement areas for existing areas of HJG and SSSR will be located adjacent and within 25 m of proposed HJG and SSSR translocation recipient sites, because:

- areas are easier to locate;
- time taken for slashing / brushcutting is minimised; and
- managed areas of threatened species habitat are contiguous.

Control of weed species will be achieved by hand-pulling to avoid potential damage to native wetland species, including HJG and SSSR.

Translocation of HJG

Recipient areas suitable for establishing new populations of HJG and SSSR were identified as part of habitat mapping of the Conservation Zone.

Hairy Joint Grass

Translocation of HJG is based on methods employed successfully by Ecos Environmental (Benwell 2012) as part of translocation of this species for the Ballina Bypass Pacific Highway upgrade project.

Site Preparation

The following strategies are proposed for the preparation of the recipient site:

- noxious and environmental weeds are to be eradicated prior to translocation being undertaken;
- one week prior to direct seeding, the recipient site will be slashed; and
- mulch is to be removed from the recipient sites.

Seed Collection

Seed will be collected from the site between April and May and stored in paper bags in a dry cool place until the time of planting. Seed collection is to be undertaken by a suitably qualified ecologist under a Section 132C Licence issued by OEH for the activity.

Direct Seeding

Direct seeding is to be carried out in winter (June) to mimic the natural cycle of seed dispersal and recruitment in wild populations of HJG. Seed is to be mixed with river sand and spread over target recipient sites.

Post-translocation Maintenance
The results of translocation trials for this species (Benwell 2012) indicate that HJG seedling recruitment is enhanced by biomass reduction. Therefore, post-translocation maintenance of recipient sites will consist of a single annual slashing event aimed at reducing pasture biomass and creating spaces in the ground layer to assist in seed germination. This will occur in June once seeding of HJG has finished.

Translocation Monitoring

Ongoing maintenance and management of the recipient sites and translocated plants will be vital to the success of the translocation project. Accordingly, an ongoing monitoring program will be instigated to track the condition of the recipient sites and individual translocated plants. Results of the monitoring programme will lead to adaptive management responses if required.

The maintenance and monitoring program will incorporate actions that are largely derived from recommendations for monitoring in *Guidelines for the Translocation of Threatened Plants in Australia* (Vallee *et al* 2004). Once established in recipient sites, HJG will be maintained via annual biomass removal and weed control. Annual results of the monitoring program will be reported to OEH.

Contingency Measures

Monitoring techniques to measure the success of these indicators are:

- *A reduction in weed cover* – weed cover in the Conservation Zone will be monitored. Any opportunistic observations of weeds will be recorded to inform a 'priority weed map' for the Conservation Zone. The extent of these weed infestations will be recorded. A simple map showing the locations of priority weeds will be prepared to inform future weed control works. A significant increase in weed burden within the Freshwater Wetland EEC area would indicate unsuccessful rehabilitation.
- *Proven enhancement of HJG* – an annual survey and mapping of the distribution of HJG will be undertaken to establish changes in distribution. A decrease of >20% in the presence of this species within the habitat area would indicate unsuccessful enhancement.
- *Proven establishment of HJG* – recipient translocation sites will be monitored. The distribution of this species across seasons is variable depending on environmental conditions. To account for some of this variability, success or failure will be based on a significant deviation from a baseline vegetative cover (decrease of >20%). This baseline vegetative cover will be measured at 12 months following the translocation event.
- No substantial changes in the boundary of the Freshwater Wetlands EEC that cannot be accounted for by seasonal variation (potentially indicating a change in hydrology) – transect surveys will be used to detect potential changes in the boundary of the Freshwater Wetland EEC in the Conservation Zone. The boundary of this community is expected to fluctuate somewhat depending on climatic variability, however; it should be possible to attribute any substantial change in the location of the boundary of this community to climatic conditions or to a change in hydrology.

Results of monitoring will provide the opportunity to modify management techniques where necessary. If it is shown that the indicators are not being met, a modification to vegetation management techniques will be implemented. This modification may include:

- revision of weed control techniques;
- re-assessment of the timing, extent and technique of biomass control; or
- re-establishment of additional HJG in poorly performing areas.

As a precaution against loss of genetic diversity, a program of seed collection and propagation for HJG will be undertaken so that re-establishment on-site or off-site is possible if required.

The seed of HJG retains adequate viability for up to 3 years (Andrew Benwell pers. comm.). Seed would be collected from across the site prior to construction, and from within the Conservation Zone annually following this, and placed in cool storage.

If it is established that the compensatory works have been unsuccessful, further research into the ecology, enhancement and translocation of HJG would be initiated. This research would provide valuable information for future projects involving this species.

The methodology and scope of such research would be consistent with that undertaken to investigate translocation of HJG for the Ballina Bypass Highway Upgrade Project (Benwell 2012).

This research extended over two years and included the following components:

- genetic research to determine the extent of genetic variation among populations;
- experimental translocation to establish a new population and research the effect of site factors and follow-up management on establishment and persistence; and
- management of an existing population, including maintenance of habitat conditions favourable for recruitment.

The opportunity exists to engage a local university such as Southern Cross University or Griffith University to undertake this research, potentially as part of a research higher degree. The proponents would make a monetary contribution of $50,000 to enable that research.

Water Management Plan

The Water Management Plan addressing the requirements of the Minister's approval has been prepared by Gilbert and Sutherland, specialist hydrologists.

Gilbert and Sutherland undertook a detailed assessment of the site, resulting in modelling of the existing, pre-development, hydrological regime. This involved a number of sub-surface bores, supplemented by a detailed analysis of existing landform, soils, slope and vegetation.

MEDLI modelling was undertaken to estimate the deep drainage component of the pre-development landscape, providing a basis for identifying the reduction in recharge due to development of hardstand on the site. MEDLI was also used to determine the irrigation requirement to maintain the seepage areas at field capacity.

Based on the detailed site analysis, Gilbert and Sutherland have worked with the project engineers to develop a bio-filtration / infiltration system, to be constructed at the southern edge outside the Conservation Zone as part of the Stage 1A residential subdivision. This system will ensure appropriate seepage protection / replacement that will ensure continued water source for the freshwater wetland.

As outlined in the Gilbert and Sutherland report, MUSIC modelling undertaken to test the proposed system identified that at the completion of development, a total of approximately 229.06 ML/yr will be discharged to the wetland from the bio-filtration / infiltration system. This exceeds both the irrigation requirement and deep drainage replacement estimated by the MEDLI modelling to ensure that the pre-developed field capacity of the seepage areas is maintained. This will ensure the ongoing maintenance of wetland conditions in the central part of the Conservation Zone.

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1 Introduction

1.1 Background

On 12 December 2011, the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) issued an approval under sections 130(1) and 133 of the *Environment Protection and Biodiversity Conservation Act 1999* for the urban development of Lot 234 DP1104071 located at Hutley Drive, Lennox Head, NSW (EPBC 2007/3585).

An application has been lodged to vary this approval, to provide for an increased area of on-site ecological compensation.

The latest proposed plan for the action is shown in Illustration 1.1. As shown, the proposed development of the Pacific Pines site includes the establishment of a central Conservation Zone, which will be remediated and managed to ensure the protection and enhancement of conservation values at the site.

The requirement for EPBC Act approval arises because of the presence of Hairy Joint Grass (HJG), which is a species of flora listed as vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999.*

This Environmental Management Plan (EMP) addresses the management of the Conservation Zone in relation to this species, with the aim of ensuring the persistence of a viable HJG population into the future. The Plan addresses the requirements of EPBC approval 2007/3585, as detailed below.

1.2 Structure of the EMP

The requirement for an EMP is outlined within Condition 5 of the Approval. Associated with the current proposal to vary the approval, the Department has advised of draft updates to the Condition.

The specific requirements of that draft updated condition are listed below in Table 1.1, along with reference to the sections of this EMP within which each requirement is addressed.

Table 1.1 Requirements of Condition 5 – Environmental Management Plan

Requirements for EMP		***Section in EMP***
a)	A minimum area of 3.72 hectares to be maintained within the conservation zone as HJG habitat for the duration of the action, or until the handover of the conservation zone to the Ballina Shire Council, whichever is the later.	Section 5
b)	Identification of habitat characteristics, including hydrological regime, required for the persistence of a viable HJG population (HJG plants present within 80% of the 3.72 ha = 2.97 ha) within the conservation zone.	Sections 4 & 5
c)	Identification of limiting factors, including climatic variations that may adversely impact on the persistence of a viable HJG population within the conservation zone and measures to be implemented to minimise such adverse impacts.	Sections 4 & 5

Requirements for EMP		*Section in EMP*
d)	Measures designed to rehabilitate HJG habitat within the conservation zone to ensure persistence of a viable HJG population.	Section 5
e)	Measures designed to monitor the success of rehabilitation and the level of persistence of a viable HJG population within the conservation zone.	Section 8
f)	Remediation and/or compensation measures to be implemented in the event a viable population of HJG cannot be established within the conservation zone within 12 months of the commencement date of construction and maintained annually for the duration of the action or until the transfer of the conservation zone to the Ballina Shire Council whichever is the later.	Section 8
g)	An annual (commencing from the date of commencement) reporting mechanism to the department on the progress of rehabilitation, failures and remediation and/or compensation measures implemented to address the failures, and estimate of the viable HJG population within the conservation zone for the duration of the action or until the conservation zone has been handed over to the Ballina Shire Council whichever is the later.	Section 8

Information shown is for illustrative purposes only

Drawn by: TJP Checked by: MVE Reviewed by: RVI Date: September 2012
Source of base data: Deicke Richards, Ballina Shire Council

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North

Plan for the Action

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2

Site Overview

2.1 Locality

In this document, the broad area covered by the proposed Pacific Pines development is referred to as "the site" (i.e. Lot 234 DP 1104071).

The site is located at Lennox Head in northern NSW and is situated within the Northern Rivers Catchment Management Authority (CMA) area, South East Queensland Bioregion and Ballina Shire Local Government Area (LGA). The locality of the site is shown in Illustration 2.1.

2.2 Climate

The site experiences a warm-temperate to subtropical climate typical of coastal north-eastern NSW due to its proximity to the relatively warm waters of the Tasman Sea. Average rainfall for the area is approximately 1860 mm, as shown in Table 2.1 (Ballina Airport; Bureau of Meteorology, 2011), with the highest falls in the summer and autumn period (January to May). During these months, high intensity rain events and severe thunderstorms are not uncommon. The prevailing wind is typically from the south-east. However, strong winds from the north can occur sporadically during spring and summer (Anderson, 1999).

Table 2.1 Indicative Climate Data for Ballina Airport (4 km from the site)

Month	*Mean Daily Max Temperature (°C)*	*Mean Daily Min Temp (°C)*	*Mean Monthly Rainfall (mm)*
January	28.2	19.6	164.9
February	28.0	19.4	194.8
March	26.9	18.1	219.9
April	24.9	15.2	183.0
May	22.4	12.1	173.7
June	20.2	9.7	197.4
July	19.9	8.5	119.6
August	21.2	8.7	92.8
September	23.5	11.5	67.4
October	24.7	13.9	108.8
November	26.1	16.5	124.4
December	27.3	18.1	142.9
Annual	24.4	14.3	1860.6

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Drawn by: TJP Checked by: MVE Reviewed by: RVI Date: September 2012
Source of base data: Ballina Topographic Map 9640-3-N

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North

Site Locality

GeoLINK environmental management and design

Environmental Management Plan: Pacific Pines
1675-1040

Illustration 2.1

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2.3 Geology

The geology of the site is mapped within the Bangalow soil landscape which consists of low rolling hills on basalt with moderately deep to deep (100 - >200 cm), well-drained Kraznozems and brownish red Kraznozems (Morand, 1994). These soils are described as being strongly acidic and moderately erodible.

A geotechnical investigation of the entire site was undertaken by Ardill Payne and Partners in 2002. This investigation identified that soils in the valley section of the site, in which the Conservation Zone is situated, are poorly drained alluvial soils.

Further soils assessment was undertaken in 2011 by Gilbert and Sutherland, in the preparation of their Water Management Plan (see Appendix A). Their analysis indicated that the soils in and around the Conservation Zone are most appropriately classified, in accordance with the Australian Soils Classification (Isbell, 1996), as hydrosols and ferrosols. Hydrosols are soils that are saturated in the major part of the solum for at least 2-3 months in most years, while ferrosols are soils with B2 horizons in which the major part has a free iron oxide content greater than 5% in the fine earth fraction.

Gilbert and Sutherland also analysed the soil permeability and concluded that the soils at and around the Conservation Zone are very poorly drained, with groundwater typically found at around 0.2-0.5 m below natural surface level.

2.4 Acid Sulphate Soils

Gilbert and Sutherland conducted an acid sulphate soils assessment for the site in March 2004. In summary, the report found that potential acid sulphate soils (PASS) were observed between 0.75 m and 3.0 m below natural surface levels in the location of the water control ponds.

The report of Gilbert and Sutherland identifies three soil types found at the site that exhibited PASS characteristics. These include coarse sands, silty sands and silty clays in an increasing severity of PASS. A geotechnical investigation of the entire site has been undertaken by Ardill Payne and Partners indicates that the occurrence of PASS is unlikely to occur above the 10 m AHD contour (limit of alluvial soils). This finding is consistent with Sheet 2 of Ballina LEP 1987, which indicates the extent of Class 2 and 5 acid sulphate soils approximately follows the 10 m AHD contour.

The report of Gilbert and Sutherland identified PASS, consisting of highly plastic clays, in the area over which the Conservation Zone is situated.

2.5 Topography

The site effectively encompasses a gently sloping basin that faces towards the south-west. High points are in the north-east and east, with slopes up to a maximum of approximately 23% down to the low-lying area in the central portion of the site, which supports a freshwater spring that feeds into the Conservation Zone.

2.6 Hairy Joint Grass (HJG)

Target surveys for HJG were undertaken in November 2011 within all areas of the site representing potential habitat for the species. At the time of survey, HJG at the site was between 7 cm and 30 cm in height and was highly visible due to the specific colour of its young foliage.

Surveys for this species involved walking transects throughout suitable habitat at the site, usually between 5 m and 10 m apart, and actively searching for this species. Transects were widened to approximately 15 m in areas where HJG was considered unlikely to occur due to unfavourable microclimates being present.

Locations of the HJG were recorded using a Garmin etrex hand-held GPS unit. In areas of dense HJG, point data was collected approximately every 2 m apart to allow for the distribution of the species to be mapped. To improve the accuracy of data collection, known survey control points were also sampled prior to surveys to allow for later rectification of the data by Kennedy Surveyors. Point data information was used to develop updated distribution mapping for HJG, which is shown in **Illustration 2.2**.

A comparison with previous mapping of HJG at the site (Cardno 2010) is provided in **Table 2.2**. Differences in the mapped distribution of this species between surveys can partially be explained by the natural variations in populations, typical of this species.

Table 2.2 Comparison of HJG Mapping

Area on site (Cardno Mapping 2010)	***Area on site (GeoLINK Mapping 2011)***	***Area to be removed***	
		Cardno 2010	***Current***
3.64 ha	3.56 ha	1.08 ha	1.85 ha

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Source of base data: Ballina Shire Council & Kennedy Surveyors

North

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Distribution of Hairy Joint Grass at the Site

GeoLINK environmental management and design

Environmental Management Plan: Pacific Pines
1675-1047

Illustration 2.2

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3

Conservation Zone Overview

3.1 Extent and Layout

The Conservation Zone covers an area of approximately 14.1 ha, located as shown in Illustration 3.1. It has a predominant westerly aspect, with an elevation of approximately 5 m AHD. The topography of the Conservation Zone is generally flat to gently sloping, with a slope of less than 5%.

When rehabilitated, the Conservation Zone will create a vegetated corridor for fauna and flora habitat that extends both east-west and north-south across a significant portion of the site.

3.2 Vegetation Communities

The majority of the Conservation Zone has been subjected to a combination of disturbances by way of vegetation clearance, cattle grazing and hydrological modification (e.g. drainage channels, dams and water quality control ponds). Table 3.1 summarises the vegetation communities that are present in the Conservation Zone, which are shown in Illustration 3.2.

Table 3.1 Vegetation Communities in the Conservation Zone

Community	*Area (ha)*
Freshwater Wetlands	4.4
Littoral Rainforest	2.4
Swamp Sclerophyll Forest	0.3
Exotic-dominated grassland	7.0

3.3 Key Species and Ecological Communities

Table 3.2 summarises the key species and communities occupying the Conservation Zone, together with a description of their key habitat preferences.

As outlined above, Hairy Joint Grass (*Arthraxon hispidus*) is listed as vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). It is also listed as a threatened species under the NSW *Threatened Species Conservation Act 1995* (TSC Act).

Square-stemmed spike Rush (*Eleocharis tetraquetra*) is also listed as threatened under the TSC Act.

Three of the vegetation communities occurring within the Conservation Zone are equivalent to EECs as listed under the TSC Act. These are Freshwater Wetland, Littoral Rainforest, and Swamp Sclerophyll Forest.

Littoral Rainforest is also listed as critically endangered under the EPBC Act.

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Source of base data: Ballina Shire Council

North

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Conservation Zone Layout

GeoLINK environmental management and design

Environmental Management Plan: Pacific Pines
1675-1041

Illustration 3.1

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North

Vegetation Communities in Conservation Zone

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3.4 Overall Habitat Features

Existing native and exotic vegetation within the Conservation Zone provides habitat for a variety of native fauna by providing foraging and nesting opportunities. Also, a number of drainage channels dissect the Conservation Zone that is habitat for native birds, amphibians, fish and invertebrates. The Conservation Zone also extends around water quality control ponds and constructed drainage channels in the north-west section of the Conservation Zone, and although not part of the Conservation Zone, these features effectively contribute to the overall integrated ecology of the Conservation Zone.

Table 3.2 Significant Flora and Vegetation Communities within the Conservation Zone

Scientific Name/ Ecological Community Name	***Common Name***	***TSC Listing***	***EPBC Listing***	***Habitat Description***
Arthraxon hispidus	Hairy Joint Grass	V	V	Damp areas associated with seepages and wetland edges
Eleocharis tetraquetra	Square-stemmed Spike Rush	E	-	Sedgeland / rushland
Freshwater Wetlands of the NSW North Coast, Sydney Basin and South-east corner Bioregions	-	EEC	-	Sedgeland / rushland
Littoral Rainforest in the NSW North Coast, Sydney Basin and South-east corner Bioregions	-	EEC	CE	Closed forest remnants among Camphor Laurel regrowth
Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South-east corner Bioregions	-	EEC	-	Low-lying areas integrated with sedgeland / rushland
Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner bioregions (also mapped as SEPP 14 Coastal Wetlands)	-	EEC	-	Low-lying areas integrated with sedgeland/ rushland

Note: EEC – Endangered Ecological Community
V – Vulnerable
E – Endangered
TSC – Threatened Species Conservation Act 1995
EPBC – Environment Protection and Biodiversity Conservation Act 1999
SEPP – State Environmental Planning Policy

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4

Hairy Jointgrass Overview

4.1 Species Profile

The most contemporary scientific study of HJG is associated with research work undertaken in association with the construction of the Ballina Bypass, located in the same bioregion as the Pacific Pines site.

The latest study, *Ballina Bypass* Arthaxon hispidus *(Hairy Joint Grass) Translocation and Management Project: Final Report*, has been prepared by Dr Andrew Benwell (Ecos Environmental Pty Ltd). The full report is contained as Appendix B and contains a contemporary species profile. The information below is summarised from the profile provided by Benwell.

HJG is an annual plant species on the North Coast of NSW, as it completes its life cycle in one year. Seed germinates in late winter after a short dormant period. Growth occurs mainly during the summer wet season, with flowering in autumn before the whole plant dies.

HJG occurs mainly on lower hill slopes where the soil is damp or fed by groundwater seepage during the wet season, but the species also occurs higher on slopes in wetter years in moderate grazing pressure. It does not, however, commonly extend into the flood zone at the bottom of valleys, and Benwell suggests that this is because floods would scour away the shallow-rooted HJG plants and seed. It occurs mainly in grazing pasture dominated by exotic grasses, which suggests that it has adapted to agricultural habitat, or that its current habitat overlaps with its original habitat requirements. Benwell also notes that, typically, the pasture habitat of HJG is regularly grazed, low in height (0.3 – 0.6 m) and dominated by perennial, exotic grasses.

The original habitat may have been springs and seepages in open forest adjoining rainforest, rather than inside rainforest, as the species appears to require a well-lit understorey. The presence of the species in areas that were previously continuous rainforest suggests that it may have expanded its distribution since settlement on the North Coast, and that man-made grazing habitat is likely to have aided that expansion.

Benwell (2012) discusses why HJG is rarely found in a natural environment. He states that to the best of his knowledge, out of about 30 known populations on the North Coast of NSW, only one occurs in natural vegetation, in a woodland site west of Grafton.

A number of possible explanations for this are given by Benwell (2012):

- HJG habitat near springs and seepages coincides with intensively utilised sites within grazing land, therefore such habitat unmodified by human activity are very rare;
- the species has adapted to grazing land, effectively widening it niche;
- HJG was originally a short-lived, species that appeared after fire, but due to the cessation of regular burning in its grazed habitat, post-fire populations are rarely seen today (one was observed by Benwell after a fire near Boambee south of Coffs Harbour); and/or
- HJG is actually an exotic species introduced after settlement with the transport of livestock and goods and dispersed locally by soil adhering to hoofs or in the gut of animals.

Studies by ECOS Environmental (2004) at Koala Beach near Pottsville have shown that persistence of HJG in areas of previously cleared pasture is dependent on ongoing biomass removal by grazing stock and the maintenance of small gaps in ground layer vegetation suitable for HJG germination and establishment.

Urban residential areas such as the proposed Pacific Pines estate are not practical for incorporating grazing stock due to a number of issues relating to public safety, access and maintenance. In the absence of the option of maintaining HJG by way of the biomass removal action of grazing stock, the only practical option is to mimic this biomass removal via other means; namely slashing / brushcutting or burning. Burning is not a

practical option within an urban residential area for obvious safety reasons. Therefore slashing / brushcutting is the only viable maintenance option available to encourage the persistence of HJG in ex-grazing areas.

In the absence of annual biomass removal, HJG is likely to be gradually out-competed by the growth of vigorous exotic pasture species. In such a situation, HJG is likely to have limited germination and establishment success due to few gaps being present in the grass cover. The ongoing viability of HJG would be potentially compromised in the long-term in an environment where biomass removal was not occurring.

Interestingly, Benwell notes that HJG populations have declined when grazing animals are withdrawn from an area. He associates this with an increase in pasture grass height and density, with the build up of vegetation and shading the ground layer and inhibiting HJG seed germination. He notes previous experiments in areas of declining HJG population at Pottsville, NSW where biomass removal was reintroduced in the form of slashing and mulch removal, resulting in a marked increase in HJG population.

4.2 Occurrence and Habitat

4.2.1 HJG presence

Updated mapping of the distribution of Hairy Joint Grass was undertaken by GeoLINK as part of the preparation of the EMP. This fieldwork was conducted between 16 November and 23 November 2011.

Methodology

Targeted surveys for HJG were undertaken within all areas of the site representing potential habitat for the species in northeast NSW, based primarily on the species profile provided by Benwell. At the time of survey, HJG at the site was between 7 cm and 30 cm in height and was highly visible due to the colour of its young foliage (being lighter green in comparison to other commonly occurring exotic grasses).

Surveys for HJG involved walking transects throughout suitable habitat and noting the presence / absence of the species at intervals of 1 to 2 m. Presence of HJG was recorded using a Garmin etrex hand-held unit.

Transects were generally orientated parallel to one another at a spacing of 5 to 10 m. However, this spacing was widened to approximately 15 m in areas where HJG was considered unlikely to occur due to unfavourable microclimatic conditions. Conversely in areas where a dense occurrence of HFG was encountered, the transect spacing was decreased to 2 m to allow for a more comprehensive distribution to be recorded.

To improve the accuracy of the GPS data, known survey control points were also sampled prior to surveys being undertaken to allow for subsequent rectification of data by local surveyors. The mapped occurrence of HJG in the Conservation Zone in the 2011 / 2012 growing season is shown in Illustration 4.1. The total area occupied by HJG within the Conservation Zone was calculated to be approximately 1.4 ha.

4.2.2 Suitable HJG habitat

The mapped area of HJG (GeoLINK 2012) reflects presence-absence rather than density of this species. Consequently, some mapped areas support only light cover of HJG while other areas support comparatively dense cover.

In addition to mapping the presence of HJG, the suitable habitat for the species has also mapped within the Conservation Zone (see Illustration 4.2). Generally, existing suitable habitat was determined by identifying areas within the Conservation Zone that display some or all of the following characteristics:

- existing presence of HJG;
- on the margins, or just within the margins of, Freshwater Wetland EEC; and / or
- on a lower slope or within a soak.

In addition to these areas of existing suitable habitat, it is evident that there are also areas where there is potential habitat that is currently only slightly higher in elevation. In these areas of potential habitat, very minor habitat modification (i.e. scraping of ground less than 100mm depth) is likely to be sufficient to create suitable habitat conditions for the species.

Overall, an area of 3.85 ha of land has been mapped within the Conservation Zone as being suitable habitat for HJG.

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Hairy Joint Grass Distribution in Conservation Zone

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Source of base data: Ballina Shire Council & Kennedy Surveyors

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Hairy Joint Grass Habitat in the Conservation Zone

GeoLINK environmental management and design

Environmental Management Plan: Pacific Pines
1675-1048

Illustration 4.2

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5

Conservation Zone Rehabilitation Strategy

5.1 Background

Discussions between GeoLINK, Ballina Shire Council and OEH in February 2012 solidified the viewpoint that the best conservation outcome is to develop a mosaic of vegetation and habitat types forming an integrated suite of ecosystems within the Conservation Zone, as opposed to focusing solely on translocation of threatened species as the major component of the offset requirement.

Therefore, the focus of the compensation strategy will be on enhancing and establishing an integrated suite of ecosystems in the Conservation Zone, as is detailed in the following sections. Notwithstanding this, the rehabilitation of the Conservation Zone is also designed to ensure that there remains an ongoing and viable presence of HJG at the site. As outlined below, measures have been developed that will ensure the protection of HJG habitat as an integral part of the Conservation Zone, also ensuring a retention versus removal ratio of 2:1 for HJG at the site.

5.2 Objectives

This rehabilitation strategy details the approach that will be taken to ensure that HJG and other threatened plant species and communities are protected and enhanced within the defined Conservation Zone. The overall ecological objectives for management of the Conservation Zone are to:

- ensure that a viable HJG population persists within the Conservation Zone;
- facilitate the establishment of an integrated suite of ecosystems, representing the distribution pattern of EECs that are expected to have been present in this area pre-clearing;
- minimise maintenance inputs to this area by encouraging self-sustaining vegetation; and
- enhance the inherent ecological values of the constituent EECs and threatened species presently occupying this area.

To facilitate achievement of these objectives, a rehabilitation plan has been developed by:

- identifying the existing vegetation types and other relevant ecological habitats within the Conservation Zone;
- dividing the Conservation Zone into vegetation protection and rehabilitation areas, reflecting the preferred rehabilitation and management options for creating an integrated suite of ecosystems; and
- identifying the required management approach(s) for successfully establishing an integrated suite of ecosystems.

5.3 Mapping of Rehabilitation Areas

At a field visit by GeoLINK ecologists Tom Pollard and David Havilah on May 2012, habitat mapping was carried out to determine preferred options for rehabilitation and management. The aim of this mapping was to determine the layout for the rehabilitation and enhancement of vegetation in the Conservation Zone, to form an integrated suite of ecosystems requiring very little management input into the future.

Areas with distinct habitat characteristics were assigned as discrete areas and these were broadly mapped onto a hardcopy map of the Conservation Zone showing existing EECs and threatened species habitat. Distinct habitat areas were subsequently assigned to a rehabilitation and management treatment option (see below), determined by factors such as habitat characteristics, likelihood of success of a particular treatment, and consequences for ongoing maintenance, and APZ requirements.

The management approach for discrete areas within the Conservation Zone consists of a combination of:

- Conservation and enhancement of:
  - mapped HJG (outside of Freshwater Wetland EEC);
  - existing Swamp Sclerophyll Forest EEC;
  - existing Swamp Oak Forest EEC (including mapped SEPP 14 Coastal Wetland enhancement); and
  - existing Littoral Rainforest EEC.
- Freshwater Wetland EEC rehabilitation (including enhancement of mapped HJG and SSSR within this EEC);
- Revegetation of EECs:
  - Littoral Rainforest EEC revegetation incorporating HJG;
  - Swamp Sclerophyll Forest EEC revegetation;
  - Swamp Oak Forest EEC revegetation (including mapped SEPP 14 Coastal Wetland revegetation);
  - Littoral Rainforest EEC revegetation; and
- Translocation of threatened species:
  - recipient areas for translocated HJG;
  - recipient areas for translocated SSSR.

All areas contributing to the rehabilitation strategy are mapped in Illustration 5.1. Details of the management approach for these areas are the basis of the rehabilitation strategy for the Conservation Zone and are detailed in the following sections.

5.4 Conservation and Enhancement of Communities and Threatened Species

A primary aim of the rehabilitation strategy is to retain all existing habitat occupied by threatened species and EECs within the Conservation Zone.

EECs within the Conservation Zone cover approximately7.2 ha of a total area of 14.07 ha. The location of these areas is shown on Illustration 3.2.

Individual areas of EEC vegetation at the Pacific Pines site are relatively small. Edge effects, particularly exposure to high light levels, can encourage prolific weed growth and have a serious detrimental effect on vegetation quality and the likelihood of successful unassisted regeneration.

These communities will be enhanced through management actions to eliminate highly competitive weeds and thereby encourage natural regeneration of native plant species. Additional enhancement of this community will be achieved by supplementary plantings of suitable native species within canopy gaps (including those created by treating woody weeds). As part of the overall rehabilitation strategy for the Conservation Zone, the sustainability of these existing EEC areas will also be bolstered by encouraging the establishment of additional contiguous areas of EEC by way of revegetation, and thereby limiting the impacts of weed infestation.

5.4.1 Mapped HJG

A number of areas within approximately 25 m outside of the boundary of the mapped Freshwater Wetland EEC contain extensive patches of Hairy Joint Grass, as mapped by GeoLINK in 2012 (refer to Illustration 5.1). HJG co-exists in these peripheral areas with exotic pasture grasses such as Buffalo Grass (*Stenotaphrum secundatum*), Vasey Grass (*Paspalum urvillei*) and Kikuyu (*Pennisetum clandestinum*), and the native grass Swamp Foxtail (*Pennisetum alopecuroides*).

The mapped area of HJG (GeoLINK 2012) reflects presence-absence rather than density of this species. Consequently, some mapped areas support only light cover of HJG while other areas support comparatively dense cover.

Enhancement of this community will be achieved by a combination of the following broad actions:

- selective weed control of weedy pasture grasses during the non-growing season of HJG (as detailed in the Section 6; and
- annual slashing or brush-cutting of grass in these areas following seeding of HJG to stimulate recruitment of HJG.

Detailed management actions for the HJG outside of the Freshwater Wetland EEC are contained in Table 5.1 and should be read in conjunction with the translocation strategy for HJG in Section 5.9.3.

5.4.2 Existing Swamp Sclerophyll Forest EEC

The area of Swamp Sclerophyll Forest EEC occurs within the central portion of the Conservation Zone and is dominated by mature Broad-leaved Paperbarks (*Melaleuca quinquenervia*) and Swamp Oak (*Casuarina glauca*) (see Illustration 5.1). This patch of vegetation is approximately 0.3 ha in size.

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North

Conservation Zone Rehabilitation Strategy

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Management actions to enhance this community will consist of:

- weed control of priority weed species (as detailed in the Section 6); and
- supplementary plantings of species suitable for Swamp Sclerophyll Forest EEC revegetation in canopy gaps (refer to Section 5.6.2 for detailed revegetation methodology for this area).

Management actions to enhance the existing area of Swamp Sclerophyll Forest EEC are summarised in Table 5.1.

5.4.3 Existing Littoral Rainforest EEC

Littoral Rainforest is the most extensive forested vegetation community at the Pacific Pines site. Littoral Rainforest EEC occurs as two separate regrowth patches in the north-south corridor on the western side of the Conservation Zone, and covers an area of approximately 2.4 ha (Illustration 5.1).

The northern patch of littoral rainforest in the Conservation Zone is dominated by tall Guioa (*Guioa semiglauca*) and Camphor Laurel trees. A number of threatened rainforest flora species are present within this remnant, including Rough-shelled Bush Nut, Arrow-head Vine and Red Lilly Pilly. Although native species are present in moderate abundance within the lower strata, vegetation in this area generally lacks the diversity of rainforest remnants occurring elsewhere on the site.

Weeds species dominating this zone include Camphor Laurel, Governors Plum (*Flacourtia indica*), Umbrella Tree (*Schefflera actinophylla)* and Asparagus Fern (*Asparagus densiflorus*). A large amount of general rubbish is present towards the north of this zone.

The southern patch of littoral rainforest in the Conservation Zone comprises a relatively large area of forest centred along a drainage line / ephemeral stream that is dominated by Tuckeroo (*Cupaniopsis anacardioides*) and Guioa. A relatively diverse mixture of native species also occurs within the lower strata. Part of this drainage line, occurring along the southern portion of this patch, provides habitat for the endangered species, Square-stemmed Spike Rush.

Numerous weed species are present within the area including Camphor Laurel saplings, Orange Jessamine (*Murraya paniculata*), Umbrella Tree and Tropical Soda Apple (*Solanum viarum*).

Enhancement of this community will be achieved by a combination of the following broad actions:

- weed control of all woody and herbaceous weeds and vines within the two patches of Littoral Rainforest EEC (as detailed in the Section 6); and
- supplementary plantings of suitable species within canopy gaps of these regrowth patches (plantings will also target gaps created by the staged removal of Camphor Laurel) (refer to Section 5.6.1 for detailed revegetation methodology for this area).

Management actions to enhance the existing area of Littoral rainforest EEC are summarised in Table 5.1.

5.4.4 Freshwater Wetland EEC rehabilitation (including enhancement of mapped HJG and SSSR within this EEC)

Freshwater Wetland EEC covers a relatively large area of approximately 4.4 ha in the central section of the Conservation Zone (Illustration 5.1). Existing vegetation within the Conservation Zone comprises a range of wetland habitats including reedland, sedgeland, areas of dense Swamp Ricegrass (*Leersis hexandra*) and substantial areas supporting HJG and SSSR.

Weed grasses are common in this community, with the most significant being Vasey Grass (*Paspalum urvillei*) and Pigeon Grass (*Setaria sphacelata*). A primary risk associated with the ongoing viability of the Freshwater Wetland EEC vegetation relates to removal of cattle and the probable proliferation of these exotic grasses once grazing has ceased.

Rehabilitation of the Freshwater Wetland EEC will be achieved by a combination of the following actions:

- selective weed control of weedy pasture grasses (Vasey Grass, Pigeon Grass and Kikuyu) during late winter (non-growing season of HJG) (as detailed in the Section 6: *Weed Management Plan*);
- annual slashing or brush-cutting of grass in target areas supporting HJG and SSSR during the dormant period to stimulate threatened species seedling germination and vegetative spread (the effectiveness of this technique in enhancing SSSR populations should be trialled and monitored as detailed in Section 8).
- supplementary planting of suitable wetland species targeting areas that are not currently occupied by HJG or SSSR, and those areas in which weed treatment has occurred, and/ or where the overall diversity of wetland plants is low.

Biomass reduction enhancement areas for existing areas of HJG and SSSR will be located adjacent and within 25 m of proposed HJG and SSSR translocation recipient sites. The extent of these areas will be initially marked by GPS by an ecologist for future relocation.

Benefits of locating enhancement areas in the manner described will mean that:

- areas are easier to locate;
- time taken for slashing / brushcutting is minimised; and
- managed areas of threatened species habitat are contiguous.

Management actions for rehabilitating the Freshwater Wetland EEC are contained in Table 5.1.

5.5 Management Actions for Conservation and Enhancement of Existing Communities and Threatened Species

A summary of management actions for the Conservation and Enhancement of existing communities and threatened species, as part of the rehabilitation strategy, is shown in Table 5.1.

Further detail on weed control, revegetation methodology and planting lists is provided in Section 6 and Section 5.6.

Table 5.1 Summary of Management Actions for the Conservation and Enhancement of Existing Communities and Threatened Species in the Conservation Zone

Area of Conservation Zone	*Number*	*Management Action*	*Timing*	*Detail*
Existing Swamp Sclerophyll Forest EEC	1	Weed Control	As soon as possible following adoption of EMP and CZMP	▪ staged treatment of Camphor Laurel. ▪ removal of potentially dangerous standing dead wood. ▪ removal of areas of Lantana.
	2	Revegetation	As soon as possible following adoption of EMP and CZMP	▪ supplementary planting of suitable species
	3	Maintenance	Ongoing until handover of land to council	▪ ongoing weed control
	4		Ongoing until handover of land to council	▪ replacement plantings (for losses)
Existing Swamp	5	Weed Control	As soon as	▪ treat weed shrubs focusing on

Area of Conservation Zone	*Number*	*Management Action*	*Timing*	*Detail*
Oak Forest EEC			possible following adoption of EMP and CZMP	Lantana, Winter Senna and Groundsel Bush. ▪ treat weed vines focusing on Coastal Morning Glory.
Existing Littoral Rainforest EEC	6	Weed Control	As soon as possible following adoption of EMP and CZMP	▪ eradicate exotic vine and understorey weeds, focusing on Tropical Soda Apple, Lantana, Governors Plum, Crofton Weed, Mistflower, Fishbone Fern, Asparagus Fern and Silver-leafed Desmodium. ▪ treat mature Camphor Laurel, African Olive and Orange Jessamine.
	7	Revegetation	As soon as possible following adoption of EMP and CZMP	▪ supplementary plantings of suitable species within canopy gaps of these regrowth patches (supplementary plantings will also target gaps created by the staged removal of Camphor Laurel).
	8	Maintenance	Ongoing until handover of land to council	▪ ongoing weed control
	9		Ongoing until handover of land to council	▪ replacement plantings (for losses)
Mapped HJG (outside of Freshwater Wetland EEC)	10	Weed Control	As soon as possible following adoption of EMP and CZMP	▪ treat weedy pasture grasses during the non-growing season of HJG.
	11	Biomass Reduction	Annually during June	▪ annual slashing or brush-cutting of grass in these areas following seeding of HJG to stimulate recruitment of HJG.
Freshwater Wetland EEC	12	Weed Control	As soon as possible following adoption of EMP and CZMP	▪ treat weedy pasture grasses during the non-growing season of HJG.
	13	Revegetation	Ongoing until handover of land to council	▪ supplementary planting of suitable wetland species targeting areas that are not currently occupied by HJG or SSSR.
	14	Maintenance	Ongoing until handover of land to council	▪ ongoing weed control
	15		Ongoing until handover of land to council	▪ replacement plantings (for losses)

Area of Conservation Zone	*Number*	*Management Action*	*Timing*	*Detail*
	16	Biomass Reduction	Annually during June	▪ annual slashing or brush-cutting of grass/wetland plants in target biomass reduction enhancement areas following seeding of HJG to stimulate recruitment of HJG.
	17		Annually during June Monitoring is ongoing until handover to council	▪ trial and monitor effectiveness of enhancing SSSR populations through biomass reduction.

5.6 Revegetation to Forested EECs

A primary aim of the rehabilitation strategy is to revegetate areas of the Conservation Zone with suitable species from relevant forested EECs to reproduce the vegetation patterns that are expected to have been present at the Pacific Pines site prior to clearing.

Areas suitable for revegetation to forested EECs within the Conservation Zone were identified on the following basis:

- areas not currently occupied by EECs (wetland or forested);
- areas not currently occupied, or only to a minor degree, by HJG and SSSR ('to a minor degree' was defined as being <10% cover);
- areas not identified as being suitable HJG or SSSR translocation recipient sites; and
- areas not currently occupied by existing water infrastructure (e.g. drainage channels).

Suitable revegetation areas cover approximately 4.3 ha of a total area of 14.07 ha, consisting of the following components:

- 0.1 ha of Swamp Sclerophyll Forest EEC;
- 0.3 ha of Swamp Oak Forest EEC;
- 3.3 ha of Littoral Rainforest EEC revegetation; and
- 0.6 ha of Littoral Rainforest EEC revegetation incorporating HJG.

The location of these areas is shown on Illustration 5.1.

Ecological and maintenance benefits of revegetating areas in the Conservation Zone include:

- forming larger, and more resilient areas of forested EECs,
- creating more diverse habitat for native fauna; and
- limiting maintenance requirements associated with slashing and brushcutting grass growth in the absence of cattle.

5.6.1 Revegetation to Littoral Rainforest EEC incorporating HJG

Suitable areas for revegetation to Littoral Rainforest EEC incorporating HJG are located in slightly elevated areas adjacent to existing areas of HJG, primarily on the southern side of the central section of the Conservation Zone and also north-west of the water quality treatment pond (refer to Illustration 5.1). Incorporation of HJG in this area of Littoral Rainforest EEC revegetation is intended to mimic one of the preferred natural habitats for this species on the periphery of rainforest, often near creeks and swamps (DECC 2005).

The layout of the revegetation will consist of dense clumped plantings of rainforest species interspersed with small open areas in which HJG is to be translocated. Centres of the clumped plantings are to be 10 m apart with a minimum 2 m gap between the edges of each clump. The edges of the revegetated area will expand as the vegetation matures, leading to an overall decrease in the open area. This layout will require the minimum level of maintenance by reducing light levels and thereby limiting the potential for weed establishment. Management of the HJG areas will follow the biomass reduction method outlined in Section 5.8.3. Slashing such an area is not practical due to the restricted open space and therefore brushcutting is the preferred grass reduction technique in this situation.

These areas were identified as suitable for revegetation to Littoral Rainforest EEC with HJG on the basis of having the habitat characteristics for both Littoral Rainforest EEC revegetation and HJG establishment.

Management actions for rehabilitating the Freshwater Wetland EEC are contained in Table 5.1.

5.6.2 Revegetation to Swamp Sclerophyll Forest EEC

Suitable areas for revegetation to Swamp Sclerophyll Forest EEC are located within the central section of the Conservation Zone and consist of an area to the west of the existing Swamp Sclerophyll Forest EEC and a broad island of land formed by constructed drainage channels east of the water quality control ponds (see Illustration 5.1).

These areas were identified on the basis of being located at mid elevation between existing areas of Swamp Oak Forest EEC (low elevation) and Littoral Rainforest EEC (slopes). Existing Swamp Sclerophyll Forest EEC in the central portion of the Conservation Zone also indicates the suitability of these areas for revegetation to this community.

5.6.3 Revegetation to Swamp Oak Forest EEC

Suitable areas for revegetation to Swamp Oak Forest EEC are centred on the western portion of the Conservation Zone at low elevation. This area is adjacent to substantial existing areas of Swamp Oak Forest EEC in Ballina Nature Reserve. Although not included as part of the Conservation Zone itself, the major constructed water infrastructure (water quality control ponds and associated channels) are also located in this area (refer to Illustration 5.1).

The suitability of these areas for revegetation to Swamp Oak Forest EEC was identified on the basis of being located at low elevation and in proximity to existing Swamp Oak Forest EEC in a similar situation in Ballina Nature Reserve.

5.6.4 Revegetation to Littoral Rainforest EEC

Suitable areas for revegetation to Littoral Rainforest EEC are located in a small area of the central section of the Conservation Zone on a slightly raised area of ground, as well as over the majority of the southern and northern sections (refer to Illustration 5.1) adjacent to existing patches of Littoral Rainforest EEC/ Camphor Laurel regrowth.

These areas were identified as suitable for revegetation to Littoral Rainforest EEC on the basis of being located on slightly elevated areas or mid-slopes and being in proximity to existing areas of Littoral Rainforest EEC.

5.7 Management Actions for Revegetation to Forested EECs

A summary of management actions for revegetation to forested EECs, as part of the rehabilitation strategy, is shown in Table 5.1.

Further detail on weed control is provided in Section 6. Methods for biomass reduction in HJG establishment areas are outlined in Section 5.8.3.

Table 5.2 Summary of Management Actions for Revegetation to Forested EECs in the Conservation Zone

Area of Conservation Zone	*Number*	*Management Action*	*Timing*	*Detail*
Revegetation to Swamp Sclerophyll Forest EEC	1	Weed Control	As soon as possible following adoption of EMP and CZMP	▪ preparatory spraying of grass and herbaceous weeds in planting zone
	2	Revegetation	As soon as possible following adoption of EMP and CZMP	▪ undertake plantings of suitable species
	3	Maintenance	Ongoing until handover of land to council	▪ ongoing weed control
	4		Ongoing until handover of land to council	▪ replacement plantings (for losses)
Revegetation to Swamp Oak Forest EEC	5	Weed Control	As soon as possible following adoption of EMP and CZMP	▪ preparatory spraying of grass and herbaceous weeds in planting zone
	6	Revegetation	As soon as possible following adoption of EMP and CZMP	▪ undertake plantings of suitable species
	7	Maintenance	Ongoing until handover of land to council	▪ ongoing weed control
	8		Ongoing until handover of land to council	▪ replacement plantings (for losses)
Revegetation to Littoral Rainforest EEC	9	Weed Control	As soon as possible following adoption of EMP and CZMP	▪ preparatory spraying of grass and herbaceous weeds in planting zone
	10	Revegetation	As soon as possible following adoption of EMP and CZMP	▪ undertake plantings of suitable species
	11	Maintenance	Ongoing until handover of land to council	▪ ongoing weed control
	12		Ongoing until handover of land to council	▪ replacement plantings (for losses)
Revegetation to Littoral Rainforest EEC incorporating HJG	13	Weed Control	As soon as possible following adoption of EMP and CZMP	▪ low slashing or brush-cutting of grass/wetland plants prior to hand broadcasting of HJG seed. ▪ preparatory spraying of grass and herbaceous weeds in planting zone of rainforest revegetation patches.
	14	Revegetation	As soon as possible	▪ undertake plantings of suitable

Area of Conservation Zone	*Number*	*Management Action*	*Timing*	*Detail*
			following adoption of EMP and CZMP	species in rainforest revegetation patches
	15		June in first year – 1 week after biomass reduction	▪ hand broadcast HJG seed in spaces between rainforest revegetation patches.
	16	Maintenance	Ongoing until handover of land to council	▪ ongoing weed control
	17		Annually in June	▪ annual slashing or brush-cutting of grass/wetland plants in target biomass reduction enhancement areas following seeding of HJG to stimulate recruitment of HJG.
	18		Ongoing until handover of land to council	▪ replacement plantings of tubestock (for losses)

5.8 Rehabilitation Plan for Freshwater Wetlands EEC

A rehabilitation plan for the area of Freshwater Wetlands EEC within the Conservation Zone (refer to Illustration 3.2) has been developed with the aims of reducing weed infestation, enhancing the vegetation quality, and ensuring the ongoing survival of HJG and SSSR.

The rehabilitation plan incorporates:

- weed control;
- enhancement of existing areas of HJG and SSSR;
- establishing new areas of HJG and SSSR; and
- revegetation of degraded areas.

These components are expanded on in Section 5.8.2 to Section 5.8.5.

5.8.1 Species Composition of the Freshwater Wetlands EEC

Freshwater Wetlands EEC covers 4.4 ha of the central section of the Conservation Zone. This area is dominated by a variety of wetland species including Bunchy Sedge (*Cyperus polystachyos*), a Spikerush (*Eleocharis equisetina*), River Club-rush (*Schoenoplectus validus*), Millet Swamp Millet (*Isachne globosa*) and Swamp Ricegrass (*Leersia hexandra*). The threatened species HJG and SSSR occur widely within the Conservation Zone but at a lower density.

5.8.2 Weed Species and Control

A variety of weed species are found within the Freshwater Wetlands EEC area, the most dominant of which are Vasey Grass (*Paspalum urvillei*), Pigeon Grass (*Setaria sphacelata* subsp. *sphacelata*) and Kikuyu (*Paspalum clandestinum*). Vasey Grass and Pigeon Grass are both relatively large upright clumping grass species. Control of these species will be achieved by either hand-pulling where possible to avoid potential damage to native wetland species, including HJG and SSSR. Where this is impractical, it is recommended that the control approach be to undertake careful targeted hand-spraying with herbicide of grass clumps using a knapsack coinciding with the dormant season of both threatened species in late winter.

Control of Kikuyu is impractical where they are mixed among native wetland species due to its low habit. In areas in which Kikuyu dominates and has formed a dense sward, some broad control with herbicide may be possible while avoiding overspray damage to native wetland species. The presence of HJG or SSSR in these swards should be established by an ecologist prior to spraying activities. Alternatively, as for the larger grass species, spraying should be timed to coincide with the dormant season of the threatened species in late winter.

Weed control activities are to be prioritised in areas supporting existing populations of HJG and SSSR.

Further detail of weed treatments is given in Section 6.

5.8.3 Enhancement of existing areas of HJG and SSSR

Two threatened species located within the Freshwater Wetlands EEC community are HJG and SSSR. These species are not dominant components of the community, based on cover within any given area. However, the total area occupied by one or both of these species is significant (3.1 ha out of a total size of the Conservation Zone of 14.07 ha).

HJG generally occurs on the periphery of the Freshwater Wetlands EEC or a short distance within the boundary, and also occurs in adjacent better drained areas upslope. SSSR is predominantly found within the boundary of the Freshwater Wetlands EEC in lower swampy areas, and in most cases does not co-occur with HJG. However, there are some minor areas in which there is overlap.

It has been surmised from establishment trials for HJG (Benwell 2012) that a restriction to the successful germination of HJG seed is related to competition by exotic pasture grasses. Management of HJG therefore centres on methods to limit some of this competition stress and therefore improve establishment and spread.

Enhancement is therefore achieved (in situations where stock have been excluded), by established areas of HJG being maintained and enhanced by annual slashing/ brushcutting (just after the seeding period – May or June). Benwell (2012) found that mean percent crown cover can increase from 6-15% in Year 1 to 40-90% in Year 2 under this annual grass reduction management regime.

Although no similar establishment trials have been undertaken for SSSR, the Recovery Plan for the species states that light grazing may provide both a seed dispersal mechanism and a disturbance regime suitable for the establishment of new seedlings. It may also prevent established plants from being eliminated by more competitive taller species (NPWS 1999). On this basis, it is also probable that active biomass removal by way of annual slashing/brushcutting as previously described for HJG may also prove successful in enhancing the establishment and spread of SSSR.

Undertaking such a management regime across all areas of HJG and SSSR in the Conservation Zone is likely to be time-consuming and potentially expensive. Therefore, a subset of areas has been selected within which slashing/ brushcutting is to be undertaken as previously specified in Section 5.4.4.

These areas are located adjacent to and within 25 m of proposed HJG and SSSR translocation recipient sites. The extent of these areas will be initially marked by GPS by an ecologist for future relocation.

Benefits of locating enhancement areas in the manner described is that:

- areas are easier to locate;
- time taken for slashing/ brushcutting is minimised; and
- managed areas of threatened species habitat are contiguous.

Brushcutting is the preferred technique where access is difficult for a standard tractor with slasher due to the presence of boggy ground.

5.8.4 Establishing new areas of HJG and SSSR

In order to enhance the viability of HJG and SSSR at the Pacific Pines site, existing populations of these species within the Conservation Zone will be supplemented by translocation into strategic recipient areas.

Recipient areas suitable for establishing new populations of HJG and SSSR were identified as part of habitat mapping of the Conservation Zone (Illustration 5.2). Full details of establishment of HJG and SSSR in the Conservation Zone are provided in Section 5.9.

5.8.5 Supplementary Plantings in Degraded Areas

Degraded areas of Freshwater Wetlands EEC that have significant infestation of weeds will be targeted for revegetation. In these areas supplementary plantings of species will be undertaken with the aim of discouraging future weed infestations, improving native plant cover and enhancing native species composition. At a minimum it is recommended that 0.5 ha be targeted for revegetation.

5.9 Translocation Plans for Hairy Joint Grass and Square-stemmed Spike Rush

5.9.1 Overview

This section details a strategy for translocation of HJG and SSSR from impacted areas of the site to within the Conservation Zone and recommendations on the subsequent monitoring and reporting of the success of the translocations.

The strategies outlined in the Plan are in accordance with the relevant Australian guidelines for undertaking translocation: *Guidelines for the Translocation of Threatened Plants in Australia* (Vallee *et al*. 2004).

The primary objectives of the translocation strategy are to:

- summarise existing information relevant to the translocation of the subject species;
- provide clear and concise guidance on the best methods to undertake successful translocation of the subject species;
- provide guidance on the procedures required for the successful removal and/or propagation of designated areas of the subject species from the proposed area of disturbance and subsequent establishment at an appropriate recipient site;
- determine suitable milestones during the process;
- provide clear and concise procedures to be implemented relating to ongoing maintenance of the subject translocated / propagated specimens; and
- develops simple and practical monitoring programme for the subject specimens that will aid in the overall success of the translocation process.

5.9.2 Definitions

Donor Site	site from which transplanted specimen is removed
Gene Pool	the sum of all genes possessed by the individuals of a population
Photo-point Monitoring	monitoring the progress of translocated specimens by comparing photographs taken over time at pre-determined locations
Propagation	to reproduce by asexual means such as cuttings, layering, grafting, or tissue culture, or less commonly by sexual means
Recipient Site	the site at which transplanted specimen are established

Translocation 'the deliberate transfer of plants or regenerative plant material from an ex situ collection or natural population to a location in the wild, including existing or new sites or those where the taxon is locally extinct' (Vallee *et al*. 2004)

5.9.3 Translocation of Hairy Joint Grass (HJG)

Previous Translocation of HJG

Recent experimental translocation of this species for the Ballina Bypass Pacific Highway Upgrade has been successful in establishing a new sub-population of HJG using seed and propagated seedlings (Benwell 2011; 2012). The final results of this trial (Benwell 2012) indicate that, in situations where grazing stock is excluded:

- low slashing of the translocation area immediately before seeding / planting allows a reduction in competition between the emerging HJG seedlings and other pasture species;
- direct seeding of HJG is the most effective establishment method, compared with planting seedlings (seeding occurred in June);
- HJG establishment was promoted by pasture disturbance consisting of slashing or slashing with mulch removal and to a lesser degree by herbicide spraying treatments;
- slashing then removal of mulch is not significantly more successful compared with slashing alone in promoting HJG establishment (however, this may not be the case in areas that have a heavy weedy groundcover that when slashed produces a dense layer of mulch that will need to break down later in the season in order for HJG seedlings to germinate); and
- established areas of HJG can be maintained and enhanced by annual slashing (just after the seeding period – May or June), and mean percent crown cover increased from 6-15% in Year 1 to 40-90% in Year 2 with annual slashing.

Plate 5.1 Hairy Joint-grass at the Pacific Pines Site (October, 2011)

Translocation Methodology

Recipient areas suitable for establishing new populations of HJG were identified as part of habitat mapping of the Conservation Zone (refer to Section 5.3 and Illustration 5.2).

The proposed methodology for the translocation of HJG is based on methods employed successfully by Ecos Environmental (Benwell 2012) as part of experimental translocation of this species for the Ballina Bypass Pacific Highway upgrade project.

This proposed methodology is based around:

- seed collection;
- appropriate preparation of recipient sites;
- direct seeding;
- ongoing management of the recipient site; and
- monitoring

Donor and Recipient Sites

As the proposed methodology for translocation of this species consists of seed collection, the donor site is considered to be all areas of HJG occurring on the site, as mapped by GeoLINK in 2011-2012 and shown in Illustration 3.2.

While it is envisaged that sufficient seed will be able to be collected from the site, if additional seed is required, collection from nearby areas within 5 km of the site will be investigated further in consultation with OEH.

The proposed recipient sites are contained within the designated Conservation Zone occurring within the approved Pacific Pines Estate.

The main selection criteria for the recipient sites are:

- the Conservation Zone is a designated area for the enhancement and conservation of threatened flora species occurring on the site;
- it is known habitat for this species;
- it will be secure in terms of tenure as part of the development; and
- management of threatened species / habitat occurring within the Conservation Zone is ensured under the over-arching Environmental Management Plans for the site.

Potential HJG recipient sites within the Conservation Zone were determined to display some or all of the following characteristics:

- existing cover of HJG <10%;
- on the margin of, or just within the margin of, Freshwater Wetland EEC; and/or
- on a lower slope around or within a soak.

Significant areas within the Conservation Zone were ruled out as recipient sites on the following basis:

- most of the core area of Freshwater Wetland EEC;
- existing areas already dominated by HJG or SSSR (greater than 10% cover of either);
- Swamp Sclerophyll Forest EEC; or
- more suitable to be replanted to a forested EEC.

HJG recipient sites to be reseeded are shown in Illustration 5.2. The total area is 1.33 ha.

Site Preparation

The following strategies are proposed for the preparation of the recipient site:

- recipient sites are to be marked out prior to translocation occurring;
- noxious and environmental weeds are to be eradicated prior to translocation being undertaken (refer to Section 6);
- one week prior to direct seeding occurring, the recipient site is to be slashed or manually brush cut (in areas difficult to access), grass is to be cut as low as possible; and
- if substantial mulch is generated by this activity, mulch is to be removed from the recipient sites.

Seed Collection

Seed will be collected from the site between April and May and stored in paper bags in a dry cool place until the time of planting. Seed collection is to be undertaken by a suitably qualified ecologist under a Section 132C Licence issued by OEH for the activity.

Direct Seeding

Direct seeding is to be carried out in winter (June) to mimic the natural cycle of seed dispersal and recruitment in wild populations of HJG. Seed is to be mixed with river sand at the ratio of 5 grams to 20 litres of river sand and spread over target recipient sites.

Post-translocation Maintenance

The results of translocation trials for this species (Benwell 2012) have indicated that HJG seedling recruitment is enhanced by biomass reduction. Therefore, post-translocation maintenance of recipient sites will consist of a single annual slashing event aimed at reducing pasture biomass and creating spaces in the ground layer to assist in seed germination. This will occur in June once seeding of HJG has finished. Details of the monitoring of both the recipient site and translocated plants are outlined in Section 8.

Information shown is for illustrative purposes only

Drawn by: TJP Checked by: MVE Reviewed by: RVI Date: September 2012
Source of base data: Ballina Shire Council

North

0 100

Location of Threatened Species Recipient Sites

GeoLINK environmental management and design

Environmental Management Plan: Pacific Pines
1675-1045

Illustration 5.2

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5.9.4 Timing of Translocation Process

A schedule for the timing of the translocation process is provided in Table 5.3. The schedule may require reconfiguring if there are any delays in this process.

Table 5.3 Timing of Translocation Process

Action	***Timing***	***Personnel Responsible***
Weed control in areas supporting HJG	Commencing upon approval of Environmental Management Plans – ongoing (refer to Weed Management Plan and Section 6)	Developer
Seed collection	April-May	Ecologist
Pegging out recipient site	Prior to slashing and seeding	Ecologist
Slashing of recipient site	June (first 2 weeks)	Developer
Direct seeding	June (last 2 weeks)	Ecologist
Monitoring and reporting to OEH	Annually	Ecologist

5.9.5 Translocation Project Monitoring

Ongoing monitoring to be undertaken for the translocation project is detailed in Section 8.

Ongoing maintenance and management of the recipient sites and translocated plants will be vital to the success of the translocation project. Accordingly, an ongoing monitoring program will be instigated to track the condition of the recipient site and individual translocated plants. Results of the monitoring programme will lead to adaptive management responses if required.

The maintenance and monitoring program for the translocated plants will incorporate actions that are largely derived from recommendations for monitoring in Guidelines for the Translocation of Threatened Plants in Australia (Vallee *et al* 2004). Once established in recipient sites, HJG and SSSR will be maintained in the same manner as existing enhancement of existing HJG and SSSR (via annual biomass removal and weed control) as detailed in Section 5.8.3. Annual results of the monitoring program will be reported to OEH.

5.9.6 Contingency Measures

In the case that the compensatory works to offset the loss of Freshwater Wetlands EEC, HJG and SSSR across the site are unsuccessful, a number of contingency measures will be undertaken as mitigation. The following sections detail the procedure that will be used to determine the success of the compensatory works and the proposed contingency measures.

Measuring Success of Compensatory Works

Establishing whether or not the compensatory works have been successful will rely on effective monitoring. Full details of monitoring methods that will be used are provided in Section 8.

Regarding Freshwater Wetlands EEC, Part 4 of Condition B2 requires the development of a rehabilitation plan that details the manner in which the functions and values of the Freshwater Wetlands EEC will be restored. Indicators of success for the restoration of functions and values of this community are:

1. *A reduction in weed cover;*
2. *Proven enhancement of HJG and SSSR;*
3. *Proven establishment of HJG and SSSR; and*
4. *No substantial changes in the boundary of the Freshwater Wetlands EEC that cannot be accounted for by seasonal variation (potentially indicating a change in hydrology).*

Points 2 and 3 are also relevant to the success of compensatory works relating to HJG and SSSR.

Monitoring techniques to measure the success of these indicators are:

- *A reduction in weed cover* – weed cover in the Conservation Zone will be monitored within quadrats / transects. Any opportunistic observations of weeds that are located outside of specific quadrat / transects will be recorded to inform a 'priority weed map' for the Conservation Zone. The extent of these weed infestations will be recorded with a hand-held GPS unit. A simple map showing the locations of priority weeds will be prepared for each monitoring report. This map will be provided to weed control contractors to inform future weed control works. A significant increase in weed burden within the Freshwater Wetland EEC area would be considered to indicate unsuccessful rehabilitation.
- *Proven enhancement of HJG and SSSR* – conduct an annual survey and mapping of the distribution of HJG and SSSR to establish changes in distribution of these species and intensive quadrat-based surveys at selected sites. A decrease of >20% in the presence of either of these species within their respective habitat area would be considered to be unsuccessful enhancement.
- *Proven establishment of HJG and SSSR* – recipient sites in which HJG or SSSR have been translocated are to be monitored within quadrats to record the success of the translocation. The distributions of these threatened species across seasons are variable depending on environmental conditions, particularly for HJG. To account for some of this variability, success or failure will be based on a significant deviation from a baseline vegetative cover (decrease of >20%). This baseline vegetative cover will be measured at 12 months following the translocation event.
- No substantial changes in the boundary of the Freshwater Wetlands EEC that cannot be accounted for by seasonal variation (potentially indicating a change in hydrology) – transect surveys will be used to detect potential changes in the boundary of the Freshwater Wetland EEC in the Conservation Zone. The boundary of this community is expected to fluctuate somewhat depending on climatic variability, however; it should be possible to attribute any substantial change in the location of the boundary of this community to climatic conditions or to a change in hydrology.

Adaptive Management

Results of monitoring will provide the opportunity to modify management techniques regularly where necessary to ensure greatest likelihood of the compensatory works being successful.

If it is shown through monitoring that any of above indicators are at risk of not being met, a modification to vegetation management techniques will be implemented. This modification may include, but is not limited to:

- revision of weed control techniques;
- re-assessment of the timing, extent and technique of biomass control for HJG and SSSR; or
- re-establishment of additional HJG and SSSR in poorly performing areas.

Retention of Genetic Material

As a precaution against loss of genetic diversity if the compensatory measures for HJG and / or SSSR should prove to be unsuccessful, a program of seed collection and propagation for these species will be undertaken so that re-establishment on-site or off-site is possible if required.

The seed of HJG retains adequate viability for up to 3 years (Andrew Benwell pers. comm.). To use the precautionary principle, seed would be collected from across the site prior to construction beginning, and from within the Conservation Zone annually following this, and placed in cool storage.

Little information is known on the ecology or germination of SSSR. However, it has been established that propagation is successful by way of division (Greg Elks pers. comm.). Therefore, prior to construction occurring at the Pacific Pines site, SSSR will be salvaged and clumps divided and grown up at an appropriate nursery with experience growing native wetland plants. As these plants mature they will be able to be further divided.

Research Opportunities to Investigate the Ecology and Translocation of SSSR

If it is established that the compensatory works have been unsuccessful, it is proposed that a compensatory measure be established to undertake research into the ecology, enhancement and translocation of HJG. This research would provide valuable information for future projects involving this species.

The methodology and scope of such a project would build that undertaken to investigate translocation of HJG for the Ballina Bypass Highway Upgrade Project (Benwell 2012) (see Appendix A).

This research extended over two years and included:

- genetic research to determine the extent of genetic variation among populations; eExperimental translocation to establish a new population and research the effect of site factors and follow-up management on establishment and persistence; and
- management of an existing population, including maintenance of habitat conditions favourable for recruitment.

The opportunity exists to engage a local university such as Southern Cross University or Griffith University to undertake this research, potentially as part of a research higher degree.

5.10 Revegetation Approach

A primary aim of the rehabilitation strategy is to revegetate areas of the Conservation Zone with suitable species from relevant forested EECs to reproduce the vegetation patterns that are expected to have been present at the Pacific Pines site prior to clearing.

Revegetation will also occur as supplementary plantings within existing forested EEC areas and supplementary plantings within the Freshwater Wetland EEC, including translocation of HJG and SSSR into recipient sites. Therefore the components of the revegetation approach for the Conservation Zone consist of:

- revegetation to forested EECs;
- supplementary plantings in existing forested EECs; and
- supplementary plantings in Freshwater Wetlands EEC.

This revegetation approach aims to create a mosaic of forested, grassland and wetland habitats for the purpose of protecting threatened species and communities and providing habitat for a range of native fauna.

Revegetation method, plant lists, maintenance and monitoring are each detailed in the following sections.

5.10.1 Revegetation Method

The following subsections detail the broad methods to be used for revegetation within forested EECs (both supplementary plantings and revegetation) and Freshwater Wetlands EEC (supplementary plantings).

Supplementary Plantings within Forested EECs

Supplementary plantings of species within forested EECs will be targeted into areas that are susceptible to weed infiltration. These areas consist of either existing canopy gaps, gaps created by weed control activities (particularly the removal of mature woody weeds). The aims of undertaking these supplementary plantings within forested EECs are to:

- improve the diversity and integrity of the constituent native vegetation;
- form a buffer for threatened species (within Littoral Rainforest EEC areas); and
- reduce ongoing weed maintenance by reducing light levels.

Table 5.4 details the methodology and timing for undertaking supplementary plantings within forested EECs and revegetation for the purpose of recreating forested EECs.

Table 5.4 Actions and Timing for Supplementary Plantings/ Revegetation of Forested EECs

Number	*Action*	*Methodology*	*Timing*
Site Preparation			
1	Site Selection	Suitable areas for supplementary plantings shall be determined by a suitably qualified ecologist or bush regenerator. Areas selected are to be marked by flagging tape or pegs.	Immediately prior to preparatory weed control.
2	Weed Control	All noxious weeds shall be managed in accordance with the relevant legal requirements for the far North Coast County Council weed control area and control methods shall follow Section 6.6.	Ongoing until handover to Council according to the schedule in
3	Weed Control	Treat groundcover weeds (grass and herbaceous weeds) with a glyphosate-based herbicide. Herbicides such as Roundup Biactive®, Weedmaster® Duo are recommended for use in proximity to waterways or wetland areas. ▪ The area to be free of weeds consists of a minimum 50 cm diameter around each location to receive tubestock. ▪ Ensure that the area to be sprayed does not support HJG.	Prior to planting – ensuring enough time (minimum 2 weeks) has elapsed for the herbicide to take full effect.
Planting			
4	Ground preparation	▪ The planting hole should be prepared by loosening the soil to at least twice the depth of the plant tube. ▪ 100-150 grams of slow-release fertiliser suitable for native plants with appropriate low phosphorus levels should be added to each planting hole to assist in plant establishment.	Immediately prior to planting and fertilising.
5	Planting	▪ Planting of suitable species is to be undertaken according to the species in Table 5.6 at the densities specified. ▪ Planting is to be carried out when soil moisture is high – either in the second half of summer or autumn, or following a substantial rainfall event in excess of 50 mm.	Late summer or autumn or alternatively following a substantial rainfall event of 50 mm or more.
6	Watering	Water plants during and after planting. At least 5 litres of water should be allowed per plant to settle soil and provide moisture for establishment.	Immediately following planting and prior to mulching.
7	Mulching	▪ Apply weed-free organic mulch to bare areas to limit weed regrowth. ▪ Replenish mulch around each plant (each spring)	Mulching would continue until handover to Council.

Number	Action	Methodology	Timing
8	Installation of tree guards	Immediately after planting and mulching	Immediately following planting and mulching
Maintenance			
9	Watering	▪ Water plants during and after planting. At least 5 litres of water should be allowed per plant to settle soil and provide moisture for establishment. ▪ Watch closely for early signs of wilting and rewater the trees at approximately weekly intervals until good rain has occurred	Watering should not be necessary after 2 months and / or a reasonable wet season
10	Weed Control	▪ Keep the planting areas free of weeds (treatment methods as specified in Section 6.6. Recommend a glyphosate-based herbicide to treat generic grass and herbaceous weed regrowth). ▪ Herbicides such as Roundup Biactive®, Weedmaster® Duo are recommended for use in proximity to waterways or wetland areas.	Quarterly for the first 24 months and every 6 months following this once established and until handover to Council (as part of the standard weed control for the site that will be undertaken – Section 6 and WMP of the EMP). Regular monitoring of weeds as per Section 8 to be undertaken, with the results of weed monitoring to be incorporated into routine weed control activities.
11	Replanting and Replacing Tree Guards	▪ Replant to replace for losses where more than 10% of plants have perished. ▪ Use planting methods above and refer to the plant lists which follow. ▪ Straighten or replace tree guards that have become detached or which have been damaged.	Ongoing until handover to Council.
12	Monitoring and reporting	As prescribed in Section 8	▪ As part of the annual monitoring report provided to OEH. ▪ A report would also be provided to Council on handover.

Note: a number of the measures in this table are sourced from 'Bush Regeneration – Recovering Australian Landscapes' (Buchanan 1994)

Supplementary Plantings within Freshwater Wetlands EEC

Supplementary plantings of species within the area of the Conservation Zone supporting Freshwater Wetlands EEC will be targeted into areas that are degraded and have significant weed infestation. The aims of undertaking these supplementary plantings are to:

- discourage future weed infestations;
- improve native plant cover; and
- enhance native species composition.

The methodology for undertaking supplementary plantings within Freshwater Wetlands EEC is distinct from that for revegetation within forested EECs and therefore is specified separately in Table 5.5.

Table 5.5 Actions and Timing for Supplementary Plantings in Freshwater Wetlands EEC

Number	*Action*	*Methodology*	*Timing*
Site Preparation			
1	Site Selection	Suitable areas for supplementary plantings shall be determined by a suitably qualified ecologist or bush regenerator. Areas selected are to be marked by flagging tape or pegs.	Immediately prior to preparatory weed control.
2	Weed Control	All noxious weeds shall be managed in accordance with the relevant legal requirements for the far North Coast County Council weed control area and control methods shall follow Section 6.6.	Ongoing until handover to Council according to the schedule in
3	Weed Control	Hand-weed areas to be replanted. If herbicide-based control is necessary, use an approved herbicide that has a low impact on waterways and wetlands such as Roundup Biactive®, Weedmaster® Duo. Due to the relatively small size of the wetland plants to be planted, the area to be free of weeds consists of a minimum 25 cm diameter around each location to receive tubestock. ▪ Ensure that the area to be planted do not support existing populations of HJG or SSSR.	Prior to planting – ensuring enough time (minimum 2 weeks) has elapsed for any herbicide used to take full effect.
Planting			
4	Planting	▪ Planting of suitable species is to be undertaken according to the species in Table 5.6 at the densities specified. ▪ In areas of standing water, ensure that roots are firmly rooted in the soil beneath the water surface. In drier areas hand dig a small hole to plant into. ▪ Planting is to be carried out when soil moisture is adequate and not during the dry spring period. ▪ No fertiliser is to be added to plant holes as this could adversely effect on the nutrient balance of the wetland and encourage weed growth.	Any time of year excluding the dry spring period.
5	Mulching	Apply weed-free organic tea-tree mulch to bare areas to limit weed regrowth.	Annually

Number	Action	Methodology	Timing
6	Installation of Plant Protection	For smaller plants it may be necessary to net over the planted area to discourage water birds from ripping the plants out.	Immediately following planting
Maintenance			
7	Weed Control	▪ Keep the planting areas free of weeds (treatment methods as specified in Section 6.6. for noxious and environmental weeds. ▪ Hand-weed where possible and where not use an approved herbicide that has a low impact on waterways and wetlands such as Roundup Biactive®, Weedmaster® Duo.	Quarterly for the first 24 months and every 6 months following this once established and until handover to Council (as part of the standard weed control for the site that will be undertaken – Section 6 and WMP of the EMP). Regular monitoring of weeds as per Section 8 to be undertaken, with the results of weed monitoring to be incorporated into routine weed control activities.
8	Replanting	▪ Replant to replace for losses where more than 10% of plants have perished. ▪ Use planting methods above and refer to the plant lists which follow.	Ongoing until handover to Council.
9	Mulch	Apply weed-free organic mulch to bare areas	Annually
10	Monitoring and reporting	As prescribed in Section 8	▪ As part of the annual monitoring report provided to OEH. ▪ A report would also be provided to Council on handover.

5.10.2 Species Selection

Species Selection

Plants are to be sourced from local, licensed nurseries to avoid planting stock with inadequate genetic diversity. Plants will have local provenance from seed sourced from natural wild populations as close as possible to the site. Plants will be supplied as tubestock that is healthy, sun-hardened and not root-bound.

Planting densities were determined on the following basis:

- Littoral Rainforest EEC planting density was determined according to the suggested spacing of plants in the manual "*Subtropical Rainforest Restoration*" produced by the Big Scrub Rainforest Landcare Group [BSRLG] (2005). An average density for rainforest plantings of 2.5 m was selected, which is in the middle of the range of 1.5 – 4 m suggested in the BSRLG guidelines.
- Littoral Rainforest EEC incorporating HJG is to be planted at the same density as that specified for Littoral Rainforest. The overall density of the entire revegetated area will be lower, because the HJG areas between the planted patches of vegetation effectively lower the overall density.

- Swamp Oak Forest EEC and Swamp Sclerophyll Forest EEC planting density was determined to be 4 m, less than that for Littoral Rainforest EEC, reflecting the more open nature of these communities.
- Freshwater Wetlands planting density reflects the dense nature of wetland vegetation and was determined to be 1 m.

Species lists and planting densities for each community to be revegetated is provided in Table 5.6.

Table 5.6 Species List for each Community to be Revegetated and density of Plantings

Community		
Common Name	***Scientific Name***	***Number Of Plants / Planting Area***
Littoral Rainforest EEC (and Littoral Rainforest EEC incorporating HJG)		
Beach Acronychia	*Acronychia imperforata*	300
Beach Bird's Eye	*Alectryon coreaceus*	300
Black Wood	*Acacia melanoxylon*	240
Blue Lilly Pilly	*Syzygium oleosum*	300
Brown Kurrajong	*Commersonia bartramia*	480
Celery Wood	*Polyscias elegans*	300
Foambark	*Jagera pseudorhus*	300
Guioa	*Guioa semiglauca*	600
Hairy Walnut	*Endiandra pubens*	300
Large Mock Olive	*Notelaea longifolia*	300
Red Kamala	*Mallotus phillipensis*	480
Riberry	*Syzygium leuhmannii*	300
Scentless Rosewood	*Synoum glandulosum*	300
Three-Veined Cryptocarya	*Cryptocarya triplinervis* var. *triplinervis*	600
Tuckeroo	*Cupaniopsis anacardiodes*	600
Umbrella Cheese Tree	*Glochidion sumatranum*	480
White Bean	*Ailanthus triphysa*	300
		5940 (3.3 ha) within Littoral Rainforest EEC revegetation areas and 540 (0.6 ha) within areas incorporating HJG = 6480 in Total
Swamp Oak Forest EEC		
Swamp Oak	*Casuarina glauca*	60
Umbrella Cheese Tree	*Glochidion sumatranum*	40
Cheese Tree	*Glochidion ferdinandi*	20
Broad-leaved Paperbark	*Melaleuca quinquenervia*	10
Red Ash	*Alphitonia excelsa*	30
Tuckeroo	*Cupaniopsis anacardioides*	20
		180 (0.3 ha)
Swamp Sclerophyll Forest EEC		
Pink-flowered Doughwood	*Melicope elleryana*	8
Umbrella Cheese Tree	*Glochidion sumatranum*	6
Swamp Oak	*Casuarina glauca*	6
Small-leaved Fig	*Ficus obliqua*	4
Blackwood	*Acacia melanoxylon*	4

Community		
Common Name	***Scientific Name***	***Number Of Plants / Planting Area***
Brush Ironbark Wattle	*Acacia disparrima*	4
Swamp Turpentine	*Lophostemon suaveolens*	4
Willow Bottlebrush	*Callistemon salignus*	4
Broad-leaved Paperbark	*Melaleuca quinquenervia*	20
		60 (0.1 ha)
Freshwater Wetlands EEC		
Soft Twigrush	*Baumea rubiginosa*	800
Bunchy Sedge	*Cyperus polystachyos*	800
a Spikerush	*Eleocharis equisetina*	800
Red-fruit Saw-sedge	*Gahnia sieberiana*	100
Juncus	*Juncus usitatis*	100
Frogsmouth	*Philydrum lanuginosum*	400
Restio	*Restio tetraphullus* subsp. *meiostachyus*	700
River Club-rush	*Schoenoplectus validus*	700
A Rush	*Schoenus brevifolius*	700
		5000 (0.5 ha)

5.11 Summary of EEC Establishment

Over time, as the areas of revegetation establish and mature, the total area of EECs across the Pacific Pines site will be increased. The area of existing EEC in the Conservation Zone and the extra established areas are summarised in Table 5.7.

Table 5.7 Summary of EECs Retained and Established within the Conservation Zone

EEC	***Existing area within the Conservation Zone (ha)***	***Additional area established by revegetation (ha)***
Littoral Rainforest	2.4	3.9
Swamp Sclerophyll Forest EEC	0.3	0.1
Swamp Oak Forest EEC	0.0	0.3
Freshwater Wetland EEC	4.4	0

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6

Weed Management Strategy

6.1 Aim and Introduction

This weed management strategy provides an overview of weed infestation in the Conservation Zone and details treatment approaches to minimise the negative impacts of weeds on the ecological values of this area. The primary aims of this strategy are to:

- control declared noxious weeds;
- minimise the extent of environmental weed infestation in existing areas of native vegetation;
- create a weed-free area prior to revegetation; and
- minimise negative impacts of weed grasses on HJG and SSSR recovery and establishment.

A detailed weed survey of the entire site was conducted by a GeoLINK ecologist in spring 2011. Significant weed species recorded during this survey in the Conservation Zone are listed in Table 6.1.

Table 6.1 Significant Weed Species in the Conservation Zone

Family	***Scientific Name***	***Common Name***
Asteraceae	*Ageratina adenophora*	Crofton Weed
Asteraceae	*Ageratina riparia*	Mistflower
Asparagaceae	*Asparagus aethiopicus*	Asparagus Fern
Asteraceae	*Baccharis halimifolia*	Groundsel Bush
Lauraceae	*Cinnamomum camphora*	Camphor Laurel
Fabaceae	*Desmodium uncinatum*	Silver-leaved Desmodium
Saliaceae	*Flacourtia indica*	Governors Plum
Convolvulaceae.	*Ipomoea cairica*	Coastal Morning Glory
Poaceae	*Kikuyu clandestinum*	Kikuyu
Verbenaceae	*Lantana camara*	Lantana
Rutaceae	*Murraya paniculata*	Orange Jessamine
Haloragaceae	*Myriophyllum aquaticum*	Parrots Feather
Davalliaceae	*Nephrolepis cordifolia*	Fishbone Fern
Oleaceae.	*Olea europaea subspecies cuspidata*	African Olive
Commelinaceae	*Tradescantia fluminensis*	Wandering Jew
Poaceae	*Paspalum urvillei*	Vasey Grass
Fabaceae (Caesalpinioideae)	*Senna pendula var. glabrata*	Winter Senna
Poaceae	*Setaria sphacelata*	South African Pigeon Grass
Solanaceae	*Solanum mauritianum*	Wild Tobacco Bush
Solanaceae	*Solanum viarum*	Tropical Soda Apple
Solanaceae	*Solanum seaforthianum*	Climbing Nightshade

Weeds are classed into broad groups depending on their characteristics and potential impacts. The main groups of weeds are:

- Noxious Weeds (as listed under the *Noxious Weeds Act 1993*).
- Weeds of National Significance (WoNS).
- National Environmental Alert List Weeds.

- Environmental Weeds.
- Agricultural Weeds.

6.2 Noxious Weeds

Noxious weeds declared under the *Noxious Weeds Act 1993* are required by law to be controlled by all landholders within a given control area. Five listed 'noxious weed' species listed under the Ballina Control Area (NSW DPI 2011) were detected at the site. One of these species, Lantana is also listed as a 'Weed of National Significance'.

No listed 'National Environmental Alert List Weeds' were detected in the Conservation Zone. Noxious Weeds/ WoNS and relevant control requirements are listed in Table 6.2.

Table 6.2 Noxious Weeds in the Conservation Zone with Control Requirements

Scientific Name	***Common Name***	***Listing***	***Control Requirements***
Ageratina adenophora	Crofton Weed	N4	The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority.
Baccharis halimifolia	Groundsel Bush	N3	The plant must be fully and continuously suppressed and destroyed.
Cinnamomum camphora	Camphor laurel	N4	As for other N4 weeds.
Lantana camara	Lantana	N4, WONS	As for other N4 weeds.
Solanum viarum	Tropical Soda Apple	N2	The plant must be eradicated from the land and the land must be kept free of the plant. The weeds are also "notifiable" and a range of restrictions on their sale and movement exist.

6.3 Agricultural and Environmental Weeds

A variety of weed species that are not listed under the Noxious Weeds Act but are considered to be environmental or agricultural weeds were identified at the site. Occurrences of such species are summarised as follows:

- A number of infestations of Governors Plum (*Flacourtia indica*) are located in the lower stratum of littoral rainforest remnants occurring at the site. This species appears to proliferating at the site and should be a control priority.
- Occurrences of Asparagus Fern (*Asparagus aethiopicus*) and Silver-leaved Desmodium (*Desmodium uncinatum*) are present within the understorey of littoral rainforest remnants. These species are expected to proliferate after the exclusion of cattle.
- Infestations of Coastal Morning Glory (*Ipomoea cairica*) and Climbing Nightshade (*Solanum seaforthianum*) are present within areas of Swamp Oak (*Casuarina glauca*) forest. Dense infestations of woody weeds including Lantana, Groundsel Bush, Wild Tobacco Bush (*Solanum mauritianum*) and Winter Senna (*Senna pendula var. glabrata*) are also present.
- Occurrences of Vasey Grass (*Paspalum urvillei*) and Pigeon Grass (*Setaria sphacelata*) are present around the fringes of the freshwater wetland. These species are expected to proliferate after the exclusion of cattle from the site and have the potential to out-compete the threatened species, Hairy Jointgrass (*Arthraxon hispidus*) and Square-stemmed Spike Rush (*Eleocharis tetraquetra*) which occur within the Conservation Zone.

6.4 Aquatic Weeds

A number of aquatic weeds were detected within drainage lines and in the water quality control ponds which are surrounded by the Conservation Zone. There is a risk that these aquatic weeds may proliferate during favourable conditions. At the time of survey (spring 2011), the dominant aquatic weed species recorded were Parrots Feather (*Myriophyllum aquaticum*) within drainage channels associated with the site and Cape Water Lily (*Nymphaea caurulea*) within the water quality control ponds.

The water control ponds at the site are known to have regular infestations of Cape Water Lily and Hairy Commelina (*Commelina benghalensisi*), which require removal to maintain the functioning of the ponds.

6.5 Potential Weed Impacts

6.5.1 General Impacts

The principle mechanisms for weeds establishing in areas associated with developments include:

- elevated nutrients entering natural environments from stormwater run-off;
- physical disturbance to the soil from the general construction process;
- increased soil moisture from shading / reduced water infiltration;
- increased light at the margins of vegetation;
- disposal of garden waste into natural environments; and
- planting of invasive plants in new gardens.

Additionally, the removal of cattle from the site may favour the proliferation of certain weed species, particularly in areas of vegetation to be retained at the site and open areas, including within the designated Conservation Zone.

6.5.2 Impacts During Construction

The construction phase of the project represents a high risk period for the spread and proliferation of weeds at the site. Key risks related to the spread of weeds during this stage of the project are:

- spread of weeds to / from the site or throughout the site by plant and machinery;
- weeds proliferating in exposed areas of soil after clearing or stripping of groundcovers; and
- inappropriate treatment / disposal of weeds.

6.5.3 Impacts within Areas of Retained Vegetation

There is a significant risk of weed proliferation in areas of retained vegetation within the Conservation Zone. Areas of littoral rainforest and Camphor Laurel forest are expected to experience an increase in lower storey and vine weeds, including Asparagus Fern and Silver-leaved Desmodium. Additionally, shrubby weeds such as Privet, Lantana, Camphor Laurel and Governors Plum are expected to spread if not controlled. The removal of cattle will favour the spread of weeds, including Pigeon Grass and Vasey Grass.

6.6 Weed Control Techniques

A summary of weed control actions for the Conservation Zone are detailed in Table 6.3. Recommended weed control techniques for weed species occurring within the Conservation Zone are included within 0. Some of the factors that have been taken into account in selecting weed control techniques include the following (Big Scrub Rainforest Landcare, 2005):

- the growth habit of the weed and its means of propagation;
- the size of the weed and the time in its lifecycle;
- predicted weather / climatic conditions;
- adjacent plants including threatened species / EECs;

- whether the use of herbicide is deemed appropriate;
- the value of the weed as habitat for fauna.

Table 6.3 Summary of Weed Control Actions for the Conservation Zone

Primary Target Species		***Actions Required***
Exotic Vine and Understorey Species	Tropical Soda Apple, Lantana, Orange Jessamine, Asparagus Fern, Winter Senna, Silver-leaved Desmodium, Crofton Weed, Mistflower, , Governors Plum, Fishbone Fern.	▪ Eradication of all exotic vine and understorey weeds occurring associated with remnant vegetation. Priority weed species include Tropical Soda Apple, Camphor Laurel saplings, Silver-leafed Desmodium, Winter Senna, Lantana, Asparagus Fern, Governors Plum and Fishbone Fern ▪ Selective spot-spraying of weeds associated with the drainage line in suitable conditions to avoid spraying of threatened species. These works are to be supervised by an ecologist to ensure overspray is minimised. Some hand-weeding may also be required and will be specified by the ecologist. ▪ Spot spraying of Lantana, Crofton Weed and Mistflower located around the periphery of remnant vegetation.
Mature Woody Weeds	Camphor Laurel, African Olive, Tobacco Bush.	▪ Spray, cut and paint and hand weed species (including Lantana, Tobacco Bush etc.) occurring within the zone during winter to avoid impacts to Hairy Jointgrass and Square-stemmed Spike Rush. ▪ Control of all Camphor Laurel and African Olive trees within the Conservation Zone using stem injection of herbicide. NB. Dead woody weed material is to be removed from the site to maximise areas for rehabilitation of Hairy Jointgrass and Square-stemmed Spike Rush.
Grass Weeds	Pigeon Grass, Vasey Grass, and Kikuyu	▪ Target spot spraying of Pigeon Grass and Vasey Grass during winter using a knapsack to avoid impacts to threatened species.

Table 6.4 Weed Control Techniques

Weed Species		***Treatment***	***Notes***
Common Name	***Scientific Name***		
Asparagus Fern	*Asparigus africanus*	Crowning, cut stems at chest height, then at ground level, spray regrowth *glyphosate* 1:50 +Protec.	Best done summer / autumn
Camphor Laurel	*Camphora cinnamomum*	Stem inject 1:1.5 larger trees, cut scrape and paint 1:1.5 small plants. Spray seedlings *glyphosate* 1:50+Protec.	Larger plants may require several treatments. Best treated during growing periods
Coastal Morning Glory	*Ipomoea cairica*	Hand pull, cut scrape and paint 1:1.5 *glyphosate*. Roll up vines, spray	
Crofton Weed	*Ageratina adenophora*	Spray *glyphosate* 1:100+Protec. Alternatively hand pull and hang up.	Treat all year round.
Fishbone Fern	*Nephrolepis cordifolia*	Hand-pull plant; follow up required: spray with metsulfuron (1.5 g:10 ltrs)	

Weed Species		Treatment	Notes
Common Name	**Scientific Name**		
Groundsel Bush	*Baccharis halimifolia*	Cut and paint 1:1.5 *glyphosate.*	Best done before flowering in autumn
Lantana	*Lantana camara*	Lop and cut, scrape and paint base 1:1.5 . Spray regrowth *glyphosate* 1:100+Protec.	Treat all year round.
Madeira Vine	*Andredera cordifolia*	Scrape as much stem as possible (on one side) and paint with 100% *glyphosate*, tubers: scrape/gouge and paint (100%): spray ground infestation 1:50 +Protec. Bag tubers.	Do not cut the stem. Treat all year round.
Mist Weed	*Ageratina riparia*	Spray *glyphosate* 1:100+Protec. Hand pull and hang up.	Treat all year round.
Orange Jessamine	*Muraya paniculata*	Cut, scrape and paint (1:1.5) *glyphosate* or spray *glyphosate* 1:100	
Pigeon Grass	*Setaria sphacelata*	Hand pull or dig up. Spray *glyphosate* 1:100+Protec.	
Silver-leaved Desmodium	*Desmodium uncinatum*	Plants : hand pull or crown, cut, scrape and paint tuberous roots (G 1:1.5). Spray *glyphosate* 1:50+Protec.	
Tobacco Bush	*Solanum mauritianum*	Stem inject 1:1.5 larger trees. Cut scrape and paint 1:1.5. Spray seedlings *glyphosate* 1:100+Protec.	Treat all year round.
Vasey Grass	*Paspalum urvillei*	Hand pull or dig up. Spray *glyphosate* 1:100+Protec.	
Wandering Jew	*Tradescantia fluminensis*	Collect and bag or roll and rake carefully, then compost or place in bin, or spray *glyphosate* 1:100+Protec.	
Winter Senna	*Senna pendula*	Hand pull young plants or spray seedlings *glyphosate* 1:50+Protec. Cut, scrape and paint 1:1.5. Stem inject large specimens 1:1.5.	

6.7 General Weed Management Actions

Regular weed control works to be undertaken every six months, targeting the control of noxious and environmental weeds occurring throughout the Conservation Zone. Additionally, a number of broad measures have been developed to ameliorate the potential impacts of the proposal on weeds. General weed management actions are provided in Table 6.5.

Table 6.5 Weed Management Actions for the Conservation Zone

Number	*Management Action*
Construction Phase	
1	All noxious weeds shall be managed in accordance with the relevant legal requirements for the far North Coast County Council weed control area and control methods shall follow Section 6.6.
2	Environmental weeds to be targeted for control along with recommended treatment methods shall follow Section 6.6.
3	Sub-contractors to be used for weed control works are to be advised of all requirements stated within this weed management plan and ecological constraints associated with the site. These should be conveyed to the contractor as part of a toolbox induction.
4	Weeds species cleared are to be disposed of at an appropriate green waste facility. Any vehicle transporting weeds to a green waste facility are to be covered to prevent the spread of weeds.
5	All vehicles / plant are to be cleaned prior to working on site and before leaving site to minimise the spread of weeds.
Operational Phase	
6	The use of herbicides within the Conservation Zone is to be undertaken primarily in winter to minimise potential impacts on threatened species.
7	Regular monitoring of weeds as per Section 7 to be undertaken, with the results of weed monitoring to be incorporated into routine weed control activities.
8	Residents are to be provided with the Ballina Shire list of suitable and unsuitable garden plants and information on appropriate disposal of garden waste at an approved waste transfer facility rather than within natural environments.
9	Lawn fertilisers are not be stockpiled / spread within 40 m of drainage lines to control the release of excess nutrients into natural environments.
General Requirements	
10	Herbicide is not to be sprayed in windy conditions (>16 km/h) to prevent overspray entering waterways or impacting threatened flora species habitat.
11	Weedmaster Duo or Roundup Biactive is to be used in proximity to waterways / drainage lines to reduce potential toxicity on aquatic fauna and ecosystems.
12	Weed control within the Conservation Zone and buffer is to be preferably undertaken using the cut/paint method or manual removal to avoid overspray affecting threatened flora species. If spraying is required, works are to be undertaken during suitable conditions with a knapsack sprayer during winter (the dormancy period for HJG and SSSR) to minimise potential impacts to these species.
12	Sub-contractors to be used for weed control works are to be advised of all requirements stated within this CZMP and ecological constraints associated with the site as part of an induction.

6.8 Timing of Weed Control Works

Weed control works prescribed by this strategy are to commence upon approval of the CZMP. At least two weed control sessions are to be conducted each year, one being in winter to allow for some limited weed control works within areas of the Conservation Zone supporting HJG and SSRR(during the dormancy period of these species).

Weed control at the site will continue until handover of the public areas, or as otherwise agreed by the Department, following consideration of the results of monitoring.

The developer will be responsible for ensuring that the measures contained within this weed strategy are undertaken in accordance with the timeframes proposed.

Given that primary weed control areas are located largely within areas of retained vegetation on the site, weed control works are to be undertaken by a qualified bush regenerator with a current Section 132 C license as required by the Office of Environment and Heritage (OEH) to ensure that appropriate techniques are utilised.

The selected sub-contractor is to be briefed on ecologically significant areas occurring at the site and the requirements of this CZMP.

6.9 Monitoring

Regular monitoring of weeds will be undertaken as detailed in Section 8 (also refer to the Monitoring Plan for the site [Appendix D of the EMP]). The results of monitoring sessions will generate recommendations for future weed control works which are to be actioned as part of ongoing weed management at the site. The developer is to be responsible for ensuring recommendations developed as part of weed monitoring are undertaken as part of weed control activities.

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7

Water Management Plan

7.1 Approval Requirement

Part 7 of Condition B2 outlines the requirements for a Water management Plan:

> *A Water Management Plan that addresses the manner in which the hydrological regime of the Freshwater wetlands EEC and associated threatened species will be maintained throughout the life of the project and is to include, but not be limited to:*
>
> *a) An assessment of the pre-development hydrological regime including surface and groundwater inflows and outflows;*
>
> *b) Measures to be implemented to ensure the pre-development hydrological regime is maintained;*
>
> *c) Mapping of the extent of the seepage areas and measures to ensure their ongoing protection; and*
>
> *d) Detailed design, installation and maintenance methods of the proposed weirs and other infrastructure identified in Illustration C7 dated 14/8/2008 to ensure the maintenance of the existing hydrological regime.*

7.2 Management Plan

The Water Management Plan addressing the requirements of the Minister's approval has been prepared by Gilbert and Sutherland, specialist hydrologists. Their report is contained in full in Appendix A.

Gilbert and Sutherland undertook a detailed assessment of the site, resulting in modelling of the existing, pre-development, hydrological regime. This involved a number of sub-surface bores, supplemented by a detailed analysis of existing landform, soils, slope and vegetation.

MEDLI modelling was undertaken to estimate the deep drainage component of the pre-development landscape, providing a basis for identifying the reduction in recharge due to development of hardstand on the site. MEDLI was also used to determine the irrigation requirement to maintain the seepage areas at field capacity.

Based on the detailed site analysis, Gilbert and Sutherland have worked with the project engineers to develop a bio-filtration / infiltration system, to be constructed at the southern edge outside the Conservation Zone as part of the Stage 1A residential subdivision. This system will ensure appropriate seepage replacement that will ensure continued water source for the freshwater wetland.

As outlined in the Gilbert and Sutherland report (Appendix A), the MUSIC modelling undertaken to test the proposed system identified that at the completion of development, a total of approximately 229.06 ML/yr will be discharged to the wetland from the bio-filtration / infiltration system. This exceeds both the irrigation requirement and deep drainage replacement estimated by the MEDLI modelling to ensure that the pre-developed field capacity of the seepage areas is maintained. This will ensure the ongoing maintenance of wetland conditions in the central part of the Conservation Zone.

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8

Mapping and Monitoring of Conservation Zone Outcomes

8.1 Background

An important component of the Conservation Zone rehabilitation strategy is ensuring that an adequate mapping and monitoring program is in place to identify ecological changes that will occur within the Conservation Zone over time.

Part 2 of Condition B2 outlines the requirements for monitoring and mapping of HJG and SSSR in the Conservation Zone:

> *A program for the mapping and monitoring of the location and density of Hairy Joint Grass and Square-stemmed Spike Rush*

This section will address this condition, and also more broadly outline a monitoring strategy for identifying changes in the vegetation within the Conservation Zone.

The monitoring plan will comprise the following stages:

- Pre-development: Baseline data will be collected prior to the commencement of any construction activities.
- Construction Phase: Monitoring events will be undertaken every six months during the construction phase of the project until all major construction works are completed at the site.
- Operational Phase: This monitoring phase will consist of biannual monitoring for five years after the release of the final subdivision certificate or as otherwise agreed by the Department of Planning (DoP) following on from the results of the monitoring plan.

8.2 Monitoring Methods

The primary methods for monitoring will comprise quadrat sampling, transect sampling and photo point monitoring. Monitoring will be undertaken annually.

8.2.1 Quadrat Sampling

Quadrat sampling will involve establishment of a number of 10 m x 10 m quadrats within representative areas of forested vegetation (including revegetation areas) and 5 m x 5 m quadrats at monitoring locations within treeless communities (such as Freshwater Wetland EEC and HJG/ SSSR translocation areas) as shown in Illustration 8.1. Where locating a 10 m x 10 m quadrat is not feasible due to the linear nature of an area, an elongated monitoring plot of equal area will suffice.

A permanent marker consisting of a steel star-post will be established on the north-east corner of each quadrat and a metal tag attached indicating the quadrat number and size. The following data will be collected within each quadrat:

- Flora species present (including weeds).
- Life form of species (tree, tall shrub, low shrub, grass/ lily).
- Percentage cover of all flora species, using a Braun Blanquet cover class rating as shown in Table 8.1.
- The diameter at breast height (DBH) of all trees (woody plants with a DBH >10 cm).
- Presence of dead plants (and identification of species if possible).

- Signs of plant discoloration / disease.
- Notes of any regeneration of native species occurring.
- General comments on the condition / health of vegetation community.

Table 8.1 Braun Blanquet Cover Classes

Braun Blanquet Score	*Cover Class*
1	<5%
2	5-25%
3	25-50%
4	50-75%
5	>75%

Datasheet proformas to be used for quadrat monitoring are provided in Appendix C.

8.2.2 Transect Sampling

In addition to 5 m x 5m quadrats which will be used to monitor HJG and SSSR, transects will be used to monitor changes in the condition and composition of vegetation within the Conservation Zone and to identify any changes in the boundaries of vegetation communities that may occur following removal of cattle from the site and construction of the estate. This will involve establishment of three 25 m x 5 m transects at monitoring locations shown in Illustration 8.1. Each transect will effectively consists of 5 contiguous quadrats with dimensions of 5 m x 5 m (total transect length 25 m).

Permanent markers consisting of steel star-posts will be established at the start and end of each transect and a metal tag attached indicating the transect number and start / finish point. Data collected within each 25 m x 5 m transect will consist of the same components collected in quadrats.

Datasheet proformas to be used for transect monitoring are provided in Appendix C.

8.2.3 Photo Point Monitoring

Photo point monitoring will be undertaken to assist in the determination of vegetation condition change. During each monitoring survey, photos will be taken at both ends of all transects (facing parallel to the transect) and at the north-east corner of each quadrat (facing south-west).

All photos will be taken from approximately 1.6 m above the ground and effectively display the nature of the vegetation within the quadrat or transect.

Information shown is for illustrative purposes only

Drawn by: TJP Checked by: MVE Reviewed by: RVI Date: September 2012
Source of base data: Ballina Shire Council

0 100

North

Proposed Monitoring Locations

GeoLINK environmental management and design

Environmental Management Plan: Pacific Pines
1675-1046

Illustration 8.1

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8.3 Specific Procedures

8.3.1 Threatened Flora Species

Rough-shelled Bush Nut, Red Lilly Pilly and Arrow-head Vine

A selection of locations supporting subject threatened flora species will be monitored using 10 m x 10 m quadrat surveys. The quadrat locations have been positioned to include these species (refer to Illustration 8.1). A number of the threatened species monitoring locations purposefully coincide with EEC monitoring locations, and are labelled as combined EEC and threatened species quadrats in Illustration 8.1. Data collected within each of these quadrats will include:

- Confirmation of the presence of all threatened flora species. These will be numbered and marked (with metal tags) during baseline surveys to allow for comparisons of survey results.
- An assessment of foliage vigour for threatened flora species within the quadrat using the following scoring method (*1-dead, 2-poor condition / discoloured, 3-minor discoloration, 4-good condition, 5-excellent condition*).
- Vegetation community composition (using parameters stated in Section 8.2.1).
- An assessment of general vegetation community health using the scoring method as stated above.
- Degree of weed infestation.
- Photographs of all threatened flora individuals within the quadrat to allow for comparisons of health / condition over time.

Hairy Joint Grass (HJG) and Square-stemmed Spike Rush (SSSR)

Two primary methods will be used to monitor these species:

- Annual survey and mapping of the distribution of HJG and SSSR within the designated Conservation Zone; and
- Quadrat surveys utilising 5 m x 5 m quadrats.

Distribution Mapping

A target survey and mapping of HJG and SSSR will be undertaken within the Conservation Zone to coincide with the growing / seeding period for both species (February-April). Survey methods for both species will replicate the methodology used previously at this site by GeoLINK in 2011-2012. A summary of these methods is provided below.

Line transects 5 m apart will be walked within the Conservation Zone, with all locations of SSSR and HJG marked with a hand-held GPS. Where larger areas of HJG and SSSR are encountered GPS points will be taken every 2-3 m to allow for the distribution of occurrences to be identified. A GIS map layer of the distribution of threatened species within the Conservation Zone will be generated and overlayed on previous years distributions to detect changes over time.

Quadrat Surveys

Quadrats (5 m x 5 m) will be established within known areas of HJG and SSSR in the Conservation Zone. Data collected within the quadrat will include:

- Counts of HJG and SSSR plants occurring within the quadrat.
- An assessment of foliage vigour for HJG and SSSR within the quadrat using the following scoring method (*1-dead, 2-poor condition / discoloured, 3-minor discoloration, 4-good condition, 5-excellent condition*).
- Vegetation community composition (using parameters stated in Section 8.2.1).
- Photographs of example HJG and SSSR individuals within the quadrat.
- Photographs of the general vegetation within the quadrat (taken from the north-east corner).

Quadrat Surveys will also aim to provide information on the success or otherwise of SSSR enhancement by biomass removal using the same method as outlined for HJG (refer to Section 5.8.3). If successful, this management technique will be adopted for future enhancement of SSSR. If unsuccessful, other methods of enhancement may need to be trialled including for example, improved weed control or removal of competitive wetland species.

8.4 Endangered Ecological Communities (EECs)

Monitoring of retained EECs within the Conservation Zone will be undertaken using quadrat surveys. Data to be collected will be as stated in Section 8.2.1. Transect surveys will also be used to detect changes in the Freshwater Wetland EEC in the Conservation Zone as detailed in Section 8.2.2. The location of proposed EEC monitoring locations is shown in Illustration 8.1.

8.5 Weeds

The density of weeds within monitoring quadrats/ transects will be collected during each monitoring session. Any opportunistic observations of weeds that are located outside of specific quadrat/ transects will be recorded to inform a 'priority weed map' for the Conservation Zone. The extent of these weed infestations will be recorded with a hand-held GPS unit.

A simple map showing the locations of priority weeds will be prepared for each monitoring report. This map will be provided to weed control contractors to inform future weed control works.

8.6 Translocation of Threatened Species

Recipient sites in which HJG or SSSR have been translocated are to be monitored to record the success of the translocation. The following methodology will be undertaken:

A quadrat (5 m x 5 m) will be established within each HJG and SSSR recipient site in the Conservation Zone as shown in Illustration 8.1. Data collected within the quadrat will include:

- Counts of HJG/ SSSR plants occurring within the quadrat.
- Density of HJG/ SSSR plants occurring within the quadrat.
- An assessment of foliage vigour for HJG/ SSSR within the quadrat using the following scoring method (*1-dead, 2-poor condition / discoloured, 3-minor discoloration, 4-good condition, 5-excellent condition*).
- Vegetation community composition (using parameters stated in Section 8.2.1).
- Photographs of the general vegetation within the quadrat (taken from the north-east corner).

The distributions of these threatened species across seasons are variable depending on environmental conditions, particularly for HJG. To account for some of this variability, success or failure will be based on a significant deviation from a baseline vegetative cover. This baseline vegetative cover will be measured at 12 months following the translocation event. Subsequent monitoring events will re-measure this vegetative cover and if a reduction of more than 20% is recorded remedial management actions should be developed.

These management actions will be based around:

- improved weed management techniques; and
- re-assessment of biomass removal techniques.

8.7 Revegetation Areas

Proposed revegetation works will be monitored using quadrat surveys. Data to be collected will be as stated in Section 8.2.1. Proposed revegetation monitoring locations are shown in Illustration 8.1. This data will feed into maintenance requirements for the revegetation areas, including weed control and replacement plantings.

8.8 Data Analysis

Data collected during the construction and operational phases will be directly compared to baseline data to detect changes in the health / condition of vegetation of the Conservation Zone. Key indicators of change are as follows:

- changes in native vegetation species numbers and structure;
- changes in exotic species numbers, cover and structure;
- changes in species assemblage;
- changes in EEC boundaries;
- changes in the ratio of dead and living planting specimens; and
- signs of discolouring or poor health in plants.

After the initial baseline monitoring data collection, the ecologist/ botanist will be required to compare monitoring results to baseline data to determine:

- if any of the above changes are occurring;
- if the change is positive or negative in terms of biodiversity values; and
- if required, to identify necessary management actions to mitigate against negative impacts on biodiversity values. Any required additions or modifications to the monitoring plan should also be stated.

When changes in vegetation condition have been identified through monitoring, it is important to remember that ecosystems are dynamic and ecological changes occur in response to natural process (e.g. drought, HJG dies off over winter). Therefore natural variations in vegetation will be considered during data analysis.

8.9 Reporting

The results of monitoring events will be incorporated into annual reports to be provided to OEH and BSC, no later than two months after monitoring sessions are undertaken.

Monitoring reports will include but not be limited to the following key sections:

- Monitoring Results – including(but not limited to) summary of findings, raw data, and sample comparisons of photo monitoring points;
- Analysis - including (but not limited to) a direct comparison of previous monitoring results, with a particular focus on the indicators of change listed in Section 8.8. Analysis will also include identification of any changes to subject components of the Conservation Zone and a discussion of the likely causes of such changes; and
- Recommendations - including (but not limited to) management actions required to be implemented to ameliorate any potential negative impacts that are identified as part of monitoring, including the provision of a simple priority weed map to be provided to weed control contractors.

8.10 Project Responsibility

8.10.1 The Developer

The developer will be responsible for funding and managing the monitoring program. They will be responsible for engaging a suitably qualified ecologist or botanist to undertake the monitoring work and ensure that regular reports are submitted to OEH and BSC within two months of completing each monitoring event.

8.10.2 Ecological / Botanical Consultant

Any ecological/ botanical consultant contracted to undertake the monitoring work will be responsible for ensuring consistency with the monitoring methodology as detailed in this monitoring plan. This is important to ensure that data derived from the monitoring program is accurate and comparable and can readily detect changes in vegetation condition of the site.

Project Team

The project team members included:

Dr Tom Pollard
Ecologist

David Havilah
Ecologist

Rob Van Iersel
Senior Planner, GeoLINK Principal

Sean Cochran
Planner

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Appendix A

Water Management Plan

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Appendix B

Ballina Bypass HJG Report

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Ballina Bypass *Arthraxon hispidus* (Hairy Joint Grass) Translocation and Management Project: Final Report

Prepared for:

Ballina Bypass Alliance

Prepared by:

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April 2012

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EXECUTIVE SUMMARY

This report documents the results of a program of conservation initiatives undertaken for the threatened species *Arthraxon hispidus* (Hairy Joint Grass - HJG) by the Ballina Bypass Alliance, which included:-

1. Genetic research to determine the extent of genetic variation among HJG populations in the Ballina-Bangalow-Lennox Head area.
2. Experimental translocation of HJG to establish a new population of HJG on land adjoining the Ballina Bypass and research the effect of site factors and follow-up management on HJG establishment and persistence.
3. Management of a HJG population at Sandy Flat adjoining the bypass, including maintenance of habitat conditions favourable for HJG recruitment at the site.

The two-year program of conservation management ran from April 2010 to April 2012.

Genetic Research

Patterns of genetic variability were examined in eight populations of HJG located between Ballina, Bangalow and Lennox Head by the Centre for Plant Conservation Genetics at Southern Cross University. Chloroplast DNA sequences in commonly variable parts of the grass genome were compared and analysis revealed no genetic variation among the collection sites, which indicated there is low genetic variation in *Arthraxon hispidus* from the Ballina-Byron region. On this basis, it was concluded there were no significant genetic constraints to conducting a local translocation of HJG in the vicinity of the Ballina Bypass.

Translocation Experiment

Translocation of HJG was carried out with the aim of establishing a target, compensatory area of HJG covering 2000m², while at the same time researching the effect of site variables and introduction method on HJG establishment and the effect of follow-up site management on HJG persistence. The translocation experiment was divided into two phases: introduction (year 1) and site management (year 2).

A recipient site was selected on the Lavis property owned by RMS adjoining the Ballina Bypass, approximately 0.7km north of the impacted site. HJG was introduced to two equal sized areas by two methods: direct seeding (Area 1) and planting of propagated seedlings (Area 2). All seed and seedlings came from the Kaehler impact/donor site.

In Area 1 different site preparation treatments were compared in eight 25m x 5m bays. The site preparation treatments consisted of:-

(i) slash pasture to ground level, rake and remove mulch (Bays 1 & 5)
(ii) mid-high slash (pasture 15-20cm tall), leave mulch (Bays 2 & 6)
(iii) mid-high slash, rake and remove mulch (Bays 3 & 7)
(iv) spray pasture with broad-spectrum herbicide, leave standing mulch (Bay 8)
(v) control - no pasture slashing (Bay 4)

Five grams of HJG grass seed were broadcast over the eight bays in Area 1 on 10/6/2010. The number of seeds per gram was calculated at 3000-3600, or 15,000-18,000 seeds per bay. Direct seeding was carried out in winter within one month of seed collection to mimic the natural cycle of seed dispersal and recruitment in local populations of HJG.

Seed was sown on 23/9/2010 to propagate seedlings for introduction to Area 2. Area 2 was also divided into eight 25m x 5m bays, which were all prepared for planting in the same way, by slashing and raking up mulch. Seedlings were planted in Area 2 on 22/11/2010 when 3-4cm high.

The amount of HJG established at the recipient site and differences in HJG between treatments was measured in terms of HJG crown-cover in autumn (March to May), when populations are flowering or seeding and the crown-cover of HJG reaches its maximum extent. HJG crown-cover was recorded by visual estimation in a grid of 2 m x 1 m quadrats covering each bay, or 60 quadrats per bay. A total of 720 quadrats were monitored.

Direct seeding in Area 1 resulted in a mean percent crown cover of HJG at end-of-season ranging from approximately 6% to 15% per bay. In the control (Bay 4) where seed was sown into unslashed pasture, the mean percent crown cover of HJG was only 0.25%. Ignoring the control, there were significant differences in HJG cover-abundance between some bays, although no obvious trend in HJG response to the different slashing, mulch removal and herbicide spraying treatments. This indicated that all the site treatments, which mimicked common forms of pasture disturbance, were effective in promoting HJG recruitment to a greater or lesser degree. There was no consistent relationship between HJG crown cover and slope position within the experimental area.

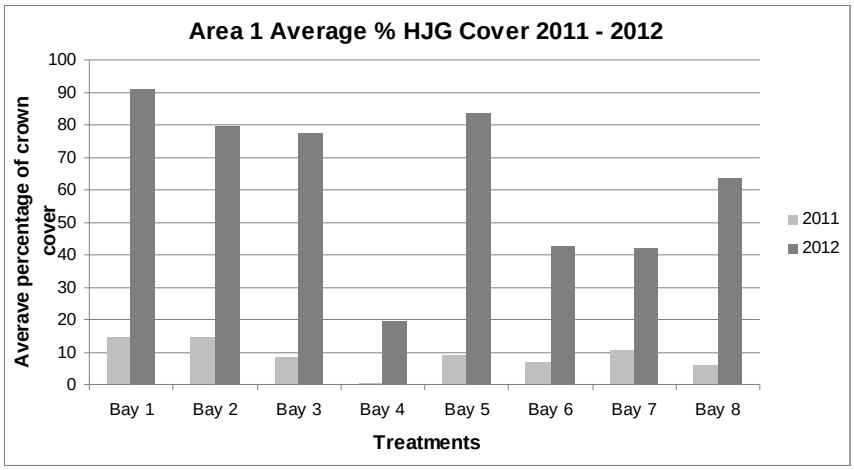
Seedling introduction in Area 2 resulted in an end-of-season crown cover ranging from 1% to 2% per bay, significantly lower than Area 1, which was direct seeded. The survival rate of planted seedling clumps ranged from 40-60% per bay. Seedling clumps that survived grew poorly and seed output was less than in Area 1. Poorer HJG establishment may have been due partly to the comparatively late timing of seedling introduction (November), relatively light slashing of the site before introduction and differences between areas in the relative abundance of competing pasture species.

The second year of the translocation experiment examined whether the HJG population established in the first year could be maintained by manipulating pasture structure through slashing, so suitable ground layer conditions are formed for recruitment of the next generation of HJG plants. Slashing of Areas 1 and 2 was carried out in May 2011 at the end of the first year seeding period. Apart from the initial slashing, no other site management was applied. Cattle and other domesticated grazing animals were excluded from the site.

HJG crown cover increased markedly in all treatment bays in 2012. Mean percent crown cover in Area 1 increased from 6-15% in Year 1 to 40-90% in Year 2, not including the control (Bay 4). Slashing of Area 2 in the second year of the translocation experiment also resulted in a substantial increase in HJG cover-abundance. Mean percent crown cover of HJG increased from 1-2% in Year 1 to 8-26% in Year 2.

The increase in HJG mean crown cover in both Areas 1 and 2 appeared to be a result of the slashing treatment applied at the end of the HJG seeding season, creating favourable conditions for HJG seed germination and seedling establishment,

combined with absence of cattle grazing and above average rainfall in both years of the translocation experiment.



The above graph shows the marked increase in HJG cover in Area 1 in response to management.

Recommended regime for managing HJG in pasture habitat

This study provided information on management of HJG in ungrazed pasture, which is potentially useful for management of HJG in road reserves or on conservation lands where cattle or other grazing animals are not permitted. Being an annual grass species that persists by seed germination from year to year, the key to HJG persistence is manipulation of the structure of pasture habitat to create low, open conditions during its recruitment period when HJG seedlings germinate from seed produced by the previous generation of plants. These conditions can be maintained by one site management treatment per year, consisting simply of running a tractor slasher over the site. The optimum time for slashing appears to be late May or June straight after the HJG seeding period.

In summary, a vigorous HJG population can be conserved in ungrazed pasture habitat using the following management regime:-

- slash pasture habitat once a year preferably in late May or June
- set slasher height as low as possible;
- slashing carried out under damp soil conditions may be preferable to dry, as seed is pressed into the soil resulting in better germination;

Management of the Sandy Flat HJG population

Part of the program of HJG conservation measures was to monitor the condition of a naturally occurring population at Sandy Flat. As preliminary data indicated that periodic reduction of pasture biomass was important for HJG persistence, annual slashing of HJG habitat at the site was carried out. Due to difficult access this was carried out with a brush-cutter. Significant changes in pasture species composition occurred, probably due to exclusion of cattle and above average rainfall years. However, the comparatively small population of HJG at this site consisting of approximately 100 plants scattered along the edge of a swampy drainage line at the base of a hill slope remained more-or-less stable in extent and number between 2009 and 2012.

1 INTRODUCTION

1.1 Background

A workshop convened by the Ballina Bypass Alliance and attended by the Department of Environment Climate Change and Water (now the Office of Environment and Heritage) and several plant conservation professionals on 10/3/2010 reviewed a number of translocation and management proposals put forward by the BBA to compensate for damage to a stand of the threatened plant species *Arthraxon hispidus* (Hairy Joint Grass) that occurred during highway construction. The program of conservation measures endorsed by the workshop included the following actions aimed at improving the conservation status of Hairy Joint Grass (HJG) in relation the Ballina Bypass Project:-

1) Genetic research to determine the extent of genetic variation among HJG populations in the Ballina-Bangalow-Lennox Head area.

2) Experimental translocation of HJG to establish a new population of HJG on land adjoining the Ballina Bypass and research the effect of site factors and follow-up management on HJG establishment and persistence.

3) Management of the HJG population at Sandy Flat adjoining the bypass, including maintenance of habitat conditions favourable for HJG recruitment at the site.

These measures were implemented over a two year period. The first year of the translocation experiment involved introduction of HJG to a new site using different methods of introduction and site preparation. The second year of the translocation experiment examined how HJG established in the first year persisted under site management. The two-year program of conservation management ran from April 2010 to April 2012.

The purpose of this report is to document the methods, results and findings of the *Arthraxon hispidus* research and conservation management program, and discuss the implications of findings for understanding of the species' ecology and conservation management. The contents of this report are set out as follows:-

- Section 2 describes the study of genetic variation in HJG populations adjoining and surrounding the Ballina Bypass project.
- Section 3 describes the HJG translocation, including the introduction experiment conducted in year one, and the effect of management in year 2.
- Section 4 describes the outcomes of management of the Sandy Flat HJG population over two years.

1.2 Species profile

Arthraxon hispidus is found in north-eastern NSW between Kempsey and the Queensland border and from near the coast west to the eastern edge of the New England Tableland. The species also occurs in Queensland. In NSW, the great majority of occurrences are north of the Richmond River in the high rainfall, Far North Coast region. *Arthraxon hispidus* (Hairy Joint Grass or HJG) is an annual plant species on the North Coast of NSW, meaning it completes its life cycle in one year (unless flowering is suppressed). HJG seed germinates in late winter after a short dormancy period (Benwell 2010). Small seedlings are able to survive the dry spring period under perennial exotic grasses and growth occurs mainly during the summer wet season. Flowering and seed set occurs in autumn between March and May then the whole plant dies. HJG occurs mainly on lower hill slopes where the soil is damp or fed by ground water seepage during the wet season, but the species also occurs on upper hill slopes in wet years. Seed burial in sachets showed that a small proportion HJG seed can retain viability for at least three years (Benwell 2010). HJG is unusual in occurring mainly in grazing pasture dominated by exotic grasses and herbs, although a few other native species may also be present in this plant community (Benwell 2010). This suggests that HJG has adapted to agricultural habitat, or that its current habitat overlaps ecologically with its original habitat requirements. HJG has a plastic growth form and can grow in dense matts of plants or as slender, single stemmed plants up to 1.5m tall in tall weed regrowth. Being an annual species, it may have the potential to undergo rapid adaptation and evolutionary change in response to changes in habitat conditions. A detailed species profile of *Arthraxon hispidus* is presented in Appendix 7.

2 GENETIC RESEARCH

2.1 Introduction

The workshop held in March 2010 agreed that an investigation of patterns of genetic variability in HJG populations in the Ballina district should be carried out before conducting a translocation of HJG. This data would be used to assess the risk of outbreeding or inbreeding depression as a consequence of moving genotypes around the landscape during translocation. A genetic study of local populations was subsequently carried out by the Centre for Plant Conservation Genetics at Southern Cross University. The objectives of study were to:

- Determine the level of genetic variation within and between populations of *Arthraxon hispidus* on the NSW North Coast, in particular the local area between Ballina, Bangalow and Lennox Head.

- Investigate the population genetics of *Arthraxon hispidus* and assess the implications of genetic data for translocation of the species.

2.2 Results of genetic analysis

Patterns of genetic variability were examined in eight populations of HJG located between Ballina, Bangalow and Lennox Head (Table 1).

Table 1: Location and habitat of eight populations sampled for genetic analysis.

Koellner - population scattered in pasture across steep SE facing slope
Sheather - population restricted to table drain cut into mid slope, cleared grazing land
Sandy Flat - population found along lower reach of a minor drainage line or gully, cleared grazing land, overgrow
Kaehler - population scattered in pasture and disturbed area on south facing mid slope, cleared grazing land
Ross Lane - population scattered on south facing hill slopes, gullies and spurs, cleared grazing land with Camphor Laurel regrowth
Lavis - first two samples on access track on hillside, other samples 300m away from marshy margin of running stream, cleared grazing land
Lennox Head - Hutley Rd South - population in marshy area of dense native species on toe of slope, cleared
T2E - Bangalow, Fraser - population in pasture in drainage depression on floodplain terrace, cleared grazing land

The results of genetic analysis were summarised by the Southern Cross University Centre for Plant Conservation Genetics as follows:-

"Leaf samples of hairy-joint grass *Arthraxon hispidus* were collected from several locations in Ballina and Byron shires, including sites proximate to current and proposed road works. Genomic DNA was extracted from leaf tissue. Sequences were obtained for individual plants from each collection site. Five chloroplast sequence regions that are commonly variable within plant species, including grasses, were targeted for this study. Analysis of the results revealed no genetic variation among the collection sites. This suggests that:
1) there is low genetic variation in *Arthraxon hispidus* from the Ballina-Byron region, or
2) sample size was too small to detect genetic variation

The results indicate that maternal gene flow (seed dispersal) occurred historically and/or currently between the collection sites in northern NSW. More detailed assessments of population structure, genetic variation and dispersal in this species would require the development of species-specific genetic markers.

This study has provided sequence data that could be of benefit for future research on *Arthraxon hispidus*. Leaf tissue and genomic DNA are archived in the Australian Plant DNA Bank" (CPCG 2010).

2.3 Implications for translocation

As no genetic variation was detected between populations in the Bangalow-Ballina-Lennox Head area, possible outcrossing depression due to translocation, caused by mixing of divergent genotypes, was considered unlikely. If there is no genetic variation then it is assumed that inbreeding depression would also be unlikely. CPCG (2010) mentions that genetic analysis of nuclear DNA and development of genetic markers may reveal more genetic variation than the chloroplast DNA method used in this study. This implies that undetected genetic variability may exist within and between HJG populations, which one would expect in an annual plant species such as HJG.

3 TRANSLOCATION AND MANAGEMENT EXPERIMENT

3.1 Background

The workshop held on 10/3/2010 agreed that a 1:1 replacement of the Hairy Joint Grass (HJG) damaged during construction required translocation of approximately 2000 square meters of HJG (Greenloaning 2009). As well as aiming to achieve the target area of translocated HJG, the translocation was designed to study the effect of different initial site conditions on HJG establishment and the efficiency of different methods of introducing the species to a new site. In the second year the translocation examined the effects of pasture management on the persistence of HJG established in the first year. This research was directed at several questions concerning the ecology of HJG populations on grazing land including:-

- What effect does slashing have on HJG germination and persistence?
- What effect does mulch cover produced by slashing have on HJG germination?
- What effects do associated pasture plants and weeds have on HJG vigour and reproductive output?
- Is it possible to translocate HJG successfully on cleared pasture land?
- What translocation methods achieve the best results?

Translocation is defined as the "deliberate transfer of plants or regenerative plant material from one place to another, including existing or new sites or those where the taxon is now extinct." (ANPC 2004). Translocations of threatened plant species are generally undertaken in two main contexts: (i) as a research or conservation measure to assist with species recovery programs, and (ii) as a measure to mitigate adverse impacts associated with development (Falk *et al.* 1996, ANPC 2004). The HJG translocation for the Ballina Bypass project falls into the second category and can be described as a 'compensatory introduction' (ANPC 2004), also entailing ecological research. The HJG translocation experiment was planned and implemented by Dr Andrew Benwell (ECOS Environmental Pty Ltd).

3.2 Translocation objectives

The objectives of the HJG translocation experiment agreed at the workshop were:-

- To establish a new compensatory stand of HJG covering approximately 2000 m².
- To conduct the translocation subject to the findings of genetic research on patterns of genetic variability in local populations of HJG.
- To translocate using different methods of introduction including direct seeding and plant-out of seedlings.
- To translocate HJG to a site close to the impacted/donor site, containing similar soil type, topography and vegetation.

- To conduct the translocation using a systematic experimental approach that compares the effects of different translocation methods and land management practices on HJG abundance.

- To recommend pasture management practices based on the translocation experiment findings that promote the persistence of HJG populations in pasture habitat.

3.3 Description of the translocation receival site

An area on the former Lavis property owned by Roads and Maritime Services was selected as the translocation receival site (Figure 1). The land is located in the valley of Emigrant Creek west of Ross Lane and adjoins the Ballina Bypass. The area chosen for introduction of HJG is located at the western end of the Lavis block, ~0.7km north of the impacted site. The site is on a lower slope with a south to southwest aspect, adjacent to a drainage line and dam. Pasture species composition and soil type were similar to pasture habitat at the impacted site. A small existing HJG population occurred in a narrow strip next to a small stream downstream of the dam, adjacent to the receival site. Characteristics of the receival site and the donor/impacted site are compared in Table 2.

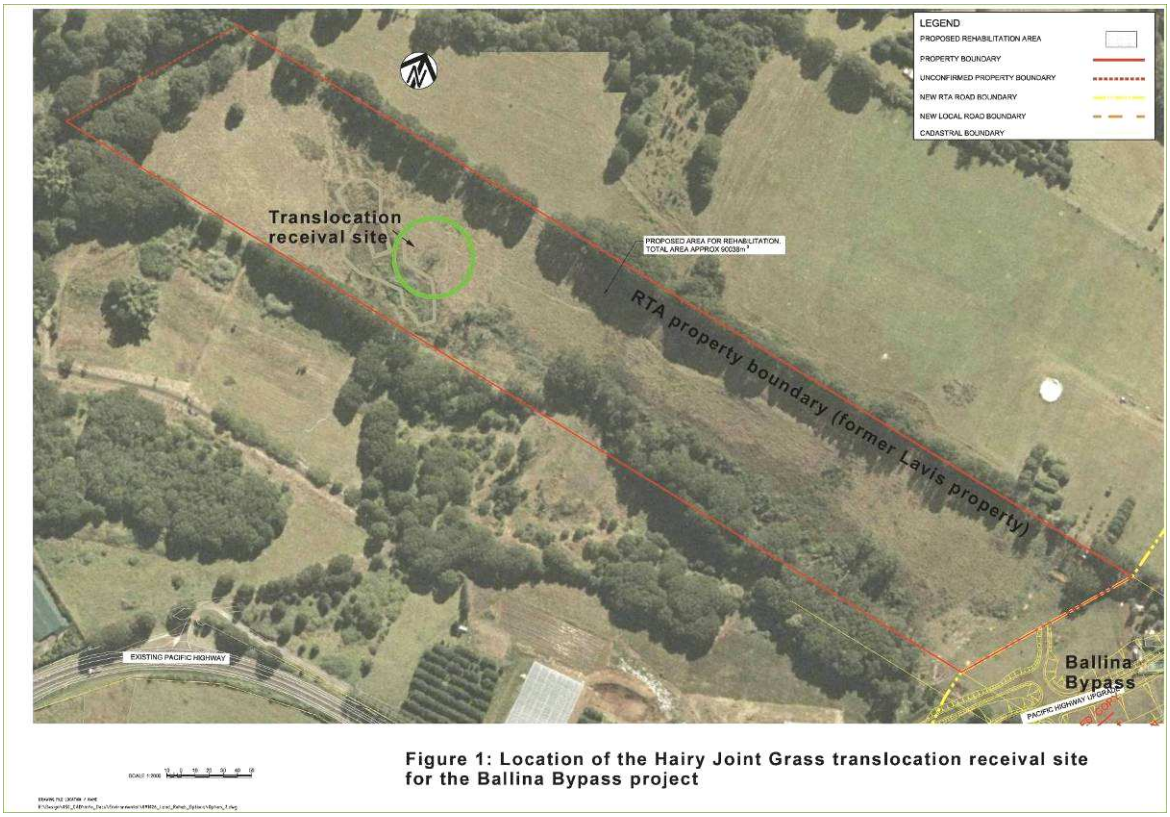


Figure 1: Location of the Hairy Joint Grass translocation receival site for the Ballina Bypass project

Table 2: Physical, biotic, logistical and tenure attributes of the impact/donor and receival sites.

Site Attribute	Preferred by species	Impact/Donor Site (Kaehler)	Receival Site (Lavis)
Physical			
slope aspect	southeast to southwest	south to southeast	south to southwest
slope angle	gentle to moderate	moderate	gentle
topographic position	lower slope, footslope	mid slope	lower slope
landform	bottom of valley, base of hills	mid valley hill slope	bottom of valley
geology	basalt	basalt	basalt
soil	krasnozem	krasnozem	krasnozem
wet season seepage zone present	yes but not essential	no	no
distance up/down slope from seepage or near-surface groundwater indicator	<30m	<100 m	<20m
above creek flood zone	yes	yes	yes
proximity to donor site	n.a.	n.a.	0.5 km
area of potential habitat available	n.a.	n.a.	1+ ha
Biotic			
pasture grass composition	Buffalo/ Paspalum/ Carpet	Buffalo/ Paspalum/ Carpet/ Kikuyu	Buffalo/ Paspalum/ Carpet/Kikuyu/ Broad-leaved Paspalum
potential problem weeds present	Lantana, Camphor Broad-leaved Weeds	nil; possibly in soil seedbank	nil; possibly in soil seedbank
Logistical			
accessibility	n.a.	n.a.	good
distance to water source	n.a.	n.a.	20-50 m
likelihood of disturbance during construction	n.a.	n.a.	low
Tenure/conservation			
land ownership/ protection mechanism	n.a.	n.a.	RMS/ covenant

Attributes of the receival site suitable for establishing HJG included:-

- availability of an area of lower slope habitat covering more than 2000 m²;
- similar physical and biotic attributes to the impacted/donor site;
- an existing small occurrence of HJG on the drainage line indicating general suitability of the site for HJG;
- dam on property to supply water during seedling introduction;
- existing access track;
- area set well back from the Ballina Bypass and unlikely to be disturbed during highway construction and maintenance; and
- tenure (RMS) suited to long-term conservation of the translocated HJG population.

3.4 Translocation method

3.4.1 Experimental design

The translocation was designed to establish a specified area of HJG (~2000 m²) at the same time as investigating the effect of method of introduction, follow-up pasture management and ecological site variables such as slope position and pasture composition on HJG abundance. Two introduction methods were used:- direct seeding and seedling plant-out. Half of the translocation area was direct seeded and the other half planted with seedlings. Each half was divided into eight, 5 metre wide by 25 metre long (up and down slope) bays, totally 1000 m². Five site preparation treatments were applied to the direct seeding bays (Figure 2), as listed below:-

1. slash pasture to ground level, rake and remove mulch (Bays 1 & 5)
2. mid-high slash (pasture 15-20cm tall), leave mulch (Bays 2 & 6)
3. mid-high slash, rake and remove mulch (Bays 3 & 7)
4. spray pasture with broad-spectrum herbicide, leave standing mulch (Bay 8)
5. control - no pasture slashing (Bay 4)

In Year 2, pasture management was applied which, based on the results of the introduction experiment, was intended to maintain and potentially increase HJG cover-abundance at the introduction site.

3.4.2 Direct seeding

Seed was collected in April and May 2010 from HJG plants that regenerated on the Kaehler site after the disturbance caused during highway construction in 2009. After carrying out the site preparation treatments described above, five grams of HJG grass seed were broadcast over the eight bays in Area 1 on 10/6/2010. Seed was weighed out with digital scales and mixed with 20 litres of river sand to spread it more evenly. Based on seed counts in several small weighed samples, the number of seeds per gram was calculated at 3000-3600, or 15,000-18,000 seeds per bay. Direct seeding was carried out in winter soon after seed collection to mimic the natural cycle of seed dispersal and recruitment in local populations of HJG.

Following high density germination of broad-leaved weed seedlings with HJG seedlings after the site preparation treatments, particularly Ragweed (Ambrosia artemesifolia), a trial spraying of broad-leaved weed killer ('Searles Lawn Weeder' - active constituents Mecoprop 97.8g/L, MCPA 23.1g/L and Dicamba 11.7g/L) was

carried out in Bay 1 of Area 1 at the start of September 2010. The herbicide was sprayed in three 0.5 m x 0.5 m test plots containing HJG seedlings and three 1 m x 1m test plots containing a high density of broad-leaved weeds. The plots were monitored to assess the effect of the herbicide on HJG seedlings and broad-leaved weeds on 25/9/2010 and 29/10/2010.

3.4.3 Seedling plant-out

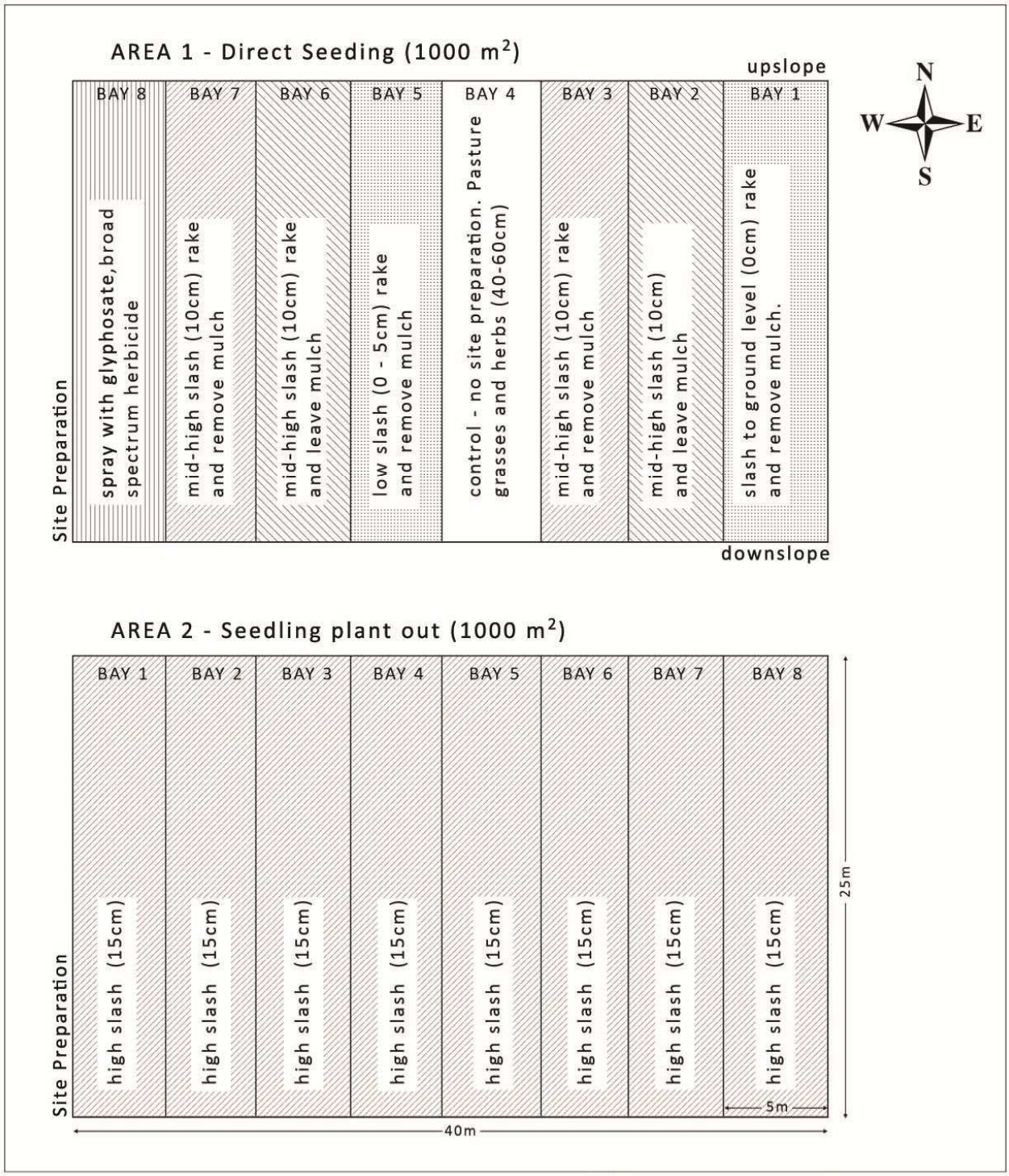
HJG seedlings were propagated from the seed collected on the Kaehler land (the donor site). Seed was sown on 23/9/2010 in sixteen 50 cm x 40 cm x 8 cm seedlings trays (i.e. two trays per bay) in seed raising mix purchased from a local supplier. Seed germination began four days after sowing. Tall grass and rank weeds on the site were slashed before introducing HJG seedlings. The same slashing treatment was applied to all the seedling plant-out bays as the slasher supplied was a fixed height clearing slasher. The slashing treatment was lighter than the mid-high slash applied in the direct seeding area.

The seedlings were planted in Area 2 on 22/11/2010. The seedlings were 3-4cm high and transplanted from the trays in small clumps approximately 5cm square rather than individually to minimise soil-root disturbance and increase survival rate under hot conditions. A total of 120 seedlings clumps each containing about five seedlings on average were planted per bay. The planted seedling clumps were mulched, watered and marked with a bamboo stake. Seedlings in bays 1-4 were given a single light application of Organic Extra pellets (chicken manure, seaweed and other additives) at planting-out. No fertiliser was added to bays 5-8. Daily watering was carried out for the first week then decreased.

3.4.4 Year 2 pasture management

Pasture management in Year 2 was based on the findings of the Year 1 experiment, which showed that reduction of pasture structure and biomass was important for HJG recruitment. The management applied consisted of slashing the whole of Area 1 and 2 to promote recruitment of HJG and thereby maintain a healthy stand of HJG covering at least 2000 m², as required by the translocation objectives. The Year 1 introduction experiment indicated that opening up the pasture plant community soon after seed production had taken place in autumn resulted in high density establishment of HJG seedlings, representing the next generation of plants.

Slashing was carried out on 9/5/2011 toward the end of the HJG seeding period using a Posi-Track vehicle with a front mounted slasher supplied by the BBA. Mulch was removed by raking, although the coarse cut and wet mulch due to wet weather at the time meant that mulch removal was patchy and not as thorough as for the Area 1 site preparation bays.



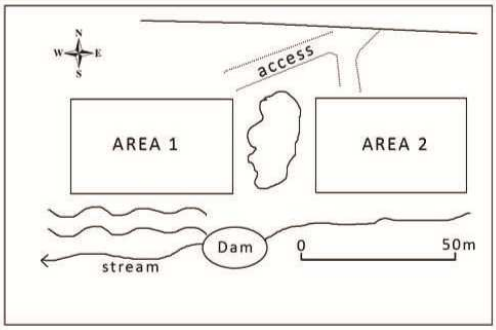


Figure 2: Hairy Joint Grass (Arthraxon hispidus) translocation experiment design showing site preparation treatments used with two introduction methods - direct seeding (Area 1) and seedling planting (Area 2)

3.4.5 Monitoring

Year 1
The following monitoring was undertaken during the year 1 introduction experiment (June 2010 to June 2011):-

Area 1 - direct seeded	**Monitoring Task**
10-11/6/2010	start of experiment to record species composition before pre-sowing site preparation treatments
3/8/2010	1 m² quadrats to monitor HJG emergence, density and growth
11/9/2010	1 m² quadrats to monitor HJG emergence, density and growth
24/9/2010	seedling density census for each bay recorded in 2m wide units (ie 5 m x 2 m)
Nov 2010 – Apr 2011	other site inspection monitoring
2-4/5/2011	end of season monitoring to record final HJG crown cover (cover-abundance) and general species composition
Area 2 - seedling plant out	
22/11/2010	record initial seedling plant out
26/11/2010	record plant condition after planting out
Dec 2010 - Apr 2011	other site inspection monitoring
5-6/5/2011	end of season monitoring to record final HJG crown cover (cover-abundance) and general species composition

Year 1 monitoring of Areas 1 and 2 was conducted to record the establishment response of introduced HJG. The end-of-season monitoring measured the crown cover of HJG established at the recipient site and differences in HJG crown cover between treatments. The crown cover of HJG reaches its maximum extent between March and May when populations are flowering or seeding. Measurement of crown cover was recorded at the start of May when HJG was seeding.

HJG crown-cover was recorded in a grid of 2 m x 1 m quadrats covering each bay, or a total of 60 quadrats per bay (the upper one meter of each bay was omitted). The percent crown-cover of HJG was estimated visually in each quadrat to the nearest 5%. Where crown cover was less than 5% it was recorded either as <5% - 1 (only one or few stems present), or <5% - 2 (more than a few stems present). Fixed values of 0.5% and 2% respectively were applied to these classes. All eight bays were monitored in Area 1. Four bays were monitored in Area 2, each of which received the same site preparation treatment.

Data recording was carried out by Dr Andrew Benwell, Eric Ogilvy and Rebecca Thomas. To minimise observer bias when recording crown cover (BLM 1999), an initial session was conducted to 'calibrate' observer measurement of crown cover. Crown cover is defined as the percentage of the ground covered within a given area covered by a horizontal projection of a plants foliage crown (Walker and Hopkins

1990). Before starting data recording, the three ecologists recorded the same plots under the direction of the senior ecologist until there was little if any variation in the percent crown cover of HJG recorded by the three observers. Further checks were made during the data collection.

Year 2
The following monitoring was undertaken during the year 2 maintenance phase of the translocation experiment (June 2011 to April 2012):-

Date	Person Days	Monitoring Task
Jul 2011	1	site inspection record - HJG emergence, density and growth
Aug 2011	1	site inspection record - HJG emergence, density and growth
Nov 2011	1	close observation - HJG emergence, density and growth; record general vegetation in each bay
Jan 2012	1	site inspection record - HJG emergence, density and growth
Mar 2012	4	record end of season HJG cover abundance in grid of 2m x 1m cells covering treatment bays; record general species composition in Area 1 and 2 (10m x 5 m blocks)

Monitoring was conducted to record the response of HJG to site maintenance. The end of season monitoring measured the cover-abundance of HJG at the end of the second HJG season after applying site maintenance designed to maintain HJG abundance. Measurement of percent crown cover was recorded in March when HJG was starting to flower. As in Year 1, the percent crown-cover of HJG was estimated visually in each quadrat, generally to the nearest 5%. All eight bays were recorded in Area 1. Four bays were recorded in Area 2 where each bay received the same site preparation treatment. Data recording was carried out by Dr Andrew Benwell and Justin O'Dowell and, as previously, an initial session was conducted to 'calibrate' observer estimation of crown cover.

3.4.6 Data analysis

Data on HJG crown-cover and the species composition of bays were entered in Excel Spreadsheets for storage and calculation of summary statistics. In the first year report, crown cover was converted to Braun-Blanquet cover-abundance classes to construct visual 'heat' or density maps of HJG cover within the treatment bays. However, the raw data also suffice for this purpose, as presented in Appendices 1 to 4. Differences in HJG abundance between bays were analysed statistically using:

- t-tests to determine if there were significant differences in mean HJG cover-abundance between bays.
- chi-square tests to determine if there were significant differences in the frequency of HJG crown cover classes between bays (Moore and McCabe 1999).

A normality test was applied to variables.
Year 1 and 2 data were graphed to show trends in HJG response over time. Standard errors were reported to enable assessment of significant differences between different combinations of treatments and different years where required.

Plate 1: Year 1 site preparation in progress in Area 1, June 2010. Bay 1 is on the left hand side. Grass slashing was carried out manually with brush-cutters.

Plate 2: Five grams of HJG seed collected from the Kaehler land was mixed with 20L of river sand and broadcast over each bay in Area 1 in June 2010.

Plate 3: Area 1 in August 2010 two months after site preparation and direct seeding. Bay 4 (control) on the left hand side; Bay 5 (hard slash, remove mulch) centre; Bay 6 (slash, leave mulch) on the right hand side.

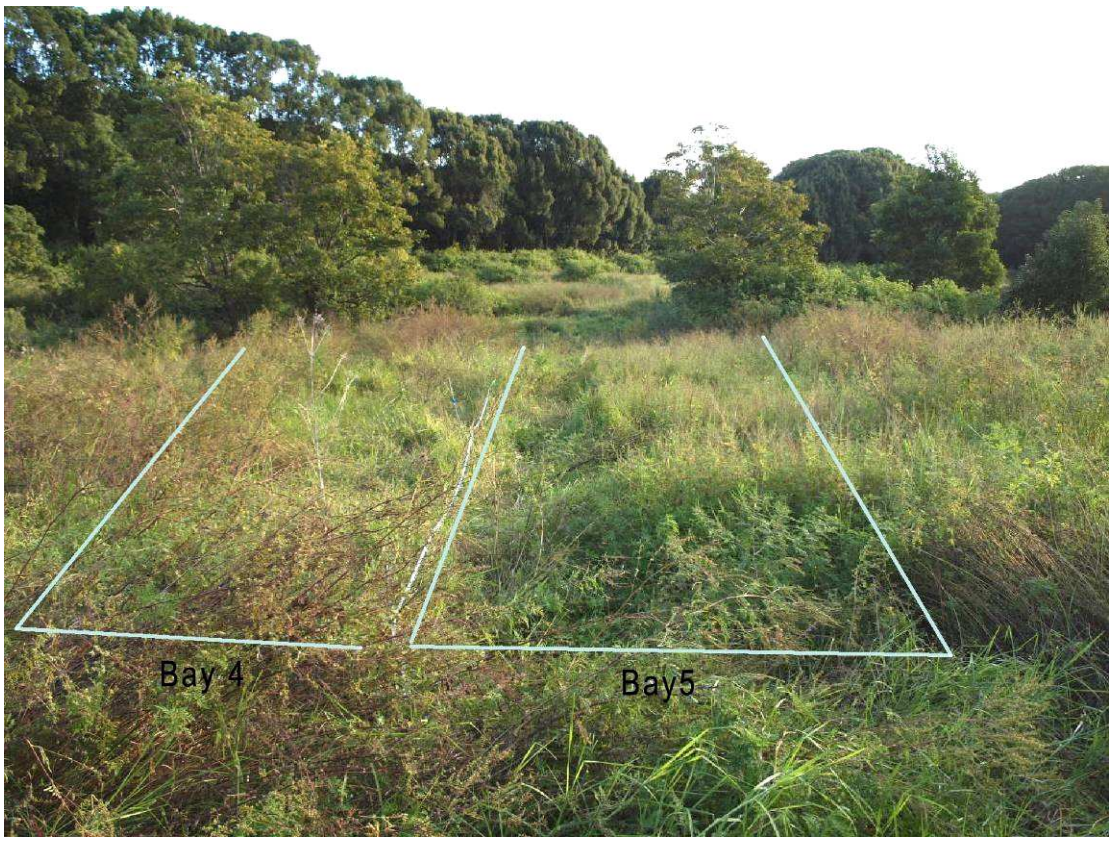


Plate 4: Area 1 at end of season monitoring 4/5/2011, showing dense pasture regrowth in the treatment bays. There was no grazing or slashing for almost 12 months. Bay 4 (control) is left of the tape and Bay 5 (hard slash, remove mulch) right of tape. Compare with Plate 3.

3.5 Results and Discussion - Year 1

3.5.1 Area 1 (direct seeding)

HJG was introduced to Area 1 by direct seeding in June 2010. Each bay received the same quantity of seed distributed evenly over each bay. HJG seedlings were first observed during monitoring on 3/8/2010. Direct seeding resulted in a mean percent crown cover of HJG at end-of-season ranging from approximately 6% to 15% per bay. In the control bay where seed was sown into unslashed pasture, the mean percent crown cover of HJG was only 0.25% and this was probably edge effect from adjoining slashed bays.

A summary of HJG crown cover results for the whole of Area 1 is provided in Table 3. Results for all bays in Area 1 are given in Appendix 1.

Table 3: Area 1 (direct seeding) mean percent crown cover ± standard error of HJG in Bays 1-8 recorded at end-of-season 2-4/5/2011. Values are shown for the whole bay, upper half and lower half of bays. The pre-sowing treatment applied to each bay is indicated.

Bays **Treatment**	**All Bay**	**Upper Bay**	**Lower Bay**
Bay 1 ground slash, remove mulch	14.77 (± 2.17)	10.44 (± 2.47)	19.48 (± 3.57)
Bay 2 mid-high slash, leave mulch	14.66 (± 2.62)	5.37 (± 1.98)	24.72 (± 4.70)
Bay 3 mid-high slash, remove mulch	8.74 (± 1.81)	3.76 (± 1.03)	14.14 (± 3.48)
Bay 4 control - no site preparation	0.24 (± 0.13)	0.06 (± 0.03)	0.43 (± 0.27)
Bay 5 low slash, remove mulch	8.88 (± 1.58)	11.15 (± 2.14)	6.42 (± 2.31)
Bay 6 mid-high slash, leave mulch	6.78 (± 1.92)	12.72 (± 3.55)	0.36 (± 0.09)
Bay 7 mid-high slash, remove mulch	10.71 (± 2.27)	13.42 (± 3.72)	7.78 (± 2.44)
Bay 8 spray herbicide (glyphosate)	6.17 (± 1.62)	10.65 (± 2.98)	1.33 (± 0.49)

Bay 1 (slash to ground level and removal mulch) had the highest HJG crown cover, although there was no significant difference between this bay and Bays 2 and 7, which received an initial high slash with mulch removal (Bay 7) and without mulch removal (Bay 2).

Leaving out Bay 4 (the control), there were significant differences in HJG cover-abundance between some bays, although no obvious trend in HJG response to the different slashing, mulch removal and herbicide spraying treatments (Table 4). HJG crown cover values over whole bays ranged from 6 to 15% per bay approximately (Bay 4 omitted). This indicated that all the site treatments, which mimicked common

forms of pasture disturbance, were effective in promoting HJG recruitment to a greater or lesser degree.

Table 4: Results of 2-sample t-tests on pairs of Bays in Area 1. Bay 4 is the control (with respect to site preparation). The site preparation treatments applied to the bays are given Table 3 above. Values are the t-test statistic (sign not relevant to interpretation).

	bay 1	bay 2	bay 3	bay 4	bay 5	bay 6	bay 7	bay 8
bay 1	-	0.04 ns	2.13 *	6.68 ***	2.20 *	2.76 **	1.29 ns	3.18 **
bay 2		-	1.86 ns	5.50 ***	1.89 ns	2.43 *	1.14 ns	2.76 **
bay 3			-	4.69 ***	-0.06 ns	0.74 ns	-0.68 ns	1.06 ns
bay 4				-	-5.45 ***	-3.40 **	-4.61 ***	-3.66 ***
bay 5					-	0.84 ns	-0.66 ns	1.20 ns
bay 6						-	-1.32 ns	0.24 ns
bay 7							-	1.63 ns
bay 8								-

*** p < 0.001, ** 0.001 < p< 0.01, *0.01 < p < 0.05, ns not significant

Effect of slashing

The establishment response of HJG in the control bay (Bay 4), where no site preparation treatment was carried out, was very small (Table 3). The unslashed pasture in this bay was 50-80 cm tall and dense. Establishment of HJG from the same quantity of seed was much greater in bays where biomass reduction (with or without mulch removal) was carried out. This demonstrated how reduction in the height and density of ground layer vegetation by slashing facilitates HJG seed germination and/or seedling growth. Biomass reduction does not have to entail complete removal of ground layer vegetation as carried out in Bay 1.

Effect of mulch

Leaving or removing slashed mulch had no marked effect on HJG establishment. However, the mulch produced in this experiment was not particularly thick. A thicker layer of mulch produced by taller or denser pasture may have produced different results, but probably only by delaying seed germination until mulch decomposes, exposing seed to light which triggers germination (given warmth and moisture).

Reducing above ground biomass by herbicide spraying and leaving the dead plant material standing also stimulated HJG recruitment (Table 3).

Table 3 shows that Bays 2 and 6 had significantly different crown covers of HJG even though they both received the same 'slash and leave mulch' treatment, which

suggested that other factors were also affecting HJG establishment. Other factors may have included:-
(i) variation in pasture species composition, particularly species that compete with or suppress HJG recruitment or growth;
(ii) variation in local topography and topsoil moisture supply - i.e. upper and lower slope effect.

With regard to point (i), Bay 2 had more Buffalo Grass (*Stenotaphrum secundatum*) and Carpet Grass (*Axonopus affine*) and Bay 6 had greater crown cover of Kikuyu (*Pennisetum clandestinum*) and Broad-leaved Paspalum (*Paspalum wettsteinii*) (see Appendix 3).

Slashing stimulated prolific germination of broad-leaved weeds, as discussed in Section 3.5.3.

Effect of slope position

To analyse the effect of slope position, the bays were divided into upper and lower halves and mean cover-abundance scores compared using t-test and chi-square (see Appendix 4). The effect of slope position on HJG establishment varied within Area 1. In Bays 1-3 of Area 1, HJG establishment was significantly greater on the lower part of the slope (Table 3). In Bays 5-8 of Area 1 the result was reversed, with establishment significantly greater on the upper half of the slope.

Plate 5: Area 1, recording HJG cover-abundance monitoring in Bay 7 (site preparation - mid-high slash, remove mulch) and Bay 8 (spray herbicide), May 2011.

Plate 6: Area 2 was planted with HJG seedlings in November 2010 after slashing pasture and clearing Lantana from the down slope section in the background.

Plate 7: Area 2 end of season monitoring May 2011; tall rank growth on the lower half of bays visible on the right hand side, shorter pasture on the upslope left hand side.

Plate 8: Area 2 end of season monitoring, May 2011 showing tall herbaceous regrowth at the lower end of bays cleared of Lantana during site preparation in November 2010 (see background of Plate 6).

3.5.2 Area 2 (seedling plant-out)

Introduction of HJG by planting out seedlings resulted in an end of season crown cover ranging from approximately 1% to 2% per bay (Table 5), significantly lower than the crown cover achieved by direct seeding. The survival rate of planted seedling clumps, as gauged from marker stakes installed at the start of the experiment, ranged from 40-60% per bay. Many seedling clumps that survived grew poorly and plants remained small and spindly. Mature plants were smaller and seed output less than in Area 1. Poorer HJG establishment may have been due partly to the comparatively late introduction time (November), light slashing of the site before introduction and pasture species composition.

Table 5: Area 2 (seedling plant-out) mean percent crown cover ± standard error, of HJG in treatment bays 2, 3, 6 and 7 recorded at flowering/seeding time 6/5/2011.

Treatment Bay	All Bay	Upper Bay	Lower Bay
Bay 2	2.44 (± 0.40)	3.35 (± 0.61)	1.47 (± 0.47)
Bay 3	1.80 (± 0.76)	2.88 (± 1.39)	0.63 (± 0.42)
Bay 6	1.08 (± 0.29)	1.75 (± 0.22)	0.35 (± 0.17)
Bay 7	0.85 (± 0.20)	0.75 (± 0.29)	0.95 (± 0.28)

The site preparation in Area 2 consisted of light slashing with a fixed height clearing slasher and mulch raking. Pasture in Area 2 was dominated by Kikuyu and Broad-leaved Paspalum, which tend to be negatively associated with HJG occurrence due to their dense, matt forming growth habit. Nevertheless, the results show that a low cover-abundance of HJG can be established in Kikuyu and Broad-leaved Paspalum pasture if it is slashed before HJG introduction, creating gaps for HJG seedling establishment.

Effect of fertiliser

In Bays 2 and 3 seedlings were fertilised with organic fertiliser pellets when planted out. At end of season, the percent crown cover of HJG in Bays 2 and 3 (combined 2.21 ± 0.44) was significantly higher ($p = 0.012$) than in Bays 6 and 7 (combined 1.00 ± 0.18) that received no fertiliser.

Effect of slope position

In Area 2, HJG crown cover was significantly greater on the upper half of the experimental area (Table 5; Appendix 4), which is counter to the usual trend of HJG being more abundant on the lower slope. This can be explained by the very tall, broad-leaved weed regrowth, which resulted after clearing of Lantana from the lower half of the site. Some HJG was still able to grow to maturity in this habitat amongst

tall herbaceous weeds, reaching a height of 1-1.5m and leaning on other species for support (see Sec 3.5.3).

3.5.3 Broad-leaved weeds

The slashing treatments applied in Area 1 resulted in germination of very high densities of broad-leaved weed seedlings, particularly Ragweed (*Ambrosia artemesifolia*). As Ragweed can grow into a large plant over two meters tall, high densities of seedlings of this species were deemed to be a potential threat to establishment of HJG seedlings. To assess whether it was feasible to spray Ragweed and other species without damaging HJG seedlings, a broad-leaved weed killer ('Searles Lawn Weeder' - active constituents Mecoprop 97.8g/L, MCPA 23.1g/L and Dicamba 11.7g/L) was sprayed in test plots. Monitoring three weeks after herbicide application found that the HJG seedlings had turned yellow and looked unhealthy. It was therefore decided not to spray and to hand weed around patches of HJG seedlings.

Further monitoring showed that rather than being smothered, HJG seedlings kept up with the regenerating weed/pasture canopy as it increased in height. At end of season, HJG plants up to 1.5 meters tall were found in patches of tall Ragweed. These spindly plants had only one or a few stems (~2mm wide) and used Ragweed and other species for support. Similar tall growth of HJG has been observed near Pottsville in a population growing in tall *Setaria sphaecelata* grassland, another exotic pasture species (Benwell 2004).

3.5.4 Response of other species to site preparation treatments

Data on the species composition of the treatment bays at the start of the experiment, before conducting site preparation, and at the end of year 1 are presented in Appendix 5. Responses of some dominant perennial grasses and herbs to slashing with or without mulch removal were evident in this data and are summarised below.

Kikuyu (*Pennisetum clandestinum*) - the 'slash and leave mulch' treatment undertaken in Area 1, Bays 2 and 6 maintained roughly the same abundance of Kikuyu; slash and remove mulch undertaken in Area 1, Bays 3 and 7 caused a marked decline in Kikuyu.

Buffalo Grass (*Stenotaphrum secundatum*) - slashing undertaken in Area 1, Bays 1, 2, 3, 5, 6 and 7 caused a marked decline in Buffalo Grass whether mulch was left or removed.

Carpet Grass (*Axonopus compressus*) - slash and mulch removal undertaken in Area 1, Bays 3 and 7 caused a marked increase in Carpet Grass.

Broad-leaved Paspalum (*Paspalum wettsteinii*) - no slashing applied in Area 1, Bay 4 produced a marked increase in Broad-leaved Paspalum in 12 months; slashing produced a modest decrease.

Broad-leaved weeds - slashing undertaken in Area 1, Bays 1, 2, 3, 5, 6 and 7 produced a large increase in broad-leaved weeds, particularly Ragweed (*Artemesia*

ambrosioides) in the first year. Billy Goat Weed (*Ageratum houstonianum*) seedlings are slower to develop, but as seedling densities were high at the end of year one, this species is likely to increase over the site.

3.6 Results and Discussion - Year 2

3.6.1 HJG in Areas 1 and 2

The second year of the translocation experiment examined whether the HJG population established in the first year could be maintained by manipulating pasture structure so suitable ground layer conditions are formed for recruitment of the next generation of HJG plants. Slashing of Areas 1 and 2 was carried out in May 2011 at the end of its seeding period.

HJG crown cover increased markedly in all treatment bays in 2012 in response the slashing treatment applied at the end of the 2011 season (see Figures 3 to 5). Exclusion of grazing and above average rainfall conditions also probably contributed to the large increase in HJG. The slashing applied with the Posi-Track vehicle was a low slash, much the same as slashing with a tractor slasher or ride-on mower. The ground was soft and wet at the time and seed would have been pressed into the ground, possibly enhancing seed germination. Apart from the initial slashing, no other site management was applied. Cattle and other farm animals were excluded from the site.

HJG mean percent crown cover in Area 1 increased from 6-15% in Year 1 to 40-90% in Year 2, not including the control (Bay 4). Slashing of the control bay in Year 2 resulted in a mean crown-cover of approximately 20% compared with 0.24% in Year 1 (Figure 4). Slashing of Area 2 in the second year of the translocation experiment also resulted in a substantial increase in HJG cover-abundance. Mean percent crown cover of HJG increased from 1-2% in Year 1 to 8-26% in Year 2.

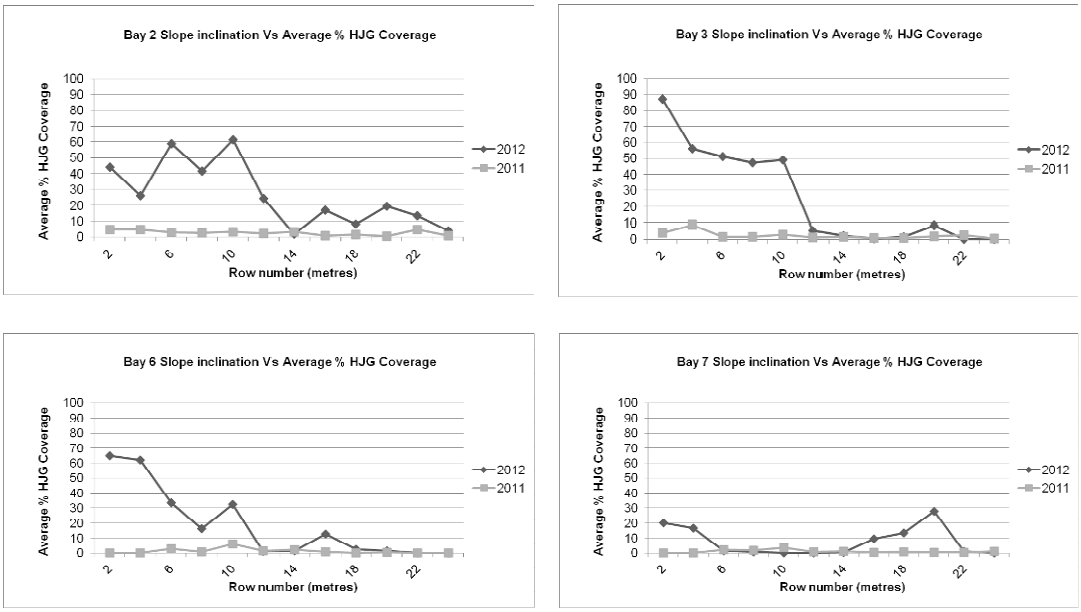
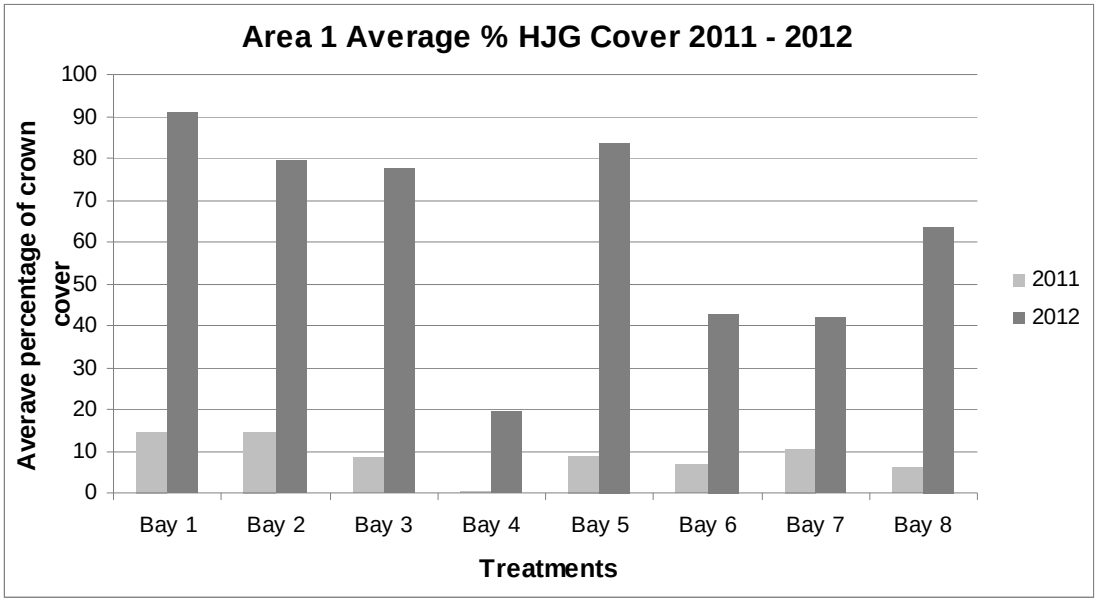


Figure 3: HJG average row crown cover recorded end-of-season in Bays 2, 3, 6 & 7 in Area 2. The graphs show mean percent crown cover down the slope (from left to right). Marked increase in HJG mean percent crown cover is evident in 2012 on the upper half of the slope and slight increase on the lower half.

Figure 4: HJG average row crown cover recorded end-of-season in Bays 1-8 in Area 1. Bay 4 was the control in Year 1 (no slashing Year 1, slashing Year 2). The graphs show mean percent crown cover down the slope (from left to right) in Area 1. There was a marked increase in HJG mean percent crown cover in the second year of the translocation experiment (2012).



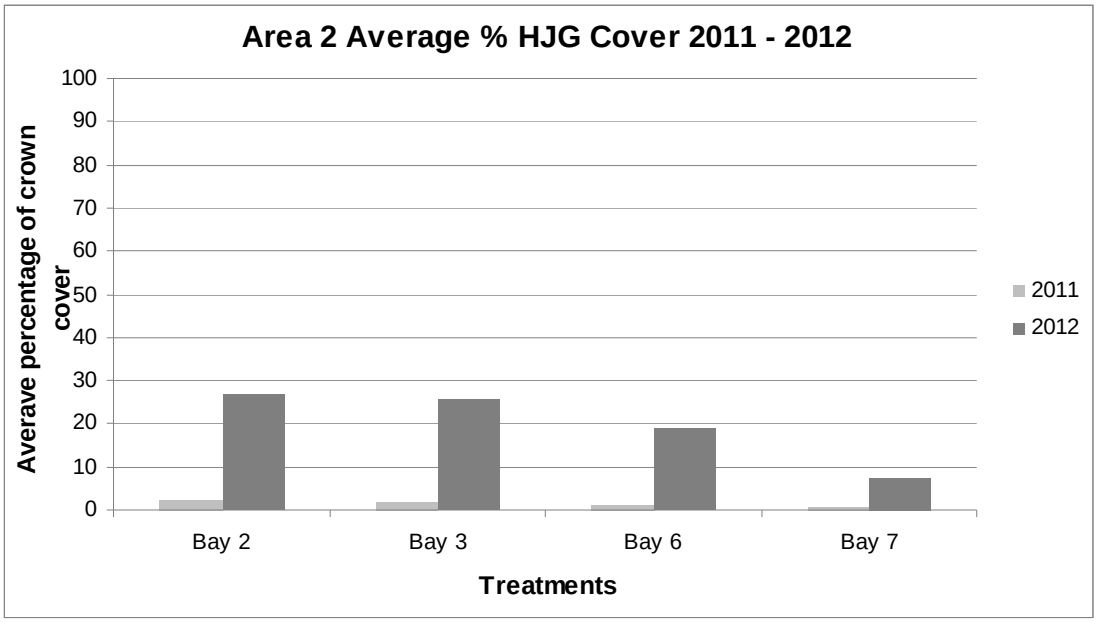


Figure 5: Bar charts showing difference in mean HJG crown-cover (per 2m x 1m cell) in treatment bays in Area 1 and Area 2, in 2011 and 2012.

Table 6: Mean HJG crown cover (± standard error) recorded autumn 2012 in whole bays and bays divided in half into upper slope and lower slope. The site preparation treatment applied in the bays in 2010 is indicated. The data is for Area 1 (introduction by direct seeding).

Bays **Treatment**	**All Bay**	**Upper Bay**	**Lower Bay**
Bay 1 ground slash, remove mulch	90.83 ± 2.31	89.83 ± 3.24	91.83 ± 3.09
Bay 2 mid-high slash, leave mulch	79.75 ± 3.28	76.50 ± 4.48	83.00 ± 4.80
Bay 3 mid-high slash, remove mulch	77.48 ± 3.84	76.37 ± 3.79	78.58 ± 5.58
Bay 4 control - no site preparation	19.43 ± 3.52	14.50 ± 4.05	24.37 ± 5.69
Bay 5 low slash, remove mulch	83.50 ± 3.67	96.00 ± 1.64	71.00 ± 6.23
Bay 6 mid-high slash, leave mulch	42.89 ± 4.69	51.92 ± 4.68	28.04 ± 5.63
Bay 7 mid-high slash, remove mulch	42.24 ± 4.65	48.95 ± 4.55	35.53 ± 6.60
Bay 8 spray herbicide (glyphosate)	63.69 ± 4.36	64.90 ± 5.92	62.48 ± 6.46

Table 7: Mean HJG crown cover (± standard error) recorded autumn 2012 in whole bays and bays divided in half into upper slope and lower slope. The site preparation treatment applied in the bays in 2010 is indicated. The data is for Area 2 (introduction by seedling plant-out)

Treatment **Bay**	**All Bay**	**Upper Bay**	**Lower Bay**
Bay 2	26.69 ± 3.90	42.70 ± 6.00	10.68 ± 2.89
Bay 3	25.70 ± 4.43	49.23 ± 6.38	2.17 ± 0.91
Bay 6	19.06 ± 3.67	35.08 ± 5.99	3.03 ± 1.12
Bay 7	7.61 ± 2.33	6.52 ± 3.57	8.70 ± 3.04

The increase in HJG mean crown cover in both Areas 1 and 2 appeared to be a result of the slashing treatment applied at the end of the HJG seeding season, creating favourable conditions for HJG seed germination and seedling establishment, combined with absence of cattle grazing and above average rainfall in both years of the translocation experiment. Monthly rainfall between June and December, which is the establishment phase of the HJG life cycle, was generally average to above average in both 2010-2011 and 2011-2012 (Figure 6).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2010	52.0	227.4	205.0	110.0	66.8	300.6	197.0	47.6	161.6	317.2	139.4	414.4	2239
2011	333.0	64.8	204.8	331.0	80.2	75.4	71.8	157.8	58.4	168.8	83.8	201.2	2030.6
2012	353.0	191.2	133.4										
Av.	174.8	194.6	215.3	183.0	173.7	197.4	119.6	92.8	67.4	108.8	124.4	142.9	1794.7

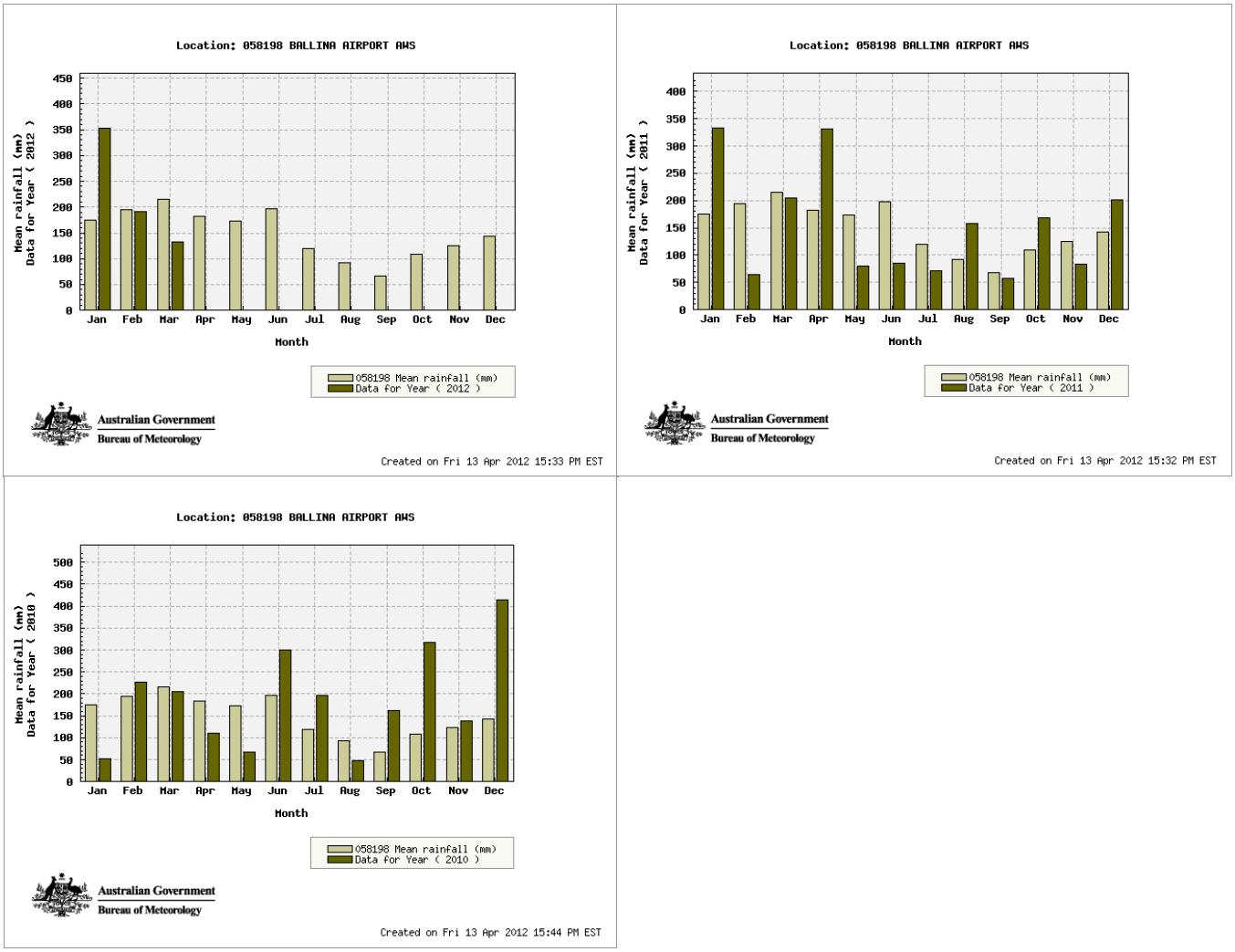


Figure 6: Monthly and mean monthly rainfall at Ballina Airport 2012, 2011 and 2010 (www.bom.gov.au).

3.6.2 Response of other species to pasture management

Area 1

There was general decrease in Ragweed (*Ambrosia artemisifolia*) and an increase in Carpet Grass (*Axonopus compressus*), Farmers Friend (*Bidens pilosa*) and some increase in Broad-leaved Paspalum (*Paspalum wettsteinii*). The abundance of other common grasses remained relatively constant - see Appendix 5. Species trends for each of the bays were as follows:-

Bay 1 - marked decrease in the crown cover of Billy Goat Weed (*Ageratum houstonianum*) and Ragweed (*Ambrosia artemisifolia*).

Bay 2 - moderate decrease in Ragweed (*Ambrosia artemisifolia*), increase in Carpet Grass (*Axonopus compressus*), Farmers Friend (*Bidens pilosa*) and Kikuyu (*Pennisetum clandestina*).

Bay 3 - decrease in Ragweed (*Ambrosia artemisifolia*), increase in Carpet Grass (*Axonopus compressus*) and increase in Broad-leaved Paspalum (*Paspalum wettsteinii*), although the latter species still uncommon in bay.

Bay 4 - increase in Ragweed (*Ambrosia artemisifolia*), as the control was not slashed in first year, increase in Carpet Grass (*Axonopus compressus*), increase in Farmers Friend (*Bidens pilosa*) and decrease in Buffalo Grass (*Stenotaphrum secundatum*).

Bay 5 - decrease in Ragweed (*Ambrosia artemisifolia*) and increase in Broad-leaved Paspalum (*Paspalum wettsteinii*).

Bay 6 - increase in Ragweed (*Ambrosia artemisifolia*), other dominant species more-or-less stable.

Bay 7 - increase in Ragweed (*Ambrosia artemisifolia*) and Farmers Friend (*Bidens pilosa*), other dominant species more-or-less stable.

Bay 8 - decrease in Ragweed (*Ambrosia artemisifolia*) and increase in Broad-leaved Paspalum (*Paspalum wettsteinii*).

Area 2

As in Area 1 there was general decrease in Ragweed (*Ambrosia artemisifolia*) and some increase in Broad-leaved Paspalum (*Paspalum wettsteinii*). Trends in each of the bays were as follows:-

Bay 2 - Billy Goat Weed decreased in lower half, Ragweed increased in the top half and decreased in the lower half, Broad-leaved Paspalum increased in the lower half.

Bay 3 - Ragweed increased in the top half and decreased in the lower half, Kikuyu (*Pennisetum clandestina*) decreased.

Bay 6 - Billy Goat Weed decreased in the lower half, Ragweed increased in the top half and decreased in the lower half, Broad-leaved Paspalum increased in the lower half.

Bay 7 - Ragweed increased in the top half and decreased in the lower half, Kikuyu decreased.

3.7 Management Recommendations for HJG in Pasture

One of the objectives of the translocation experiment was to develop management recommendations for conservation of HJG where it occurs in grazing pasture, as indicated by findings regarding habitat conditions and pasture management that promote HJG abundance and persistence. A factor potentially having a significant effect on HJG abundance that was not included in this study is grazing, which is commonly present in HJG locations. This study provided information on HJG response to site management in ungrazed pasture, which is potentially useful for management of HJG in road reserves or on conservation lands where cattle or other grazing animals are generally not permitted.

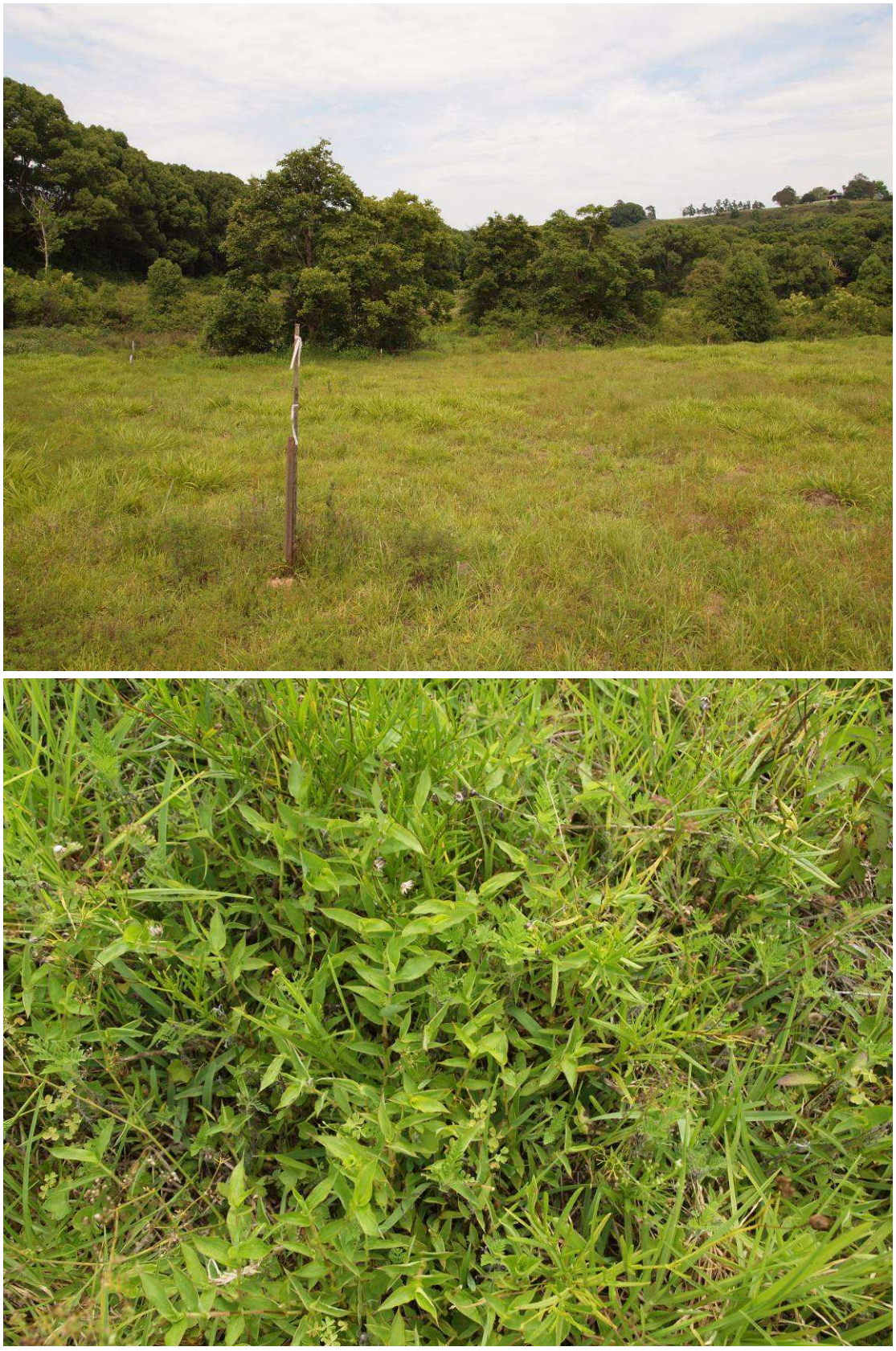
The results of the experimental translocation, including the second year site management trial, provided a clear indication of the conditions which are required to promote HJG abundance and persistence in pasture land. Being an annual grass species that persists by seed germination from year to year, the key to HJG persistence is manipulation of the structure of pasture habitat to create low, open conditions, preferably in winter when HJG seedlings germinate from seed produced by the previous generation. These conditions can be maintained by only one site management treatment per year, which consists simply of running a tractor slasher over the site. The optimum time for slashing appears to be late May or June straight after the HJG seeding period.

A vigorous HJG population can be conserved in ungrazed pasture habitat using the following management regime:-

- slash pasture habitat once a year preferably in late May or June;
- set slasher height as low as possible;
- slashing carried out under damp soil conditions may be preferable to dry, as seed is pressed into the soil potentially resulting in better germination;

Plates 9&10: Top - slashing Area 1 using a Posi-Track with front-mounted slasher in May 2011. Bottom - Area 1 after completion of pasture slashing, looking southeast from Bay 8 to Bay 1 in the background.

Plates 11&12: Top - Area 2 in May 2011 before application of slashing treatment. Bottom - slashing Area 2 with Posi-Track vehicle; the lower part of bays had very tall herbaceous regrowth.



Plates 13&14: Top - Area 1 in November 2011, six months after the end of season slashing treatment showing relatively short and open pasture structure. Bottom - close up of Kikuyu pasture with small HJG plants and other herbs in November 2011.

Plates 15&16: Top - Area 2 in November 2011, six months after the end of season slashing treatment showing pasture dominated by Broad-leaved Paspalum. Bottom - Area 2 showing young Ragweed seedlings in the foreground mixed with Kikuyu and Broad-leaved Paspalum.

Plates 17&18: Top - Area 1 in March 2012, Bay 1 on the left hand side, Bay 8 on the far right hand side. Bottom - dense area of HJG at the bottom of Bays 1 and 2, March 2012.

Plates 19&20: Top - monitoring grid in Area 1, March 2012. Bottom - HJG in Area 1 just starting to flower, March 2012.

Plates 21 & 22: Top - Area 2 in March 2012 with monitoring grid laid out over the top (upslope) end of Bays 2 and 3. Bottom - close up of HJG plants in Area 2 in March 2012, growing with Ragweed and Broad-leaved Paspalum.

4 MANAGEMENT OF HJG AT SANDY FLAT

4.1 Introduction

The 2010 workshop agreed that monitoring and management of a HJG population at Sandy Flat next to the highway construction zone be carried out during the two year conservation program. The purpose of this action was to ensure the site was properly protected and also for it to serve as an informal control to the translocation area, to compare HJG behaviour under natural environment conditions with HJG response in the translocation area.

The following management measures were implemented at the Sandy Flat HJG site: -

- Population monitoring
- Habitat maintenance
- Consideration of appropriate measures to ensure long-term protection of the Sandy Flat population.

4.2 Population monitoring

Monitoring was carried out at the Sandy Flat site to record the location and abundance of HJG plants, the species composition of the pasture plant community in which HJG occurs at Sandy Flat and general habitat conditions. Monitoring was undertaken at the start and end of the HJG season in 2010-2011 and 2011-2012. Other site inspections were conducted to monitor site conditions and the health of the HJG population.

4.3 Habitat maintenance

Slashing and manual removal of mulch was carried out on August 2010 when small HJG seedlings (1-3cm tall) were present on the site and again in 2011. The vegetation was slashed back to a height of 10-15cm and mulch raked into piles, which were left on site in case they contained seed. The aim of the maintenance was to increase HJG seed germination and seedling growth by reducing the height and density of the grass and herb plant community. This was carried out over an area covering approximately 70 meters x 30 meters, extending well upslope of the actual HJG occurrence.

4.4 Monitoring seedling emergence

<u>24/8/2010</u>
HJG seedlings were present under rank grass, roughly where HJG plants were present at the end of the preceding season. The seedlings were 1-3cm tall with 3-4 leaves. The seedlings were scattered for approximately 50 meters along the base of the northeast facing slope at the edge of a swampy, waterlogged zone along the bottom of the gully. Pasture on the opposite southwest facing slope was denser and taller and did not support HJG. The dominant grass species was Setaria (*Setaria sphacelata*) which appears to have colonised disturbed soil associated with the installation of a large power pole on top of the slope. Some Setaria has spread across to the opposite side of the drainage line where HJG was present. A selection of seedlings were marked with bamboo stakes to enable re-inspection and assessment of growth.

12/9/2010 - When inspected two and half weeks after slashing and mulch removal, the slashed dominant grasses were regenerating rapidly and there was a marked increase in HJG seedling density. The older seedlings including those marked with bamboo stakes were not adversely affected by the site maintenance.

4.5 Condition of the HJG population

A population of approximately 100 HJG plants was recorded at the Sandy Flat site in autumn 2012, as in the previous year, and a similar sized population was present when the site was first recorded in 2009. Details of the structure and species composition of the plant community are provided below. Some noticeable changes occurred between 2012 and 2011, including increased crown cover of Sour Grass (*Paspalum conjugatum*), the legume *Medicago* sp., Whiskey Grass (*Andropogon virginicus*), Harsh Ground Fern (*Hypolepis muelleri*), Setaria (*Setaria sphacelata*) and Blue Wandering Jew (*Tradescantia benghalensis*). These floristic changes may be related to the removal of grazing animals and above average rainfall over the last two years. When monitored in April 2012 some HJG plants were seeding and others were just coming into flower.

Sandy Flat HJG Site
Location: western side of the Pacific Highway (Ballina Bypass) approximately 30m from the roadside, extending 50 meters along lower reach of short drainage line. (GDA 551518,6813872).
Vegetation Type: rank grass and herbs, lantana, occasional small Camphor Laurel.
Substrate: podzol on metasediment probably influenced by basalt upslope.
Slope Position: lower/footslope
Slope Aspect: north-east
Slope Angle: 4^{o}
Grazing history: not grazed for approximately 5 years.
Quadrat Size: 50m x 20m

Date: 27/5/2011

Stratum	**Height (m)**	**Crown Cover (%)**	**Species 1**	**Species 2**	**Species 3**
Upper	0.5-1.5	100	**Paspalum urvillei*	**Paspalum dilatatum*	**Paspalum conjugatum*

Date: 6/4/2012

Stratum	**Height (m)**	**Crown Cover (%)**	**Species 1**	**Species 2**	**Species 3**
Upper	0.5-1.5	100	**Paspalum conjugatum*	**Medicago sp.*	**Setaria sphaecelata*

Botanical Name * exotic species	**Common Name**	**2011 Cover-abundance Class ****	**2012 Cover-abundance Class**
*Ageratina adenophorum	Crofton Weed	2	2
*Ageratina riparia	Mist Flower	1	1
*Ageratum houstonianum	Billy Goat Weed	3	3
*Andropogon virginicus	Whiskey Grass	2	3

*Axonopus affine	Carpet Grass	2	2
*Baccharis halimifolia	Groundsel Bush	-	1
*Bidens pilosa	Cobblers Pegs	1	2
*Crassocephalum crepidoides	Thickheads	2	2
*Cyperus pilosus	a sedge	2	2
*Gomphocarpus fruticosus	Balloon Flower	1	1
*Ipomoea cairica	Five-leaf Morning Glory	-	1
*Lantana camara	Lantana	1	2
*Medicago sp.	a legume	2	3
*Paspalum conjugatum	a grass	3	4
*Paspalum dilatatum	Paspalum	3	2
*Paspalum urvillei	Vasey Grass	3	3
*Paspalum wettsteinii	Broad-leaved Paspalum	2	2
*Pennisetum clandestinum	Kikuyu	2	2
*Senecio madagascarensis	Fireweed	2	1
*Setaria sphacelata	Setaria	1	3
*Tradescantia bengalensis	Blue Wandering Jew	-	2
*Verbena bonariensis	Purple Top	2	2
Arthraxon hispidus	Hairy Joint Grass	2	2
Commelina cyanea	Wandering Sailor	2	2
Cyclosorus interruptus	a fern	2	2
Cyperus polystachyos	Bunchy Sedge	2	1
Hypolepis muelleri	Harsh Ground Fern	1	3
Leersia hexandra	Swamp Rice Grass	3	3
Persicaria decipiens	Smartweed	2	2
Persicaria strigosa	Smartweed	2	2
Pteridium esculentum	Bracken Fern	1	1
Sacciolepis indica	Indian Cup Grass	3	3

**1- <5% crown cover, one or a few individuals; 2 <5% crown cover, any number of individuals; 3 5-25% crown cover; 4 26-50% crown cover; 5 51-75% crown cover; 6 76-100% crown cover.

Table 8: Coordinates (GDA) of HJP plants marking the extent of Sandy Flat population.

No.	Easting	Northing	Position	Topography
1	551518	6813872		minor gully
2	551520	6813867	2 m from 1, down drainage line	minor gully
3	551520	6813861	4 m from 2, down drainage line	minor gully
4	551522	6813866	5 m from 3, down drainage line	minor gully
5	551524	6813857	8 m from 4	minor gully
6	551520	6813857	12 m from 5, south	minor gully
7	551520	6813859	2 m from 6	minor gully
8	551514	6813853	10 m from 7	in standing water
9	551521	6813848	10 m from 8	minor gully
10	551493	6813873	15 m up drainage line from 1	minor gully

4.6 Incorporate into informal threatened species reserve

The 2010 workshop agreed that management of HJG on the Ballina Bypass should include addition of the HJG site at Sandy Flat, including its catchment, into the existing protection area covering an adjoining threatened flora translocation area and

surrounding rainforest restoration area on the western side of the new highway at Sandy Flat. Long-term conservation of this area could be achieved by retaining the land as RMS property, or attaching a protective covenant to the land if it is sold. Since the land supports several rare and threatened plant species it may also qualify for zoning as habitat protection under the Ballina Shire Council LEP.

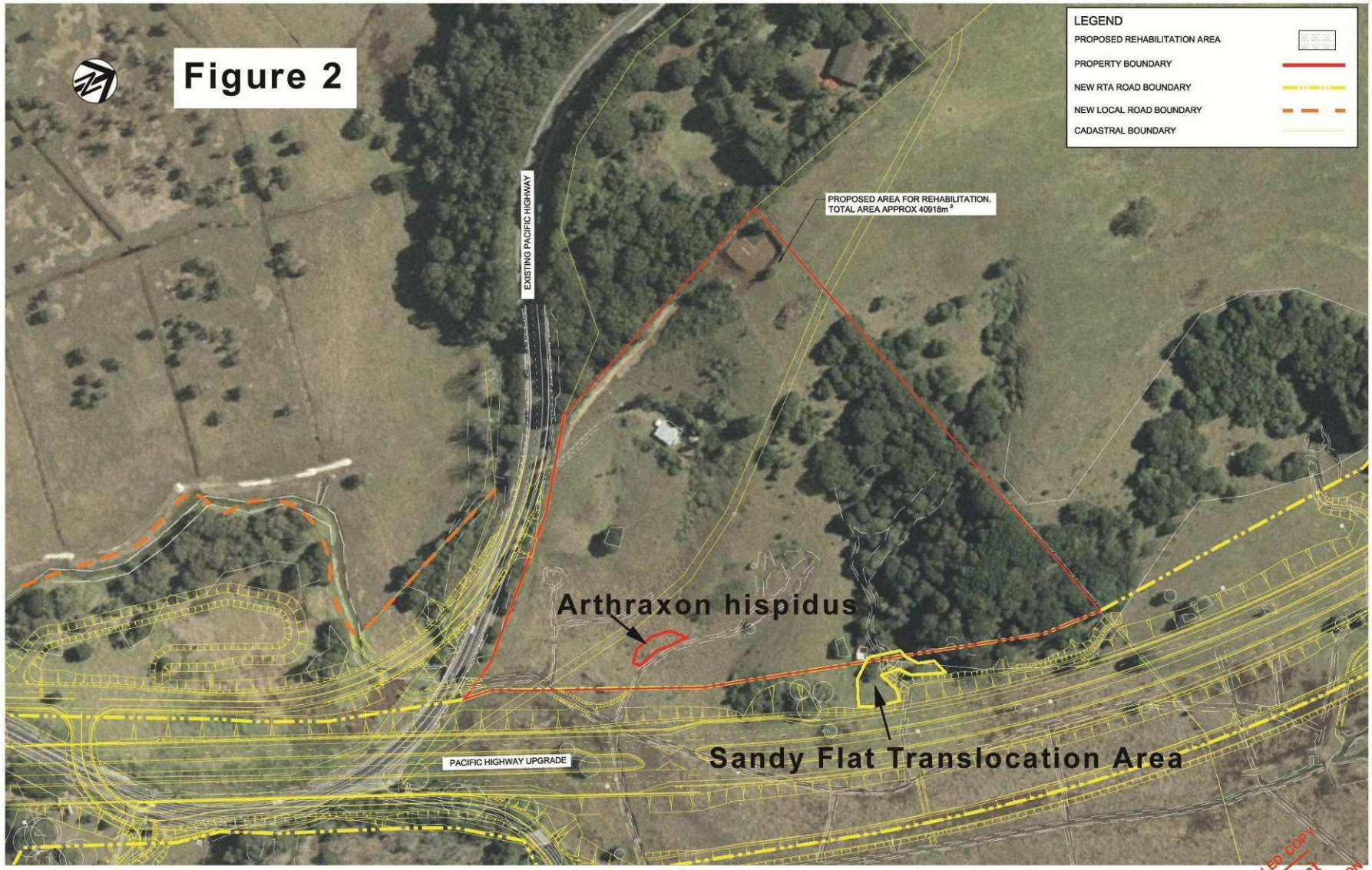


Figure 2
LEGEND
PROPOSED REHABILITATION AREA
PROPERTY BOUNDARY
NEW RTA ROAD BOUNDARY
NEW LOCAL ROAD BOUNDARY
CADASTRAL BOUNDARY
EXISTING PACIFIC HIGHWAY
PROPOSED AREA FOR REHABILITATION, TOTAL AREA APPROX 40918m²
Arthraxon hispidus
Sandy Flat Translocation Area
PACIFIC HIGHWAY UPGRADE
SCALE 1:2000 10 0 10 20 30 40 50
DRAWING FILE LOCATION / NAME
K:\Design\850_CAD\Info_Docs\Environmental\691826_Land_Rehab_Options\Option_1_1.dwg
PROPOSED FLORA REHABILITATION PLAN
OPTION 1.1
NOT FOR CONSTRUCTION
INFORMATION DOCUMENT
OPTION_1_1
UNCONTROLLED COPY
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Plates 23 &24: Top - Sandy Flat HJG site in April 2012 showing dense pasture regrowth. Bottom - close up of a HJG plant in pasture at the Sandy Flat site in April 2012. The broad-leaved herb is Billy Goat Weed (*Agertatum houstonianum*).

Plates 25 & 26: Top - The Sandy Flat HJG site in April 2012 looking from the gully containing HJG southeast to the new highway. Bottom - looking from the edge of highway west across a swale and into the small gully supporting the HJG population, April 2012.

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APPENDIX 1: End of season monitoring, autumn 2011 Area 1

Percent crown cover of HJG in treatment Bays 1 to 8

Crown Cover%	**Location: Area 1, Bay 1**					
	Treatment: Direct seed; hard slash, remove mulch					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	8	1	1	3	1	2.8
2	1	1	35	68	73	35.6
3	0.5	1	1	1	15	3.7
4	0.5	3	8	13	5	5.9
5	0	6	9	6	1	4.4
6	6	53	9	9	1	15.6
7	0	3	0	1	1	1
8	0	0	1	0.5	1	0.5
9	0	1	1	1	8	2.2
10	5	30	23	25	5	17.6
11	35	78	19	36	70	47.6
12	98	48	25	13	1	37

North

West **East**

South

Crown Cover%	**Location: Area 1, Bay 2**					
	Treatment: Direct seed; mid-high slash, leave mulch					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	1	43	1	1	53	1
2	0.5	0	0	0.5	1	0.5
3	1	1	0	0.5	1	1
4	0	0.5	1	1	0.5	0
5	0	0	1	1	2	0
6	0	23	13	16	10	0
7	1	14	7	0.5	0	1
8	68	90	11	16	0.5	68
9	18	5	0.5	0	0.5	18
10	6	0.5	0.5	0	0	6
11	0	1	1	20	5	0
12	0.5	55	100	83	85	0.5

North

West **East**

South

Crown Cover%	**Location: Area 1, Bay 3**					
	Treatment: Direct seed**,** mid-high slash, rake and remove mulch					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	0	0.5	1	0.5	0	0.4
2	1	2	13	29	1	9.2
3	0.5	1	0.5	2	1	1
4	1	1	1	10	0.5	2.7
5	10	2	4	10	1	5.4
6	1	1	2	8	1	2.6
7	0	6	9	10	1	5.2
8	0.5	5	48	10	36	19.9
9	51	5	14	44	26	28
10	5	1	15	65	68	30.8
11	0	0	4	0.5	1	1.1
12	15	5	0	0.5	0	4.1

North

West **East**

South

Crown Cover%	**Location: Area 1, Bay 4**					
	Treatment: Direct seed**, c**ontrol					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	0	0	0	0	0	0
2	0	0	0	0	0.5	0.1
3	0	0	0	0	0.5	0.1
4	0	0	0	0	0.5	0.1
5	0	0	0	0	1	0.2
6	0	0	0	0	0	0
7	0	0	0	0	0.5	0.1
8	0	0	0	0	0.5	0.1
9	0	0	0.5	1	0.5	0.4
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0.5	11	2.3

North

West **East**

South

Crown Cover%	**Location: Area 1, Bay 5**					
	Treatment: Direct seed, low slash, rake and remove mulch					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	8	5	0.5	0.5	0	2.8
2	0	13	30	7	1	10.2
3	6	18	17	5	5	10.2
4	1	1	2	6	0.5	2.1
5	10	33	9	50	30	26.4
6	6	20	28	13	23	18
7	3	9	10	4	3	5.8
8	0	1	8	0.5	0	1.9
9	0	0	5	0	0	1
10	0	1	1	1	0	0.6
11	1	28	9	5	0.5	8.7
12	1	1	1	1	0.5	0.9

North

West **East**

South

Crown Cover%	**Location: Area 1, Bay 6**					
	Treatment: Direct seed, mid-high slash, leave mulch					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	0	5	0.5	0.5	0	1.2
2	0	0	0	0	0	0
3	0	0	0	0.5	0.5	0.2
4	0	0	0	0	0	0
5	18	40	0.5	0	0.5	11.8
6	100	83	70	1	3	51.4
7	8	30	40	16	1	19
8	0	0	1	1	0	0.4
9	0	0	0	0.5	0	0.1
10	0	0	0.5	0	0	0.1
11	0	0	0.5	0	0	0.1
12	0	0.5	0	1	1	0.5

North

West **East**

South

Crown Cover%	**Location: Area 1, Bay 7**					
	Treatment: Direct seed, mid-high slash, rake and remove mulch					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	48	43	54	15	0	32
2	0	1	23	1	0.5	5.1
3	0	0	0.5	0	0	0.1
4	8	0	0.5	0	0	1.7
5	0	0	0	5	0.5	1.1
6	0	10	50	55	55	34
7	0	0.5	70	80	30	36.1
8	0.5	0	18	24	30	14.5
9	5	5	0	0	0	2
10	20	20	0.5	0	0	8.1
11	0	1	0	0	0	0.2
12	0	0	0.5	0	0	0.1

North

West **East**

South

Crown Cover%	**Location: Area 1, Bay 8**					
	Treatment: Direct seed, spray with glyphosate					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	65	40	0	0.5	8	22.7
2	0.5	0	0	0	0	0.1
3	34	50	48	8	0.5	28.1
4	13	16	20	35	4	17.6
5	1	1	0	0.5	0	0.5
6	3	1	0	0	0.5	0.9
7	0	0	0.5	0.5	0.5	0.3
8	1	4	6	1	4	3.2
9	1	1	0.5	0	0.5	0.6
10	0	0	0	0	0.5	0.1
11	1	1	1	5	0	1.6
12	13	1	0.5	0	0	2.9

North

West **East**

South

APPENDIX 2: End of season monitoring, autumn 2011 Area 2

Percent crown cover of HJG in treatment Bays 2, 3, 6 & 7

Crown Cover%	**Location: Area 2, Bay 2**					
	Treatment: Seedling plant-out, slash					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	0.5	15	5	1	1	4.5
2	15	0	1	4	4	4.8
3	1	5	1	5	3	3
4	0	0	1	3	9	2.6
5	5	3	0	9	0	3.4
6	5	0	5	0	0.5	2.1
7	4	6	5	0.5	0	3.1
8	0	0	0.5	1	3	0.9
9	1	0	0.5	1	5	1.5
10	0	0.5	0	0	1	0.3
11	1	13	9	0	0	4.6
12	2	1	0.5	0	0	0.7

North

West **East**

South

Crown Cover%	**Location: Area 2, Bay 3**					
	Treatment: Seedling plant-out, slash					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	1	1	1	0.5	13	3.3
2	5	0	1	19	41	13.2
3	0	0	0	0	1	0.2
4	0.5	0	0	0.5	0.5	0.3
5	0	0	1	1	8	2
6	1	0	0	0.5	0	0.3
7	0	0	0	0.5	0	0.1
8	1	1	1	0	0	0.6
9	0	0.5	0	0	0	0.1
10	13	1	1	0	0	3
11	0	1	0	0	0	0.2
12	0	0	0	0.5	0	0.1

North

West **East**

South

Crown Cover%	**Location: Area 2, Bay 6**					
	Treatment: Seedling plant-out, slash					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	0	0	0	0	0	0
2	0	0	0	0	0	0
3	1	1	1	0.5	10	2.7
4	0.5	1	0	2	0	0.7
5	5	5	10	9	2	6.2
6	1	4	0.5	1	0	1.3
7	0.5	0	9	1	1	2.3
8	1	1	0.5	0.5	1	0.8
9	0	0	0	0.5	0	0.1
10	0	0.5	0	0.5	1	0.4
11	0	0	0	0.5	0	0.1
12	0	0	0	0	0.5	0.1

North

West **East**

South

Crown Cover%	**Location: Area 2, Bay 7**					
	Treatment: Seedling plant-out, slash					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0.5	0	4	3	0	1.5
4	8	0	0	1	5	2.8
5	4	0	0	0	0	0.8
6	0	0	0	0	0	0
7	0.5	0	0	0	0	0.1
8	1	0	0	0	0	0.2
9	3	4	1	0	0	1.6
10	1	0.5	1	1	0	0.7
11	0	0	1	1	1	0.6
12	0	5	0	5	1	2.2

North

West **East**

South

APPENDIX 3: End of season monitoring, autumn 2012 Area 1

Percent crown cover of HJG in treatment Bays 1 to 8

Crown Cover%	**Location: Area 1, Bay 1**					
	Treatment: Direct seed; hard slash, remove mulch					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	100	100	100	100	100	100
2	95	85	95	100	100	95
3	40	55	35	100	100	66
4	75	100	80	100	100	91
5	80	100	100	95	75	90
6	100	100	100	95	90	97
7	60	100	80	100	90	86
8	90	100	100	100	100	98
9	15	100	100	100	100	83
10	55	100	100	85	95	87
11	100	100	100	100	100	100
12	100	100	100	95	90	97

North

West **East**

South

Crown Cover%	**Location: Area 1, Bay 2**					
	Treatment: Direct seed; mid-high slash, leave mulch					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	90	100	80	90	100	92
2	65	65	30	50	95	61
3	55	75	95	75	50	70
4	50	30	100	80	75	67
5	30	35	100	100	100	73
6	90	90	100	100	100	96
7	100	100	100	100	80	96
8	100	100	100	100	100	100
9	100	100	95	85	35	83
10	50	40	45	35	55	45
11	40	30	100	100	100	74
12	100	100	100	100	100	100

North

West **East**

South

Crown Cover%	**Location: Area 1, Bay 3**					
	Treatment: Direct seed**,** mid-high slash, rake and remove mulch					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	10	50	75	70	100	61
2	95	90	100	100	100	97
3	0	6	60	100	85	50.2
4	65	75	95	100	50	77
5	65	75	95	100	100	87
6	50	95	100	95	90	86
7	75	100	100	100	100	95
8	60	100	100	100	100	92
9	90	100	100	100	100	98
10	0.5	65	95	90	95	69.1
11	50	90	100	90	25	71
12	80	80	40	30	2	46.4

North

West **East**

South

Crown Cover%	**Location: Area 1, Bay 4**					
	Treatment: Direct seed**, c**ontrol					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	2	2	2	10	3.3	2
2	0.5	10	8	5	11.7	0.5
3	2	0.5	2	0.5	2	2
4	2	0.5	8	55	26.1	2
5	40	2	2	10	28.8	40
6	0.5	5	35	20	15.1	0.5
7	2	2	15	85	21.8	2
8	0	0	0.5	20	4.1	0
9	15	50	40	40	29.1	15
10	5	5	10	5	5	5
11	0.5	5	100	90	39.2	0.5
12	20	35	50	90	47	20

North

West **East**

South

Crown Cover%	**Location: Area 1, Bay 5**					
	Treatment: Direct seed, low slash, rake and remove mulch					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	100	100	100	100	80	96
2	100	100	100	100	80	96
3	100	100	100	100	90	98
4	35	100	100	100	100	87
5	100	100	100	100	100	100
6	100	100	100	100	95	99
7	50	90	100	100	50	85
8	10	90	55	25	10	38
9	75	100	100	55	0	66
10	40	80	95	90	25	66
11	100	100	100	85	15	80
12	95	100	100	100	95	98

North

West **East**

South

Crown Cover%	**Location: Area 1, Bay 6**					
	Treatment: Direct seed, mid-high slash, leave mulch					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	2	2	15	85	90	38.8
2	0.5	30	40	50	40	32.1
3	0	0.5	2	10	80	18.5
4	25	40	0.5	50	45	32.1
5	100	80	90	80	100	90
6	100	100	100	100	100	100
7	100	40	85	60	30	63
8	25	5	75	30	2	27.4
9	0	0	40	25	2	13.4
10	0	40	80	50	10	36
11	0	0	2	10	65	15.4
12	35	10	50	70	75	48

North

West **East**

South

Crown Cover%	**Location: Area 1, Bay 7**					
	Treatment: Direct seed, mid-high slash, rake and remove mulch					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	100	90	90	75	0.5	71.1
2	30	45	50	70	10	41
3	30	25	10	15	0.5	16.1
4	75	40	35	15	2	33.4
5	0.5	55	65	100	100	64.1
6	10	80	100	80	70	68
7	65	90	100	70	70	79
8	35	25	40	15	2	23.4
9	95	100	90	2	0	57.4
10	80	65	5	5	0.5	31.1
11	2	15	20	2	2	8.2
12	15	25	25	5	0.5	14.1

North

West **East**

South

Crown Cover%	**Location: Area 1, Bay 8**					
	Treatment: Direct seed, spray with glyphosate					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	90	85	25	15	100	63
2	80	35	35	50	50	50
3	90	100	90	100	50	86
4	95	90	90	95	90	92
5	100	80	10	2	5	39.4
6	30	85	75	65	40	59
7	80	100	100	100	95	95
8	85	80	75	85	60	77
9	100	15	10	5	100	46
10	95	55	50	30	80	62
11	100	100	50	40	0.5	58.1
12	30	50	90	2	12	36.8

North

West **East**

South

APPENDIX 4: End of season monitoring, autumn 2012 Area 2

Percent crown cover of HJG in treatment Bays 2, 3, 6 & 7

Crown Cover%	**Location: Area 2, Bay 2**					
	Treatment: Seedling plant-out, slash					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	15	30	5	90	80	44
2	30	5	30	50	15	26
3	85	80	15	55	60	59
4	5	60	65	70	8	41.6
5	80	100	95	30	2	61.4
6	60	50	2	2	7	24.2
7	2	2	5	0	0	1.8
8	10	20	40	15	0.5	17.1
9	30	5	0.5	0.5	5	8.2
10	10	7	60	20	0.5	19.5
11	55	7	0.5	0	5	13.5
12	10	5	0	0	5	4

North

West **East**

South

Crown Cover%	**Location: Area 2, Bay 3**					
	Treatment: Seedling plant-out, slash					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	90	60	90	100	95	87
2	30	15	65	85	85	56
3	50	15	35	75	80	51
4	0.5	25	75	85	50	47.1
5	10	20	55	60	100	49
6	0.5	20	2	2	2	5.3
7	5	2	2	2	0.5	2.3
8	0	0	0	0	2	0.4
9	0.5	0.5	5	0.5	0.5	1.4
10	0	0	8	10	25	8.6
11	0.5	0	0	0.5	0	0.2
12	0.5	0	0	0	0	0.1

North

West **East**

South

Crown Cover%	**Location: Area 2, Bay 6**					
	Treatment: Seedling plant-out, slash					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	90	80	70	40	45	65
2	90	95	40	70	15	62
3	55	2	35	50	25	33.4
4	40	15	10	15	2	16.4
5	50	95	15	2	1	32.6
6	0	5	0	0.5	0	1.1
7	0.5	5	0.5	0.5	0.5	1.4
8	2	20	15	2	25	12.8
9	0.5	2	5	0.5	5	2.6
10	0	5	0	0	2	1.4
11	0	0	0	0	0	0
12	0	0	0	0	0	0

North

West **East**

South

Crown Cover%	**Location: Area 2, Bay 7**					
	Treatment: Seedling plant-out, slash					
	Sample area: 5m x 25m					
	Date:4/5/2011					
Row No.	**1**	**2**	**3**	**5**	**4**	**Av**
1 (2m x 1m)	85	10	5	0.5	0	20.1
2	70	5	8	0	0	16.6
3	5	2	0.5	0	0	1.5
4	2	0	2	0	0	0.8
5	0	0	0	0	0.5	0.1
6	0	0	0	0	0	0
7	2	0	0	0	0	0.4
8	5	40	0.5	0	2	9.5
9	60	2	2	2	0.5	13.3
10	40	15	25	50	10	28
11	0	0	0	5	0	1
12	0	0	0	0	0	0

North

West **East**

South

APPENDIX 5: Plant species composition in treatment bays in Areas 1 and 2

Plant species composition was recorded at the start of the translocation experiment, before conducting site preparation (10/6/2012) and at the end of Year 1 (5/5/2011) and Year 2 (2012). The bays were divided into northern (upslope) and southern (downslope) halves for recording species composition. The values are percent crown cover.

AREA 1	10/06/2010	10/06/2010	5/05/2011	5/05/2011	/03/2012	/03/2012
Bay 1 close cut remove mulch	Nth half	Sth half	Nth half	Sth half	Nth half	Sth half
Ageratum houstonianum	7	2	5	25	1	1
Ambrosia artemisifolia (alive)	0.5	0.5	90	75	1	5
Ambrosia artemisifolia (dead)	75	75				
Axonopus compressus	10	5	40	50	50	20
Bidens pilosa	0.5	0.5	0.5	1	1	1
Digitaria dydactyla	25	1	1		20	10
Gomphocarpus fruticosus	0.5		0.5		0.5	
Lantana camara	0.5					0.5
Paspalum conjugatum					0.5	
Paspalum dilatatum	10					
Paspalum urvillei		0.5		1		0.5
Paspalum wettsteinii	10	2	7	1	15	10
Pennisetum clandestinum	70	80	2	25		60
Senecio madagascarensis	0.5		0.5		0.5	0.5
Stenotaphrum secundatum	2	15				
Verbena bonariensis	0.5			0.5	0.5	0.5
Vicia fabra	0.5					
Digitaria aff parviflora			10	1		
Fimbrystylis dichotoma			0.5			
Clover			0.5		0.5	
Microlaena stipoides			1			
Carex inversa			2	10		
Paspalidium distans			1			
Conyza bonariensis				0.5	0.5	0.5
Glycine clandestina				0.5		
Andropogon virginicus				0.5		0.5
Centella asiatica					0.5	1
Cyperus sesquiflorus					0.5	0.5
	10/06/2010	10/06/2010	5/05/2011	5/05/2011	15/03/2012	15/03/2012
Bay 2 cut leave mulch	Nth half	Sth half	Nth half	Sth half	Nth half	Sth half
Ageratina adenophorum		1				
Ageratina riparia		0.5				
Ageratum houstonianum	4	0.5	1	5		
Ambrosia artemisifolia (alive)	0.5	0.5	60	60	30	40
Ambrosia artemisifolia (dead)	70	70				
Axonopus compressus	10	10	20	10	60	30
Bidens pilosa	0.5	1	1	1	5	15
Cinnamomum camphora		0.5		0.5		
Cyperus sp.	0.5					
Digitaria dydactyla	20	2	15	2	15	1
Gomphocarpus fruticosus	0.5		0.5			
Hypolepis muelleri		1				

Paspalum dilatatum	15	2			20	2
Paspalum urvillei		0.5		0.5		0.5
Paspalum wettsteinii	5	2	7	5	20	5
Pennisetum clandestinum	50	70	10	20	5	50
Senecio madagascarensis	2	1	0.5	0.5	0.5	0.5
Sida rhombifolia	0.5		0.5		0.5	
Stenotaphrum secundatum	15	20	10	15		
Verbena rigida	0.5	0.5	0.5			0.5
Clover			1		0.5	
Digitaria aff parviflora			1	1		
Fimbrystylis dichotoma				0.5		
Centella asiatica				1	1	1
Verbena bonariensis				0.5		
Glycine clandestina				0.5		
Carex inversa				1		
Conyza bonariensis				0.5	0.5	0.5
Lantana camara				0.5		
Cyclosorus interrupta				0.5		
Verbena bonariensis					0.5	0.5
	10/06/2010	10/06/2010	5/05/2011	5/05/2011	15/03/2012	15/03/2012
Bay 3 mid high cut remove mulch	Nth half	Sth half	Nth half	Sth half	Nth half	Sth half
Ageratum houstonianum					0.5	0.5
Ambrosia artemisifolia (alive)	0.5	0.5	70		5	15
Ambrosia artemisifolia (dead)						
Axonopus compressus	10	10	40	15	60	50
Bidens pilosa	0.5	2	4	1	1	10
Centella asiatica	0.5			1		
Digitaria dydactyla	10	5	5	15		
Gomphocarpus fruticosus	0.5		0.5			
Paspalum dilatatum	15	10			30	10
Paspalum wettsteinii	3	0.5	5	1	10	10
Pennisetum clandestinum	40	20	30	10		
Senecio madagascarensis	1	0.5	1	1	0.5	0.5
Sida rhombifolia	0.5	0.5	0.5			
Stenotaphrum secundatum	40	80	5	65		
Trifolium repens	0.5				0.5	
Oxalis corniculata			1		0.5	
Cyperus sesquiflorus			1			
Ageratum houstonianum			1	1		
Cyclosorus interruptus				0.5		
Oplismenus aemulus				1		
	10/06/2010	10/06/2010	5/05/2011	5/05/2011	15/03/2012	15/03/2012
Bay 4 control	Nth half	Sth half	Nth half	Sth half	Nth half	Sth half
Ageratum houstonianum	0.5	1	1	1	0.5	0.5
Ambrosia artemisifolia (alive)	0.5	0.5	25	50	60	80
Ambrosia artemisifolia (dead)	60	70				
Axonopus compressus	10	15	5	5	5	40
Cyperus polystachyos	0.5					
Digitaria dydactyla	20	5	10			
Paspalum wettsteinii	0.5	3	7	15	15	30
Pennisetum clandestinum	85	30	70	30	80	20
Senecio madagascarensis	0.5	1	1	0.5	0.5	0.5

Sida rhombifolia		0.5	0.5		0.5	
Stenotaphrum secundatum	20	70	40	70		40
Verbena bonariensis	0.5			0.5		
Bidens pilosa			1	1	15	10
Gomphocarpus fruticosus			0.5			
Carex inversa			1			
Rumex crispus			0.5			
Oxalis corniculata			0.5			
Ageratum riparia				0.5		
Persicaria strigosa				0.5		
Trifolium repens					0.5	0.5
Centella asiatica					0.5	0.5
Verbena bonariensis					0.5	0.5
Vicia fabra					0.5	
Paspalum dilatatum					2	5
Conyza bonariensis					0.5	0.5
	10/06/2010	10/06/2010	5/05/2011	5/05/2011	15/03/2012	15/03/2012
Bay 5 close cut remove mulch	Nth half	Sth half	Nth half	Sth half	Nth half	Sth half
Ageratum houstonianum		2	1	1	1	1
Ambrosia artemisifolia (alive)	0.5	0.5	90	60	10	5
Ambrosia artemisifolia (dead)						
Axonopus compressus	10	10	20	40	20	60
Bidens pilosa	0.5	0.5	1	5	0.5	0.5
Centella asiatica	0.5		1	1	1	0.5
Gomphocarpus fruticosus	0.5		0.5		0.5	0.5
Paspalum conjugatum		0.5				
Paspalum dilatatum	2	10			0.5	0.5
Paspalum wettsteinii	0.5	15	1	15	2	30
Pennisetum clandestinum	40	20	60	30	70	50
Pratia purpurascens	0.5	0.5		0.5		
Senecio madagascarensis	0.5	0.5	1	1	0.5	0.5
Sida rhombifolia	0.5					
Stenotaphrum secundatum	60	70	5	5		25
Verbena bonariensis	0.5	0.5			0.5	
Vicia fabra	0.5					
Conyza bonariensis			0.5	1	0.5	0.5
Oxalis corniculata			1	1		
Paspalidium distans			1			
Paspalum conjugatum			1			
Cyperus sesquiflorus				0.5		0.5
Cyperus polystachyos					0.5	
Glycine clandestina						0.5
	10/06/2010	10/06/2010	5/05/2011	5/05/2011	15/03/2012	15/03/2012
Bay 6 cut leave mulch	Nth half	Sth half	Nth half	Sth half	Nth half	Sth half
Ageratum houstonianum	0.5	1		1	0.5	1
Ambrosia artemisifolia (alive)	0.5	0.5	15	60	30	85
Ambrosia artemisifolia (dead)						
Axonopus compressus	10	10	20	40		25
Bidens pilosa	0.5	0.5	2	3	20	5
Centella asiatica	0.5	0.5	1	1	1	2
Chloris gayana	0.5	0.5		1		5
Gomphocarpus fruticosus	0.5	0.5				

Paspalum dilatatum	2	5			0.5	1
Paspalum wettsteinii	0.5	10	1	30	2	20
Pennisetum clandestinum	60	20	90	5	95	1
Pratia purpurascens	0.5	0.5	1	1	0.5	
Senecio madagascarensis	0.5	0.5	1	1		
Sida rhombifolia		0.5				
Solanum prinophyllum	0.5	0.5		0.5		
Stenotaphrum secundatum	40	80	5	50		60
Geranium solanderi			0.5			
Solanum prinophyllum			0.5			
Cyperus sesquiflorus			1		1	
Vicia fabra				0.5		
Conyza bonariensis				1	0.5	0.5
Crassocephalum crepidoides				0.5	0.5	
Hydrocotyle acutiloba				0.5		
Cyperus sesquiflorus				0.5		
Carex inversa					0.5	
Glycine clandestina					0.5	0.5
Hypocheirus radicata						0.5
	10/06/2010	10/06/2010	5/05/2011	5/05/2011	15/03/2012	15/03/2012
Bay 7 mid high cut remove mulch	Nth half	Sth half	Nth half	Sth half	Nth half	Sth half
Ageratum houstonianum	5	0.5	5			
Ambrosia artemisifolia (alive)	2	1	25	15	30	55
Ambrosia artemisifolia (dead)						
Axonopus compressus	10		15	10	2	10
Bidens pilosa	0.5	2	2	10	15	15
Chloris gayana		15		40	1	15
Digitaria dydactyla		5		10		15
Paspalum wettsteinii	0.5	25	2	15	5	10
Pennisetum clandestinum	50	70	55	40	90	55
Pratia purpurascens	0.5		1		0.5	0.5
Senecio madagascarensis	0.5	0.5	2	2	0.5	0.5
Stenotaphrum secundatum	50	15	40	5	0.5	
Verbena bonariensis	0.5	0.5			0.5	
Centella asiatica			0.5		1	0.5
Commelina cyanea			2		0.5	
Hydrocotyle acutiloba			2		0.5	
Axonopus compressus				3		
Conyza bonariensis					0.5	0.5
Crassocephalum crepidoides					0.5	
Cyperus sequiflorus					0.5	0.5
Oplismenus aemulus					0.5	
Paspalum dilatatum					0.5	0.5
	10/06/2010	10/06/2010	5/05/2011	5/05/2011	15/03/2012	15/03/2012
Bay 8 spray	Nth half	Sth half	Nth half	Sth half	Nth half	Sth half
Ageratum houstonianum	10	3	2	2	1	0.5
Ambrosia artemisifolia (alive)	0.5		70	20	5	15
Ambrosia artemisifolia (dead)	2	2				
Andropogon virginicus	0.5				0.5	
Bidens pilosa	0.5	2	20	15	5	5
Chloris gayana	20	80	50	65	40	60
Commelina cyanea		0.5		2		

Guioa semiglauca		0.5				
Paspalum wettsteinii	5	2	20	15	65	15
Pennisetum clandestinum	60	20	0.5			
Stenotaphrum secundatum	5					
Lantana camara			0.5		0.5	
Phytolacca octandra			0.5		0.5	
Pratia purpurascens			1			
Carex inversa			2	2		
Commelina cyanea			2			
Centella asiatica			0.5		0.5	1
Oxalis corniculata					0.5	
Cyperus sesquiflorus					0.5	0.5
Axonopus compressus						2
Paspalum urvillei						0.5

AREA 2	5/05/2011	5/05/2011	15/03/2012	15/03/2012		
Bay 2	Nth half	Sth half	Nth half	Sth half		
Ageratum houstonianum	2	55	2	5		
Ambrosia artemisifolia (alive)	10	60	65	25		
Bidens pilosa	5	2	2	5		
Carex inversa	5	20				
Commelina cyanea	2					
Gomphocarpus fruticosus	0.5					
Oplismenus aemulus	2	2				
Paspalum urvillei	0.5					
Paspalum wettsteinii	100	45	95	70		
Pennisetum clandestinum	5	2				
Setaria sphacelata	0.5	15				
Digitaria aff parviflora		2				
Axonopus compressus		2				
Ageratina riparia		0.5				
Salvinia coccinia		0.5				
Glycine clandestina		0.5				
Cyperus sesquiflorus		2				
Digitaria dydactyla		2				
Sigesbeckia orientalis		0.5				
Senecio madagascarensis			0.5	0.5		
Verbena rigida			0.5	0.5		
Verbena bonariensis			0.5	0.5		
Oxalis corniculata			0.5	0.5		
Centella asiatica			0.5	0.5		
Cynodon dactylon			0.5			
Juncus ursitatus			0.5			
	5/05/2011	5/05/2011	15/03/2012	15/03/2012		
Bay 3	Nth half	Sth half	Nth half	Sth half		
Ageratum houstonianum	5	10				
Ambrosia artemisifolia (alive)	2	15	70	5		
Axonopus compressus	0.5		0.5			
Bidens pilosa	1	2	1	2		
Centella asiatica	2		0.5	0.5		
Commelina cyanea	1		0.5	0.5		
Cyperus sesquiflorus	0.5		0.5			

Drynaria cordata	0.5					
Oxalis corniculata	0.5					
Paspalum wettsteinii	50	80	80	90		
Pennisetum clandestinum	80		35			
Senecio madagascarensis	0.5		0.5			
Setaria sphacelata		0.5		0.5		
Ageratina riparia		2				
Glycine clandestina		0.5				
Ligustrum sinensis		0.5		0.5		
Salvia coccinia		0.5		0.5		
Carex inversa		10				
Oxalis corniculata			0.5	0.5		
Trifolium repens			0.5			
Sigebeckia orientalis				0.5		
Verbena bonariensis				0.5		
Juncus ursitatus			0.5	0.5		
Cinnamomum camphora				0.5		
Solanum mauritanicum				0.5		
Cirsium vulgare				0.5		
Cyperus gracilis				0.5		
	5/05/2011	5/05/2011	15/03/2012	15/03/2012		
Bay 6	Nth half	Sth half	Nth half	Sth half		
Ageratum houstonianum	2	10	0.5	0.5		
Ambrosia artemisifolia (alive)	5	15	60	25		
Bidens pilosa	2	2	5	1		
Gomphocarpus fruticosus	0.5					
Oplismenus aemulus	2		0.5	0.5		
Paspalum wettsteinii	80	50	95	35		
Pennisetum clandestinum	20		1	0.5		
Senecio madagascarensis	0.5		0.5			
Setaria sphacelata		10		25		
Sida rhombifolia		0.5				
Ageratina riparia		10				
Carex inversa		5				
Sigesbeckia orientalis		30		0.5		
Toona ciliata		0.5		0.5		
Verbena bonariensis			0.5			
Centella asiatica			0.5	0.5		
Axonopus compressus				0.5		
Oxalis corniculata				0.5		
Conyza bonariensis				0.5		
Solanum mauritanicum				2		
Lantana camara				0.5		
Ageratina riparia				5		
Passiflora subpeltata				0.5		
Glycine large leaved				1		
Cyperus gracilis				0.5		
	5/05/2011	5/05/2011	15/03/2012	15/03/2012		
Bay 7	Nth half	Sth half	Nth half	Sth half		
Ageratum houstonianum	2	10	0.5	0.5		
Ambrosia artemisifolia (alive)	2		15	30		
Bidens pilosa	2	2	0.5	0.5		

Drynaria cordata	0.5					
Paspalum wettsteinii	100	70	95	80		
Pennisetum clandestinum	5		3	0.1		
Ambrosia artemisifolia (alive)		70				
Carex inversa		10				
Sigesbeckia orientalis		15				
Oplismenus aemulus		2				
Sida rhombifolia		1				
Ageratina riparia		10		5		
Commelina cyanea		2				
Verbena bonariensis			0.5			
Senecio madagascarensis			0.5			
Commelina cyanea		0.5	0.5			
Centella asiatica		0.5	0.5			
Conyza bonariensis		0.5	0.5			
Oxalis corniculata		0.5	0.5			
Lantana camara		0.5				
Oplismenus aemulus		0.5	0.5			
Solanum mauritanicum				3		
Ageratina adenophorum				1		
Sida rhombifolia				0.5		
Crassocephalum crepidoides				0.5		
Juncus ursitatus				0.5		
Geranium solanderi				0.5		
Persicaria lapathifolia				0.5		
Cyperus gracilis				0.5		

APPENDIX 6: Statistical analysis outputs

T-test Area 2 bays 2 and 3 split into upper and lower

Two-sample T for upper vs lower Bays 2 and 3 combined

	N	Mean	StDev	SE Mean
upper	120	3.21	8.94	0.82
lower	120	1.21	3.61	0.33

Difference = mu upper - mu lower
Estimate for difference: 2.004
95% CI for difference: (0.265, 3.743)
T-Test of difference = 0 (vs not =): T-Value = 2.28 P-Value = 0.024 DF = 156

Chi-Square Test: Chi-square on Area 2 bays 2 and 3 upper and lower, cover classes 0, 1, 2 and 3, too many zeros in other cover classes, violates test condition

Expected counts are printed below observed counts

	C1/0	C2/1	C3/2	C4/3	Total
1	61	21	15	21	118
	71.39	16.86	14.87	14.87	
2	83	13	15	9	120
	72.61	17.14	15.13	15.13	
Total	144	34	30	30	238

Chi-Sq = 1.513 + 1.018 + 0.001 + 2.523 +
1.488 + 1.001 + 0.001 + 2.481 = 10.027
DF = 3, P-Value = 0.018

1 = upper
2 = lower (more zeros in lower.....)

Two-Sample T-Test and CI: upper, lower Area 2, bays 6&7

Two-sample T for upper vs lower

	N	Mean	StDev	SE Mean
upper	120	1.36	3.53	0.32
lower	120	0.65	1.81	0.17

Difference = mu upper - mu lower
Estimate for difference: 0.708
95% CI for difference: (-0.006, 1.423)
T-Test of difference = 0 (vs not =): T-Value = 1.96 P-Value = 0.052 DF = 177

no significant difference but mean is higher on the upper again - more sdlgs planted.

Chi-Square Test: Area2, Bays 6&7

Expected counts are printed below observed counts

	C1	C2	C3	C4	Total
upper	85	9	13	13	120
	84.50	13.50	13.00	9.00	

```
    lower   84       18       13        5      120
         84.50    13.50    13.00     9.00

Total      169       27       26       18      240

Chi-Sq =  0.003 +  1.500 +  0.000 +  1.778 +
          0.003 +  1.500 +  0.000 +  1.778 = 6.561
DF = 3, P-Value = 0.087
```

Two-Sample T-Test and CI: Area 2 all 2&3, all 6&7

```
Two-sample T for all 2&3 vs all 6&7

           N      Mean     StDev   SE Mean
all 2&3  240      2.21      6.88      0.44
all 6&7  240      1.00      2.82      0.18

Difference = mu all 2&3 - mu all 6&7
Estimate for difference:  1.206
95% CI for difference: (0.262, 2.150)
T-Test of difference = 0 (vs not =): T-Value = 2.51  P-Value = 0.012  DF =
317
```

APPENDIX 7: *Arthraxon hispidus* (Hairy Joint Grass) Species Profile

Conservation status
Hairy Joint Grass (*Arthraxon hispidus*) is listed as a threatened species under the NSW Threatened Species Conservation Act 1995 and the Commonwealth Environment Protection and Biodiversity Conservation Act 1999.

Distribution
HJG occurs in the North Coast region of NSW between Kempsey and Queensland border and from the coast west to the eastern edge of the New England Tableland. The great majority of known locations are from the Far North Coast, north of the Richmond River. HJG also occurs in Queensland.

Life history
HJG is described in the Flora of NSW as a perennial (Harden 1993), however monitoring has shown that *Arthraxon hispidus* is annual (ECOS Environmental 2004; 2007; 2010), at least on the North Coast of NSW. Plants flower and produce seed in autumn then the whole plant dies. Occasional plants may be seen persisting longer if flowing is suppressed by slashing or grazing. Monitoring found that seed germinates in winter after a short dormancy period. Seedling density can be sparse to very high (1000+ seedlings/m²), depending on the amount of seed produced. Small seedlings are able to survive the dry spring period under taller, perennial grasses even when rainfall is well below average, although considerable thinning of seedling numbers occurs (Benwell 2010). Various factors can suppress and delay seed germination including cold temperatures, dense pasture and shading. If slashing covers HJG seed with a thick layer of mulch, germination is inhibited well into spring or early summer until the mulch breaks down. Growth rate increases in summer with the onset of the rainy season and peaks in autumn. Mature HJG plants are shallow rooted and lack rhizomes or swollen stem bases found in perennial grass species. A seed burial study showed that approximately 5% of seed buried in sachets retained viability after three years (ECOS Environmental 2012), therefore it would be possible for a HJG population to re-appear on a site if above ground plants were temporarily lost due to unfavourable growing conditions (e.g. dense ground layer regrowth).

Habitat
The habitat of HJG is described as rainforest in the Flora of NSW (Harden 1993) and as rainforest, eucalypt forest and woodland in Leigh *et al.* (1984). However, nearly all extant populations of HJG occur in cleared, treeless grazing land. The description of habitat as rainforest seems very unlikely and may derive from collection information on old herbarium labels, which indicate the specimen was collected near rainforest (since cleared) rather than within it. Typically, the pasture habitat of HJG is regularly grazed, low in height (0.3 - 0.6 m) and dominated by perennial, exotic grasses. There are very few occurrences of HJG in what could be called natural habitat. To the writer's knowledge, out of about 30 known populations on the North Coast of NSW only one occurs in natural vegetation, a woodland site west of Grafton. This situation is unique for a threatened species and not easily explained. Possible explanations for the unusual habitat of HJG include:-

- the core habitat of HJG near springs and seepages coincides with prized and intensively utilised sites within grazing land, therefore areas of such habitat unmodified by human activity (ie. in pre-European condition) are very rare;
- the species has adapted to grazing land, effectively widening it niche;
- HJG was originally a short-lived, species that appeared after fire, but due to the cessation of regular burning in its grazed habitat, post-fire populations are rarely seen today (one was observed by the writer after a fire near Boambee south of Coffs Harbour).
- HJG is actually an exotic species introduced after settlement with the transport of livestock and goods and dispersed locally by soil adhering to hoofs or in the gut of animals.

Extensive observation of HJG distribution in the local district shows that HJG prefers lower slopes in hilly terrain where ground-water seepage and capillary water rise maintain damp to boggy soil conditions during most of the year, particularly during the west season (January to June). Usually these sites do not extend into the flood zone at the bottom of valleys, apparently because flood scour away shallow rooted HJG plants and seed. Under moderate grazing pressure and above average spring to summer rainfall (which favour seedling establishment), HJG may expand beyond its core lower slope habitat zone to mid and upper slopes with a southeast to southwest aspect.

The original habitat of HJG may have been springs and seepages in open forest adjoining rainforest, rather than inside rainforest, as the species appears to require a well-lit understorey. Aboriginal burning may have played an important role in preventing rainforest encroachment and maintaining open habitat conditions suitable for the species. The great majority of HJG populations are presently located on cleared grazing land, with a concentration between Ballina, Byron Bay, Lismore and foothills of the Nightcap Range within the area of the former Big Scrub rainforest. The species presence in areas that were probably continuous rainforest suggests that HJG may have expanded its distribution since settlement, and that man-made, grazing habitat may have favoured this expansion. HJG is associated mostly with high rainfall country (1200-1800mm) and moderate to high soil fertility.

Seed dormancy and germination
Germination trials found that HJG seed has an innate dormancy period of 1-2 months after seed maturation. This correlated with the pattern of germination seen under field conditions, which occurred 1-2 months after seed production and plant die-off (ECOS Environmental 2010). Induced dormancy may result from absence of light, warmth (comparative) and moisture, which are all necessary to initiate seed germination. Absence of any one of these factors will result in induced seed dormancy.

Seed can remain viable within the topsoil or beneath dense grass vegetation for at least three years. Some seed retained viability after burial of seed in nylon sachets for 12 months. Dry storage of seed under ambient temperature conditions for 12 months reduced seed viability by about 50%.

Effect of grazing and land management
Studies at Koala Beach near Pottsville indicated that the persistence of HJG in cleared pastureland is dependent on biomass removal by grazing animals and maintenance of

gaps in ground layer vegetation where seed germination and seedling establishment can occur (ECOS Environmental 2004). Pasture height and density increase rapidly under the regions high rainfall when grazing animals are excluded. The build up of vegetation and litter shades the ground layer and inhibits seed germination, resulting in population contraction. Trials in which biomass removal was reintroduced in the form of slashing and mulch removal at two locations with contracting populations, produced a marked increase in both populations (ECOS Environmental 2004 and 2007).

Overall, research results indicate that the abundance of HJG within a given area of grazed pasture is likely to fluctuate in response to variation in grazing intensity through the effect of grazing on vegetation structure. Monitoring has shown that HJG is not favoured as a fodder plant by cattle, often being left ungrazed, but in more intensively grazed paddocks direct grazing occurs, as well as trampling of HJG plants while cattle seek out other preferred grasses.

Dispersal
HJG seed appears to have no morphological adaptations for dispersal by wind or on animal fur. The very short spines on the outer glume enclosing the caryopsis, or seed, do not cling to fur, but may help the seed adhere to soil carried on hooves or paws. Domestic and native mammals could disperse seed to new sites in this way. Monitoring has shown that HJG seed germinates at high density under plants present in the previous year, indicating that the great majority of seed undergoes little dispersal. Considering the narrow habitat requirements of this species, this would be to its advantage by concentrating recruitment at points where the species survived and matured previously.

Research has produced circumstantial evidence that very little dispersal of HJG occurs where cattle are absent from HJG habitat. Dispersal was measured in terms of new seedlings appearing in potential habitat adjoining a large stand of HJG when tall suppressing ground layer vegetation was removed for three consecutive years (ECOS Environmental 2004).

Species interactions
In pasture habitat in the area between Lismore, Ballina and Byron Bay, HJG tends to be positively associated with Buffalo Grass (*Stenotaphrum secundatum*), Paspalum (*Paspalum dilatatum*), Carpet Grass (*Axonopus affine*) and Whiskey Grass (*Andropogon virginicus*), and negatively associated with Broad-leaved Paspalum (*Paspalum wettsteinii*), Kikuyu (*Pennisetum clandestinum*) and Couch (*Digitaria dydactyla*), but exceptions have been observed. The latter three species are dense, mat forming grasses, while the former species have a more up upright grown form. All these grasses are perennial and exotic. Various broad-leaved weeds are also present.
Research showed that when the ground layer was cleared in HJG habitat in winter (after HJG had produced seed) by cutting pasture back to ground level, then allowing the pasture to regenerate, HJG seedlings which regenerated with the rest of the pasture community, appeared unaffected by competition from extremely high densities of seedlings of other exotic broad-leaved weeds and grasses. Once germinated, HJG seedlings kept pace with the increasing height of the regenerating pasture community, eventually reaching heights of up to 1.5 meters (ECOS Environmental 2004).

APPENDIX 8: Details of *Arthraxon hispidus* samples collected for genetic analysis.

22/03/2010	Easting GDA	Northing GDA	Distance	Geology	Topography	Plant Community
Koellner - population scattered in pasture across steep SE facing slope						
1	551501	6810229		basalt	steep, SE aspect, lower slope	Buffalo Grass, Carpet Grass, Paspalum dilatatum
2	551505	6810236	12 m from 1, upslope	basalt	steep, SE aspect, lower slope	
3	551505	6810244	10 m from 2, upslope	basalt	steep, SE aspect, mid slope	
4	551507	6810247	15 m from 3, upslope	basalt	steep, SE aspect, mid slope	all Buffalo Grass
5	551491	6810248	10 m from 4, upslope	basalt	steep, SE aspect, mid slope; survey post - top of cut?	
6	551483	6810244	15 m from 5, across	basalt	steep, SE aspect, mid slope	
7	551477	6810247	10 m from 6, upslope	basalt	at track below Hoop Pines	
8	551489	6810226	20 m from 7, downslope	basalt colluv. over metasediment	steep, SE aspect, mid slope	more Carpet Grass, Mist Flower
9	551495	6810204	30 m from 8, downslope	basalt colluv. over metasediment	moderate, SE aspect, lower slope	
10	551498	6810215	15 m from 9, downslope	basalt colluv. over metasediment	moderate, SE aspect, lower slope	
total collection distance from lowest to highest point on slope ~ 65 m						
Sheather - population restricted to table drain cut into mid slope, cleared grazing land						
1	551628	6812531		basalt	mid slope, table drain, SW aspect	Kikuyu, Bidens, A.houstonianum, Conyza
2	551627	6812527	going down drain	basalt	mid slope, table drain, SW aspect	
3	551630	6812527	going down drain	basalt	mid slope, table drain, SW aspect	
4	551627	6812525	going down drain	basalt	mid slope, table drain, SW aspect	
5	551630	6812522	going down drain	basalt	mid slope, table drain, SW aspect	
6	551635	6812520	going down drain	basalt	mid slope, table drain, SW aspect	

7	551634	6812513	going down drain	basalt	mid slope, table drain, SW aspect	
8	551641	6812503	~30 m down drain from 1	basalt	mid slope, table drain, SW aspect	
9	551626	6812532	going up drain from 1	basalt	mid slope, table drain, SW aspect	
10	551619	6812540	8 m from 9, up drain	basalt	mid slope, table drain, SW aspect	
total collection distance/length of stand along table drain ~ 45 m.						
Sandy Flat - population found along lower reach of a minor drainage line or gully, cleared grazing land, overgrown						
1	551518	6813872		metased, basalt upslope	minor gully/drainage line	P.urvillei, Setaria, A.houtonianum, Leersia hexandra, Hypolepis muelleri, Paspalum conjugatum, Persicaria decipiens, Thickheads
2	551520	6813867	2 m from 1, down drainage line	metased, basalt upslope	minor gully/drainage line	
3	551520	6813861	4 m from 2, down drainage line	metased, basalt upslope	minor gully/drainage line	
4	551522	6813866	5 m from 3, down drainage line	metased, basalt upslope	minor gully/drainage line	
5	551524	6813857	8 m from 4	metased, basalt upslope	minor gully/drainage line	
6	551520	6813857	12 m from 5, south	metased, basalt upslope	minor gully/drainage line	
7	551520	6813859	2 m from 6	metased, basalt upslope	minor gully/drainage line	
8	551514	6813853	10 m from 7	metased, basalt upslope	in standing water	
9	551521	6813848	10 m from 8	metased, basalt upslope	minor gully/drainage line	
10	551493	6813873	15 m up drainage line from 1	metased, basalt upslope	minor gully/drainage line	
total collection distance ~ 50 m.						
1/04/2010						
Kaehler - population scattered in pasture and disturbed area on south facing mid slope, cleared grazing land				basalt	moderately steep to gentle mid slope, S aspect	
1	551354	6815029	in pasture to east of disturbed area	basalt	moderately steep to gentle mid slope, S aspect	Carpet Grass, Buffalo Grass, Verbena bonariensis, Senecio madagascarensis, Conyza
2	551361	6815031	10 m E across slope from 1	basalt	moderately steep to gentle mid slope, S aspect	

3	551369	6815033	10 m E from 2	basalt	moderately steep to gentle mid slope, S aspect	
4	551377	6815031	15 m E from 3	basalt	moderately steep to gentle mid slope, S aspect	
5	551385	6815034	15 m E from 4 across slope	basalt	moderately steep to gentle mid slope, S aspect	
6	551398	6815034	12 m from 5, Big Plant in disturbed area	basalt	moderately steep to gentle mid slope, S aspect	
7	551389	6815022	15 m from 6, Big Plant in disturbed area	basalt	moderately steep to gentle mid slope, S aspect	
8	551385	6815023	5 m from 7, Big Plant in disturbed area	basalt	moderately steep to gentle mid slope, S aspect	
9	551382	6815023	5 m from 8, Big Plant in disturbed area	basalt	moderately steep to gentle mid slope, S aspect	
10	551394	6815016	Big Plant, bottom of disturbed area, next to barrier mesh	basalt	moderately steep to gentle mid slope, S aspect	
total collection distance ~ 40 m.						
Ross Lane - population scattered on south facing hill slopes, gullies and spurs, cleared grazing land with Camphor Laurel regrowth						
1	550917	6815491	at gate	metased, basalt upslope		Carpet Grass, Paspalum dilatatum, Digitaria didactyla, Centella
2	550923	6815488	15 m from 1 to east	metased, basalt upslope		
3	550924	6815488	2 m from 2	metased, basalt upslope		
4	550933	6815478	1st gully, 15m from 3	metased, basalt upslope		
5	550973	6815489	40 m up gully from 4	metased, basalt upslope		
6	550996	6815485	25 m from 5	metased, basalt upslope		Paspalum dilatatum, P. wettsteinii (invading), D.didactyla, Ageratum houstonianum, Bracken, Mist Flower
7	551007	6815498	on spur, 10 m from 6	metased, basalt upslope		
8	551009	6815489	8 m from 7, on spur	metased, basalt upslope		
9	551007	6815487	edge of next rill, high up, 5 m from 8	metased, basalt upslope		
10	551011	6815472	15 m from 9, other side of rill	metased, basalt upslope		
total collection distance ~ 150 m.						
Levis - first two samples on access track on hillside, other samples 300m away from marshy margin of running stream, cleared grazing land						
1	551103	6816094	on track, 1/3rd of way down	basalt	moderately steep to gentle mid slope, SW aspect	Paspalum dilatatum, Ragweed, Carpet Grass, Mist Flower
2	551073	6816100	20 m from 1	basalt	moderately steep to gentle mid slope, SW aspect	

3	550796	6816112	edge of dam valley bottom	basalt	basaltic alluvium	
4	550778	6816128	20 m from 3, downstream	basalt	marshy margin zone of running stream	Isachne globosa, Hypolepis muelleri, Ageratum houstonianum, Paspalum urvillei, Crofton Weed
5	550776	6816131	8 m from 4, downstream	basalt	marshy margin zone of running stream	
6	550771	6816132	5 m from 5, downstream	basalt	marshy margin zone of running stream	
7	550755	6816146	18 m from 6, downstream	basalt	marshy margin zone of running stream	
8	550751	6816157	15m from 7, downstream limit	basalt	marshy margin zone of running stream	
9	550746	6816147	other Sth side of stream	basalt	marshy margin zone of running stream	
10	550752	6816136	10 m from 9	basalt	in pasture	Kikuyu, Ragweed
Lennox Head - Hutley Rd South - population in marshy area of dense native species on toe of slope, cleared						
1	556996	6812062		basalt alluvium	marshy toe of slope, flat	Leersia hexandra, Hypolepis muelleri, Isachne globosa, Crofton Weed, Blechnum indicum, Perscaria decipiens, Ipomoea cairica
2	556990	6812064	6 m from 1	basalt alluvium	marshy toe of slope, flat	
3	556975	6812073	15 m from 2	basalt alluvium	marshy toe of slope, flat	
4	556982	6812055	20 m from 3	basalt alluvium	marshy toe of slope, flat	
5	556986	6812049	6 m from 4	basalt alluvium	marshy toe of slope, flat	
6	556972	6812045	6 m from 5	basalt alluvium	marshy toe of slope, flat	
7	556971	6812049	5 m from 6	basalt alluvium	marshy toe of slope, flat	
8	556955	6812034	15 m from 7	basalt alluvium	marshy toe of slope, flat	
9	556944	6812034	10 m from 8	basalt alluvium	marshy toe of slope, flat	
10	556935	6812031	10 m from 9	basalt alluvium	marshy toe of slope, flat	
total length of population approx. 100 m.						
T2E - Bangalow, Fraser - population in pasture in drainage depression on floodplain terrance, cleared grazing land						
1	552307	6827068		basalt	minor drainage rill on floodplain terrace	Carpet Grass, Buffalo Grass, Paspalum dilatatum, Bidens, Fireweed
2	552308	6827053	15 m from 1, top of rill	basalt	minor drainage rill on floodplain terrace	
3	552320	6827073	20 m from 1, down rill Nth	basalt	minor drainage rill on floodplain terrace	

4	552331	6827082	15 m from 3, down rill	basalt	minor drainage rill on floodplain terrace	
5	552348	6827088	10 m from 4, down rill	basalt	minor drainage rill on floodplain terrace	
6	552363	6827095	10 m from 5, down rill	basalt	minor drainage rill on floodplain terrace	
7	552388	6827115	20 m from 6, down rill	basalt	minor drainage rill on floodplain terrace	
8	552402	6827121	15 m from 7, down rill	basalt	minor drainage rill on floodplain terrace	
9	552439	6827129	30 m from 8, east side of swale	basalt	minor drainage rill on floodplain terrace	
10	552394	6827065	50 m from swale, to east	basalt	minor drainage rill on floodplain terrace	

Appendix C

Monitoring Datasheets/ Proformas

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Table C1: Quadrat Monitoring Field Data Sheet

Date:	Person/s undertaking monitoring:	Quadrat Number:	Easting and northing of north-eastern corner (GDA 94):		
Vegetation Community:					
General comments on degree of weed infestation, health of vegetation etc.:					
Photo point details:					
Canopy					
Species	^Cover Class (Braun-Blanquet)	*Life-form	Average Height (m)	Diameter at Breast Height (DBH) (cm)	Comments
Mid-Stratum					
Species	^Cover Class (Braun-Blanquet)	*Life-form	Average Height (m)	Diameter at Breast Height (DBH) (cm)	Comments

Ground Cover					
Species	^Cover Class (Braun-Blanquet)	*Life-form	Average height (m)	n/a	Comments
Threatened Species					
Species	Code/Number	Height (m)	Diameter at Breast Height (DBH) (cm)	#Foliage Vigour (1-5)	Evidence of Recruitment / Reproduction

Foliage Vigour (1-dead, 2-poor condition / discoloured, 3-minor discoloration, 4-good condition, 5-excellent condition).

^ Braun Blanquet Cover Classes (1 - <5%, 2 – 5-<25%, 3 – 25-<50%, 4 – 50-75%, 5 - >75%)

* Life-forms (tree - >10 cm DBH and >5 m height; tall shrub - 1-5 m height; small shrub - <1 m height; grass/lily – low-growing monocots)

Table C2: Transect Monitoring Field Data Sheet

Date:	Person/s undertaking monitoring:	Transect Number:	Easting and northing of transect start (GDA 94):	Easting and northing of transect end (GDA 94):	
General comments on the degree of weed infestation, health of vegetation etc.:					
Photo point details:					
Quadrat 1					
Vegetation Community:				Comments on health of vegetation in quadrat:	
Species	^Cover Class (Braun - Blanquet)	*Life-form	Average Height (m)	Diameter at Breast Height (DBH) (cm) (where applicable)	Comments
Quadrat 2					
Vegetation Community:				Comments on health of vegetation in quadrat:	
Species	^Cover Class (Braun-Blanquet)	*Life-form	Average Height (m)	Diameter at Breast Height (DBH) (cm) (where applicable)	Comments

Quadrat 3 (etc. up to Quadrat 25)					
Vegetation Community:				Comments on health of vegetation in quadrat:	
Species	^Cover Class (Braun-Blanquet)	*Life-form	Average Height (m)	Diameter at Breast Height (DBH) (cm) (where applicable)	Comments

Foliage Vigour (1-dead, 2-poor condition / discoloured, 3-minor discoloration, 4-good condition, 5-excellent condition).

^ Braun Blanquet Cover Classes (1 - <5%, 2 – 5-<25%, 3 – 25-<50%, 4 – 50-75%, 5 - >75%)

* Life-forms (tree - >10 cm DBH and >5 m height; tall shrub - 1-5 m height; small shrub - <1 m height; grass/lily – low-growing monocots)