EXPERIMENTAL CONTROL OF EXOTIC SPINY RUSH, *JUNCUS ACUTUS* FROM SYDNEY OLYMPIC PARK: II. EFFECTS OF TREATMENTS ON OTHER VEGETATION

Swapan Paul, Robyn Young and Alex MacKay

Sydney Olympic Park Authority
E-mail: Swapan.Paul@sopa.nsw.gov.au

ABSTRACT

This paper deals with saltmarsh vegetation and weeds in plots after two experimental treatments to control the Spiny Rush (*Juncus acutus)* were applied. One experiment was based on the physical removal of *J. acutus* and the other on the application of Glyphosate and salt. The physical-removal experiment had four treatments and the Glyphosate-based experiment had five treatments, including a control. Each of these nine treatments had three replicate quadrats, each 2m x 2m size; hence there were 27 quadrats in total. Including the pre-experiment data, systematic observations were made on 11 occasions at varying intervals. Observations were made on mortality, coverage, re-growth and seedling growth of *J. acutus,* weeds and saltmarsh vegetation coverage. The results of the effects of the treatments on *J. acutus* have been reported previously. The present paper reports the effects of the treatments on saltmarsh vegetation and weeds. The results of this section of the experiments have indicated that considerable self-regeneration of saltmarsh vegetation can occur within one year after physically removing *J. acutus*. However, if significantly faster regeneration was required, saltmarsh transplanting could be undertaken.

INTRODUCTION

The problem

Juncus acutus is a perennial rush endemic to Asia, Europe and North America. It grows to 1.5m high (Sainty & Jacobs 1981) with short rhizomes forming large tussocks. The stems and modified cylindrical leaves are pungent. It is an aggressive competitor, especially to the native rush, *Juncus kraussii,* and once established, can spread rapidly to create a compact mass. It has become well established in coastal NSW.

This is the second paper of a two-part experiment conducted in Badu Saltmarsh within Sydney Olympic Park to test the efficacy of methods for controlling and/or eradicating *J. acutus*. The experiments were conducted over a period of 30 months, between March 2001 and September 2003. The first paper dealt with the mortality and re-growth of *J. acutus*.

J. acutus is widespread in the saltmarsh areas of Sydney Olympic Park, mainly in Badu Saltmarsh and the Brickpit (Figure 1). In Badu Saltmarsh, *J. acutus* is widely distributed, covering about 20% of the 7.0ha saltmarsh. Aerial photographs suggest that over the last few decades it has expanded rapidly. Its continuing spread is a

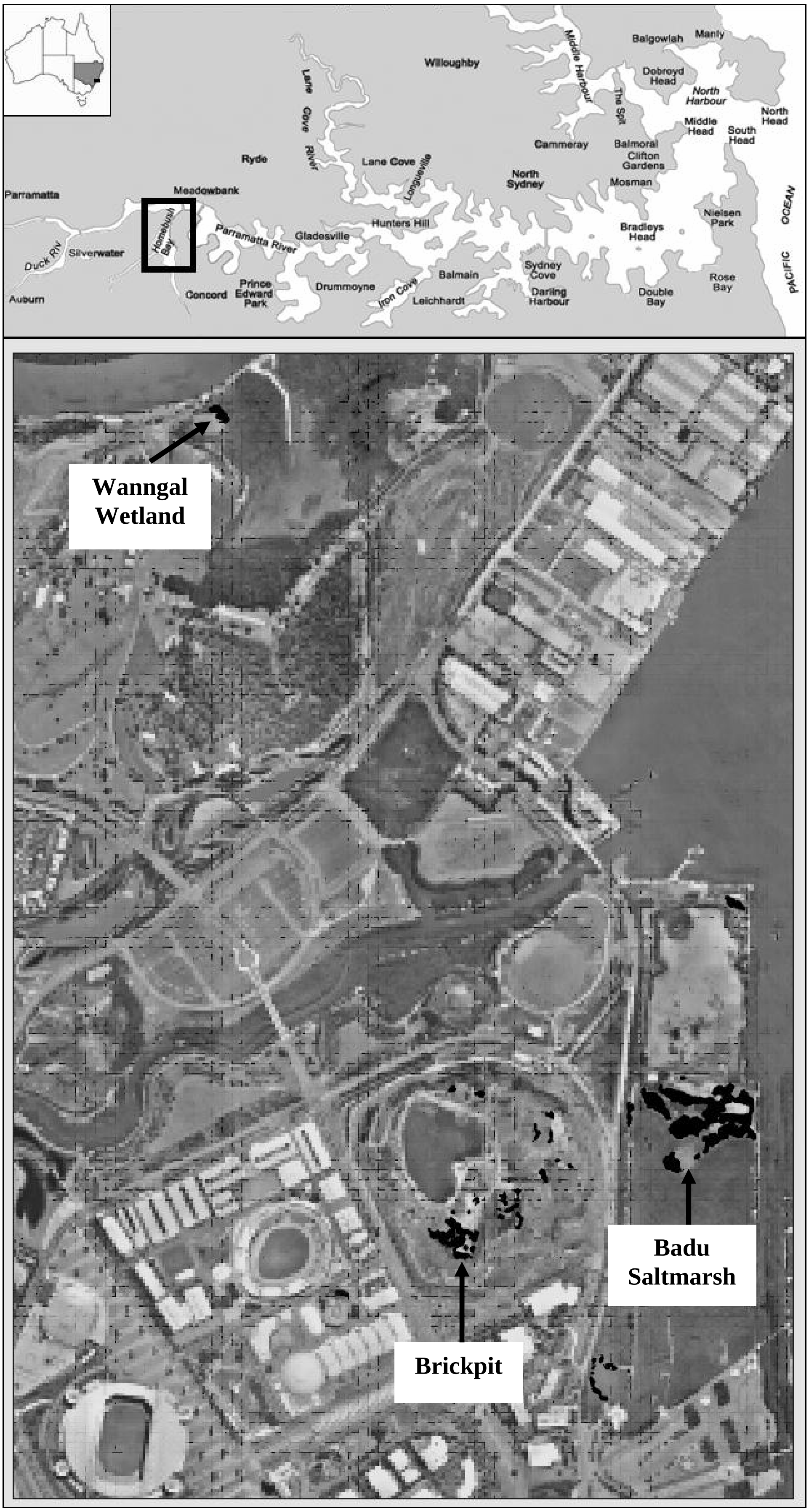

Figure 1: Locations of *J. acutus* in precincts of Sydney Olympic Park.

threat to the viability of much of the saltmarsh area, and therefore requires eradication and the development of a long-term, integrated management plan for its continuing control (Burchett & Pulkownik 1997).

History of the study area

Badu Saltmarsh in Sydney Olympic Park is an artificial creation resulting from the deposition of the dredged sediments from Homebush Bay in the late-1950s (Anon 1978). Over time, saltmarsh plants, predominantly *Sarcocornia quinqueflora,* colonised the area.

Observations from previous trials

Staff in Sydney Olympic Park have made several attempts to remove *J. acutus* from the Park. Most of these trials, conducted between 1998 and 2000, did not have replicate quadrats and were not systematically designed, so no meaningful inferences could be drawn. These trials did not take into account the effects of any other vegetation. However, the results of some of these trials provided direction for the present experiments. A summary of the casual observations is provided in Paul and Young (2006).

EXPERIMENTAL DESIGN

Two concurrent experiments were conducted, as described below:

Experiment I: Physical excavation-based

- Treatment-P1 (Excavate + revegetate): Physical excavation of *J. acutus* using a 'Bobcat' excavator and then levelling the ground to the extent that no water logging could take place. Transplant local provenance saltmarsh plants.
- Treatment-P2 (Excavate + add *J. acutus* mulch): Physical excavation of *J. acutus* using a 'Bobcat' excavator and level the ground to the extent that no water logging could take place. Cover the quadrats with *J. acutus* mulch.
- Treatment-P3 (Excavate + add traditional garden mulch): Physical excavation of *J. acutus* using a 'Bobcat' excavator and then levelling the ground to the extent that no water logging could take place. Cover the quadrats with traditional garden mulch.
- Treatment-P4 (Excavate + do nothing): Physical excavation of *J. acutus* using a 'Bobcat' excavator and then levelling the ground to the extent that no water logging could take place. Do nothing else.

Experiment II: Glyphosate-based

- Treatment-G1 (Glyphosate to whole plant): Single application of Glyphosate in the form of 'Round-up Bi-active' to whole plant at a recommended dilution rate of 50:1.
- Treatment-G2 (Control – Mark + do nothing): Mark quadrats of *J. acutus* and do nothing. Treated as a Control.
- Treatment-G3 (Cut + raw salt): Cut *J. acutus* plants to 5-10cm above ground level and hand apply crystals of raw salt at $4.0kg/1.0m^2$ to actual bases of the plants.
- Treatment-G4 (Cut + apply Glyphosate): Cut *J. acutus* plants to 5-10cm above ground level and add a single application of

Glyphosate in the form of 'Round-up Bi-active' on the plants regenerated to a length of 10.0cm at a recommended dilution rate of 50:1.

- Treatment-G5 (Cut + do nothing): Cut *J. acutus* plants to 5-10cm above ground level and do nothing.

Quadrat design

Each treatment had three replicate quadrats. Each quadrat measured 2.0m x 2.0m. Quadrats were separated by at least one metre and the Glyphosate-based treatments were distributed at random. Physical-based treatments were distributed closer to roads due to accessibility issues; however, within the limits of this requirement, the quadrats were randomised. In all, 27 quadrats were required.

Null hypotheses

Two hypotheses were tested:

1. There will be no significant differences between the physical excavation-based treatments.
2. There will be no significant differences between the Glyphosate-based treatments.

Assumptions

The experiments were conducted with the following three assumptions:

1. *J. acutus* populations in the various experimental quadrats will behave similarly;
2. The extent and duration of tidal and rainwater inundations within experimental quadrats will be similar;
3. Any influences of extrinsic factors on various treatment blocks will be similar.

Methods of application of treatments

Physical removal of *J. acutus*, application of Glyphosate and raw salt, cutting, mulching and native planting was all carried out as described in Paul and Young (2006). Transplanting of 20 bare-rooted plants was carried out in the designated quadrats by transferring *Sarcocornia quinqueflora*, *Lampranthus tegens*, *Wilsonia backhousei* and *Triglochin striata* in equal numbers. All plants were sourced from within the Park, with *Sarcocornia* and *Triglochin* sourced from the same saltmarsh.

Collection of data

Before the treatments, data were gathered on 13 December 2000 on the coverage of saltmarsh vegetation, weeds and existing *J. acutus*. Treatments were applied in March 2001 and data collection began from 30 August 2001. Data was initially gathered at monthly intervals to observe any rapid growth effects, and was later gathered at irregular intervals. A mesh quadrat was used to collect vegetation coverage data. The quadrat used was 1.0m x 1.0m and had 25 sub-quadrats (each 0.2m x 0.2m).

Data was gathered on recruitment of new *J. acutus*, rates of coverage with saltmarsh vegetation and weeds for the P1, P2, P3 and P4 treatments. Rates of dieback, recruitment of new *J. acutus*, weeds and saltmarsh vegetation were recorded for G1 and G2. For G3, G4 and G5 re-growth of shoots of *J. acutus*, recruitment of new *J. acutus*, weeds and saltmarsh vegetation were recorded. For estimating *J. acutus* re-growth or seedling growth, the length of eight individual stems of *J. acutus* were measured at random from the respective quadrats.

Data analysis

Data were analysed using a suitable statistical package, GMVA5 for two-factor ANOVA (Underwood & Chapman 1998). SNK Multiple Range tests were also performed in GMVA5 to locate specific significant differences between treatments.

RESULTS AND DISCUSSIONS

The results of the treatments on *J. acutus* mortality and re-growth are presented and discussed in Paul and Young (2006). The results of the treatments on saltmarsh vegetation and weeds are presented here.

Physical-based treatments

Saltmarsh vegetation

In this study saltmarsh species that were monitored/recorded on the site were *Sarcocornia quinqueflora, Lampranthus tegens, Wilsonia backhousei, Triglochin striata, Tetragonia tetragonioides, Atriplex semibaccata* and *Sporobolous virginicus*.

In the pre-treatment survey of the plots the average percentage coverage of area by saltmarsh vegetation in each treatment was low. In each of P1 and P4 plots, the average coverage was 5%, in P2 it was 1%, and in P3 it was 0%. There was average coverage of 8% in the control plots (G2) (Appendix I).

Revegetation in treatment P1 resulted in an increase of the average percentage coverage of saltmarsh vegetation. On the first sampling after the treatment was applied (30 August 2001) the average percentage was 14 and had increased to 96% by 10 September 2003 (Figure 2). As mentioned above, only 5% of saltmarsh vegetation was present in this treatment before the treatment was applied, this was all *S. quinqueflora*. However, by September 2003 the average percentage coverage of *S. quinqueflora* reached 57%. Similarly, *Suaeda australis* also accounted for a large proportion (35%) by September 2003 (Appendix I).

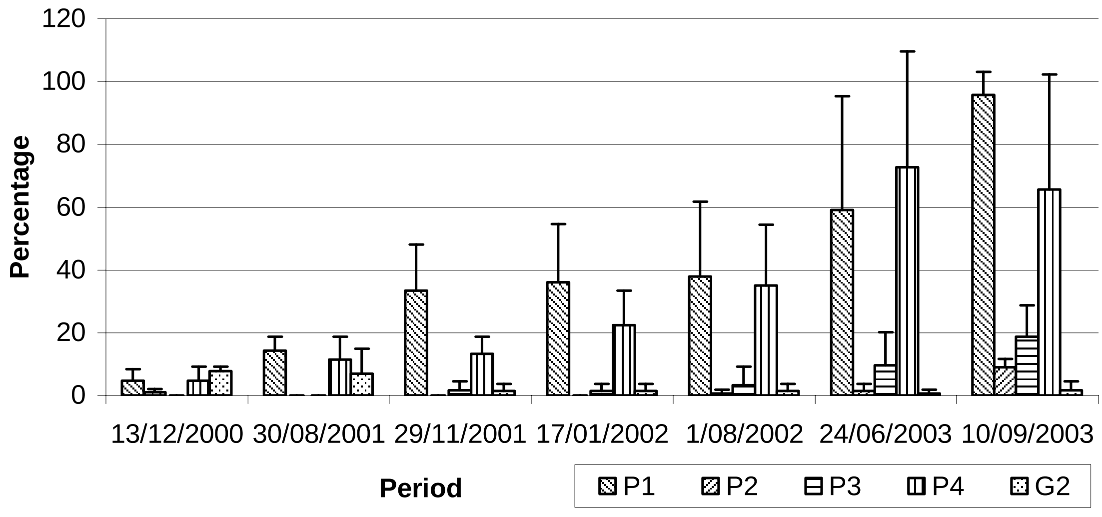

Figure 2: Percentage coverage of saltmarsh vegetation in physically treated plots, including Control (G2).

In treatment P2 the average percentage cover of saltmarsh vegetation was not as high as in P1, and no saltmarsh vegetation greater than 1% was seen post-treatment until 1 August 2002 (Figure 2). All saltmarsh vegetation was along the margins of the quadrats. Maximum average percentage occurred on 10 September 2003 (9%). Saltmarsh vegetation mostly consisted of *S. quinqueflora* by 10 September 2003 (6%) (Appendix I) but also half as much *S. australis* was present (Appendix I).

Treatment P3 also showed increasing average percentages of saltmarsh vegetation between 29 November 2001 (2%) and 10 September 2003 (19%) (Figure 2). The majority of vegetation in this plot was found to be *S. australis* (11%) and had been present since 29 November 2001 (Appendix I), but *S. quinqueflora* was also present as vegetative regrowth coming from outside the quadrat from 24 June 2003 (Appendix I).

Saltmarsh vegetation also increased in treatment P4 from 11% in the first sampling after treatment (30 August 2001) to a maximum of 73% in June 2003 (Figure 2). *S. australis* accounted for the major proportion of saltmarsh vegetation in September 2003 (Appendix I), whilst *S. quinqueflora* was present with an average coverage of 14% (Appendix I).

In the Control treatment (G2) the average coverage was 7% four months after the treatment was applied and then it fluctuated between <1% and 2% (Figure 4) (Appendix II).

ANOVA clearly demonstrates that after the data were transformed (Square-root of the individual values + 1), treatment P1 (transplanted with saltmarsh vegetation) and treatment P4 (with no transplanting) had significantly higher coverage of saltmarsh vegetation than all other treatments ($P<0.01$; Table 1). Interestingly, significant differences (weaker, at $P<0.05$; SNK test (Table 2)) existed between P1 and P4, suggesting that transplanting did have an added advantage in colonisation by saltmarsh vegetation. However, looking at the graphs it is clear that this difference was more pronounced during the early periods of vegetation growth, particularly during the first 12 months. ANOVA confirms that it took about one year before this significant difference was evident. The data clearly indicate that even without transplanting with saltmarsh vegetation similar vegetation coverage can be achieved but it may take about a year. Nevertheless, this also suggests that for faster colonisation within a period shorter than 12 months, transplantation may be necessary. It has been also observed in other parts of the Park that where tidal flushing was more frequent than these relatively elevated areas of saltmarsh, faster colonisation occurred (Paul & Kandan-Smith 2001). SNK tests also showed that weaker but significant differences ($P<0.05$) existed between the data sets on saltmarsh vegetation coverage within a growth period of only three months (between 24 June and 10 September 2003) (Table 3). Unlike weeds, native vegetation was apparently less affected during the drier months or the drought.

Table 1: Cochran's Test and ANOVA Results for Variation Between Treatments and Collection Dates

Test Statistic	Physical - Saltmarsh Vegetation	Physical - Weeds	Glyphosate - Saltmarsh Vegetation	Glyphosate - Weeds
Cochran's Test (C)	0.1227	0.3083	0.1371	0.1444
Cochran's P	NS	0.01	NS	NS
Transformation	Sqrt (x+1)	None	None	Ln (x+1)
Treatment F	101.19	19.47	9.63	7.26
Treatment P	0.0000	0.0000	0.0000	0.0000
Treatment d.f.	4	4	4	4
Treatment MS	124.4519	601.7983	1575.9000	4.4365
Period F	12.26	3.36	3.91	1.39
Period P	0.0000	0.0006	0.0003	0.2039
Period d.f.	9	9	9	9
Period MS	15.0776	112.3187	134.6685	0.8478

[When Cochran's P is not significant (NS) it implies that the ANOVA is strong and the ANOVA results are comparable. When it is significant, with significant level of confidence it concludes that the ANOVA results are not comparable.]

Table 2: SNK Multiple Range Test Results for Comparisons Between Treatments of Saltmarsh Vegetation Coverage and Weeds Coverage

Saltmarsh vegetation											Weeds					
Treatment	P1	P2	P3	P4	Treatment	G1	G2	G3	G4	G5	Treatment	G1	G2	G3	G4	G5
P1		**	**	**	G1		NS				G1		NS	NS		
P2					G2						G2					
P3		NS			G3	**	**		*	**	G3		NS			
P4		**	**		G4	*	**			NS	G4	NS	NS	NS		
G2		NS			G2	NS	NS				G2	**	**	**	**	

NS - non significant; * indicates significance at levels at P<0.05; ** indicates significance at levels at P<0.01.

Table 3: SNK Multiple Range Test results for comparisons between sampling dates

a) Physical-based Treatments

Saltmarsh Vegetation										
	1	2	3	4	5	6	7	8	9	10
1										
2	NS									
3	NS	NS								
4	NS	NS	NS		NS					
5	NS	NS	NS							
6	NS	NS	NS	NS	NS		NS			
7	NS	NS	NS	NS	NS					
8	*	NS	NS	NS	NS	NS	NS			
9	**	**	**	**	**	**	**	*		
10	**	**	**	**	**	**	**	**	*	

Key:
1 - 13th December 2000
2 - 30th August 2001
3 - 27th September 2001
4 - 25th October 2001
5 - 29th November 2001
6 - 20th December 2001
7 - 17th January 2002
8 - 1st August 2002
9 - 24th June 2003
10 - 10th September 2003

b) Glyphosate-based Treatments

Weeds											Saltmarsh Vegetation										
	1	2	3	4	5	6	7	8	9	10		1	2	3	4	5	6	7	8	9	10
1		NS		NS				NS			1		NS	NS	NS	NS	NS	NS			
2								NS			2				NS						
3	NS	NS		NS	NS		NS	NS	NS	NS	3		NS		NS	NS					
4		NS						NS			4										
5	NS	NS		NS				NS			5		NS		NS						
6	NS	NS	NS	NS	NS		NS	NS	NS	NS	6		NS	NS	NS	NS					
7	NS	NS		NS	NS			NS	NS		7		NS	NS	NS	NS	NS				
8											8	NS	NS	NS	NS	NS	NS	NS			
9	NS	NS		NS	NS			NS			9	NS	*	*	*	*	NS	NS	NS		
10	NS	NS		NS	NS		NS	NS	NS		10	NS	**	*	**	*	*	*	NS	NS	

* - significant at $p < 0.05$ ** - significant at $p < 0.01$

Weeds

The weeds that were seen in the treatment quadrats are *Aster subulatus*, *Paspalum* spp., *Melilotus* spp. and *Centaurea* spp.; with *Aster* the most abundant species. All these weed species are collectively called weeds.

With the exception of the control (G2), no weeds were recorded pre-treatment. However, all plots contained weeds after the treatment was applied. Plots in treatment P1 were observed to contain an average coverage of 5% weeds. This was seen on the first sampling (30 August 2001) after the treatment was applied (Figure 3). This coverage decreased to nearly 0% and fluctuated between an average of 0 and <1% during the rest of the sampling period. In treatment P2 no weeds were recorded until 10 September 2003 when 3% was observed (Figure 3). Plots P3 had an average of <1% initially, which disappeared until 10 September 2003 when average coverage was 1% (Figure 3). Weeds in treatment plots P4 initially averaged 20%, which decreased to an average low on 1 August 2002 (2%) and rose again to 19% (Figure 3).

Although the above differences were observed, because Cochran's C was significant even after all types of transformations of the data sets, it is clear that there was no significant difference in the percentages of weeds that appeared in the Physical treatments over the entire treatment period (Table 1).

Drops in the weeds during drier months were probably a reflection of seasonal attributes, or due to the drought condition in late 2002; however, weeds reappeared in subsequent seasons.

Glyphosate-based Treatments

Saltmarsh vegetation

The pre-treatment survey of the plots found that G3 plots on average had the highest initial percentage of saltmarsh vegetation (25%) and G4 and G5 plots had the lowest average percentages (2 and 3% respectively). G1 plots contained an average pre-treatment coverage of 11%. There was an average cover of 8% in the control plots (G2) (Appendix II).

Post-treatment, no saltmarsh vegetation was observed in treatment plots G1 until August 2002 (2%), after which it increased in the following 13 months to an average of 24% (Figure 4). The trend in G1 was mostly affected by the percentage of *S. australis* (between 2 and 24%); however, on one sampling time *S. quinqueflora* had a large influence (15% on 24 June 2003) (Appendix II). G3 plots increased from an average 13% to 38% by September 2003 (Figure 4). Of these percentages, *S. quinqueflora* accounted for 26%, and *S. australis* for 12% (Appendix II). A similar trend was observed in G4 with the average percentage of saltmarsh vegetation increasing from 1% (30 August 2001) to 39% (10 September 2003) (Figure 4). *S. australis* had the largest percentage in this treatment, however, *S. quinqueflora* and *T. tetragonioides* were also present (Appendix II). Post-treatment, G5 plots increased to an average of 16% (10 September 2003) with a slight decrease observed in June 2003 (Figure 4).

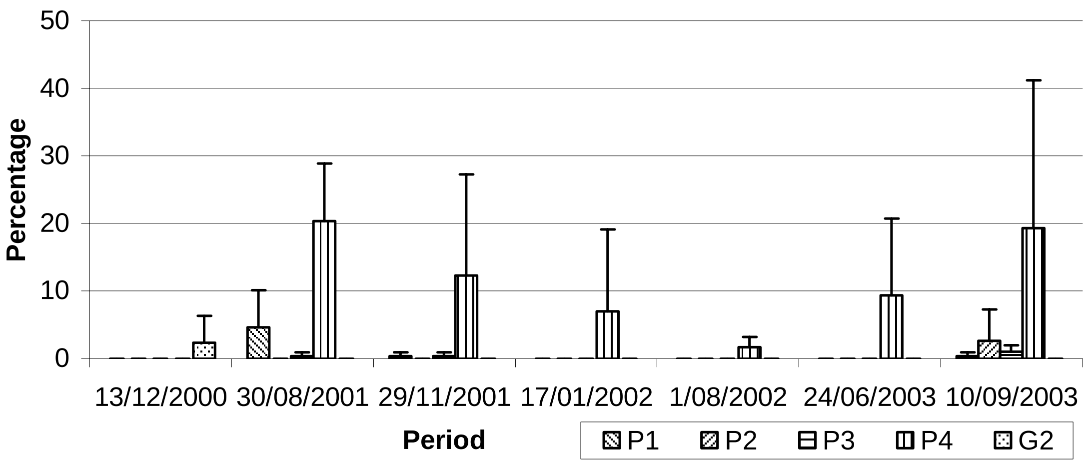

Figure 3: Changes in percentage coverage of weeds in Physically treated plots, including the Control (G2).

This treatment mainly consisted of *S. australis* but also *S. quinqueflora* (Appendix II). In the control treatment the average coverage was 7% four months after the treatment was applied and then it fluctuated between <1% and 2% (Figure 4).

ANOVA showed a significantly higher coverage of saltmarsh vegetation in G3, the treatment that had Cut Bases and Salt (P<0.01; Table 1). However, SNK test suggest that weakly higher percentage cover existed in G2 and G1 (P<0.05; Table 2). ANOVA also suggested that it took 22 months from treatment before significant differences could be seen (August 2001 and June 2003).

Compared with the situation in Physical-based treatments, the Glyphosate-based treatments took additional 10 months before significantly higher coverage was evident.

It is interesting to note that significantly higher growths of saltmarsh vegetation occurred in salt treated plots. The additional salt over the background concentration could have promoted better growth in these species. It may also be a result of lesser weed infestation due to the presence of additional salt in these plots when saltmarsh vegetation took advantage.

Table 4 summarises the treatment results.

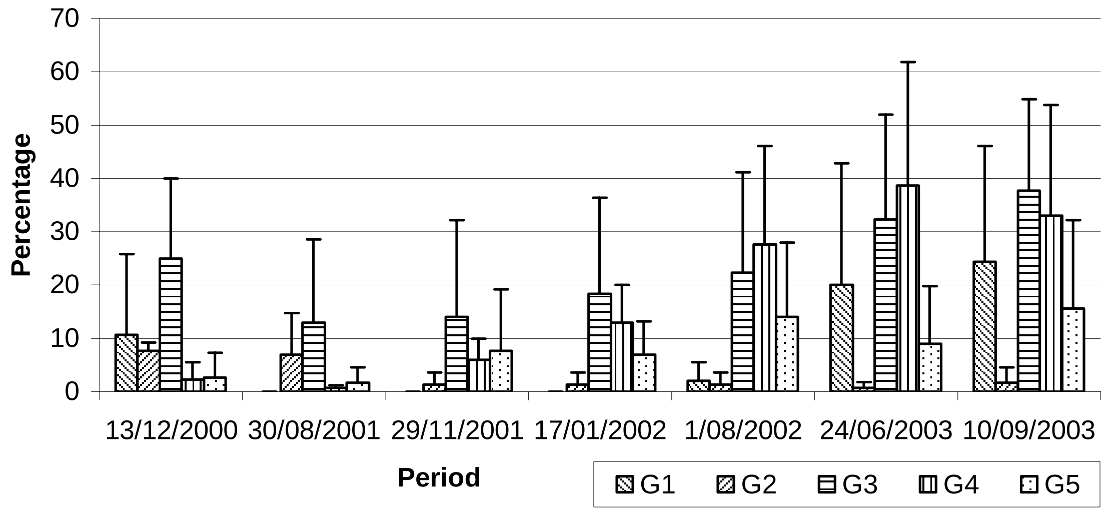

Figure 4: Percentage coverage of Saltmarsh Vegetation in Glyphosate treated plots.

Table 4: Comparative Status of the Trial Results on Saltmarsh Vegetation and Weeds Between Treatments.

Treatment	Saltmarsh vegetation	Weeds
P1	100%	<5%
P2	10%	2%
P3	5%	Nil
P4	70%	20%
G1	22%	7%
G2 (Control)	7%	Nil
G3	37%	Nil
G4	39%	3%
G5	15%	7%

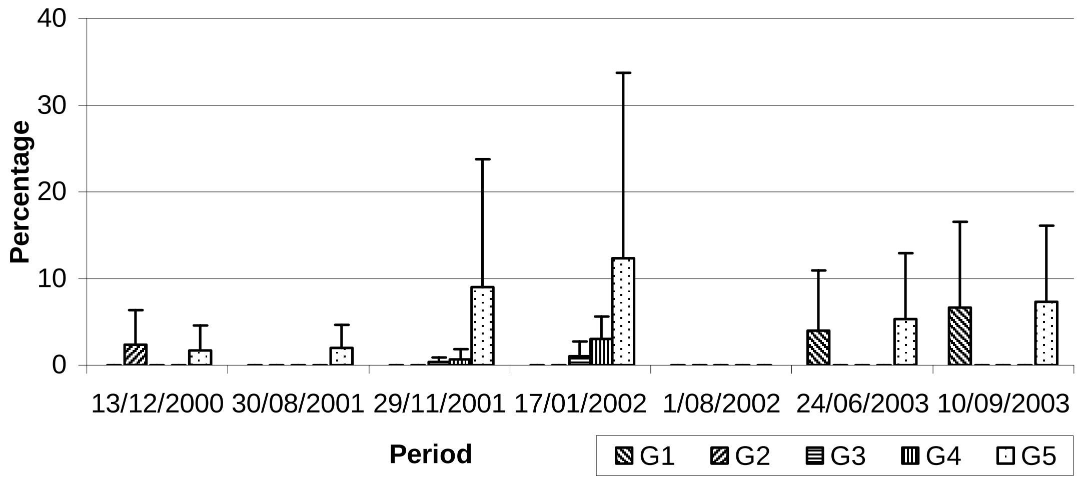

Figure 5: Changes in percentage coverage of weeds in Glyphosate treated plots.

Weeds

Weeds were found to cover no more than an average of 3% in each plot prior to the applications of the treatments. In plots G1, G3 and G4 no weeds were recorded pre-treatment, however, in both plot G5 and the control (G2), weeds were noted to cover an average 2% (Appendix II).

Subsequently, plots of treatment G1 averaged no weeds until the 24 June 2003 when coverage was averaged at 4% and increased to 7% by 10 September 2003 (Figure 5). Plots G3 and G4 similarly had almost no weeds present over the duration of the sampling period, these percentages were averaged to be <1 and 3% respectively and occurred at mid-experiment only (Figure 5). In the plots where *J. acutus* was cut (G5), the coverage of weeds continued to increase. The maximum average coverage that this plot reached was 12% (17 January 2002), after this time coverage declined to 0 and ever since has increased to 7% (Figure 5). The control (G2) was found to have no weeds post-treatment in any of the three replicates (Figure 5).

ANOVA (with Log natural (X + 1)) showed significant differences (P<0.01) between G5 (Cut + Do Nothing) and all other treatments. However, the differences were not significant over the entire length of the study, suggesting that if *J. acutus* is be removed by cutting and leaving the bases with no treatments, weeds will invade quickly.

It was interesting to note that weed coverage in salt treated plots were very low, closer to the coverage in G1. There is no evidence in this treatment that suggest that salt application can effectively restrict weed infestation/growth but it provides a hint that by applying concentrated salt it may be possible to attack general weeds in elevated areas of saltmarsh. However, it should not be considered as a method as such without further experimental trials, which will require considerations of other habitat and environment.

MANAGEMENT RECOMMENDATIONS

It is recommended that:

- After physically removing *J. acutus*, transplantation of saltmarsh vegetation may not be necessary because such vegetation will self-colonise within one year.
- In areas where faster colonisation is required such areas may be transplanted with saltmarsh vegetation. The optimal numbers for transplantation may vary but in this instance 5 plants/m^2 appeared adequate.
- Although mulching slows down the process of self-colonisation with saltmarsh vegetation and weeds, it is clear that *J. acutus* mulch can be used for this purpose.
- Because application of raw salt is probably a friendlier option in a saltmarsh area, further short-term trials may be conducted on potential repeat application of raw salt to examine any effects on weeds. Rates higher than 4.0kg/m^2 may be tried.

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Appendix I: Raw Data of Percentage Cover of *J. acutus*, saltmarsh vegetation and weeds in Physically treated plots.

Sampling Date	**Trial**	**13/12/00**			**30/08/01**			**27/09/01**			**25/10/01**			**29/11/01**			**20/12/01**			**17/01/02**			**1/08/2002**			**24/06/03**			**10/09/2003**		
Plot		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Juncus acutus	P1	81	98	81	0	0	0	0	0	0	0	0	6	0	0	6	0	0	8	0	0	8	0	0	3.5	0	0	0	0	0	0
Atriplex semibaccata	P1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lampranthus tegens	P1	0	0	0	6	3	9	15	13	5	9	7	8	14	8	14	10	10	12	8	9	13	7	0	6	0	0	0	0	0	0
Sarcocornia quinqueflora	P1	3	2	9	6	7	4	6	8	6	6	5	5	10	6	14	6.5	10	20	5	12	20	7	13	16	11	97	4	51	100	20
Sporobolus virginicus	P1	0	0	0	0	0	0	0	2	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Suaeda australis	P1	0	0	0	0	0	0	1.5	0	3	9	0	0	18	0	6	16.5	1	15	12	1	20	16	2	36	10	3	40	25	0	80
Triglochin striata	P1	0	0	0	4	0	1	2	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wilsonia backhouseii	P1	0	0	0	2	0	0	2.5	0	1	3	0	3	4	3	3	3	4	2.5	4	0	4	4	1	5.5	10	0	2	11	0	0
Saltmarsh Vegetation	P1	3	2	9	19	10	14	27	24	22	33	12	16	46	17	37	36	25	49.5	29	22	57	34	16	63.5	31	100	46	87	100	100
Weeds	P1	0	0	0	1	2	11	9	1	22	0	0	0	0	0	1	0	0	0.5	0	0	0	0	0	0	0	0	0	1	0	0
Juncus acutus	P2	78	98	97	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Sarcocornia quinqueflora	P2	0	2	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	4	10	4
Suaeda australis	P2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	6	1	2
Saltmarsh Vegetation	P2	0	2	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	4	10	11	6
Weeds	P2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0
Juncus acutus	P3	90	100	100	1	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Sarcocornia quinqueflora	P3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0	10	4	8
Suaeda australis	P3	0	0	0	0	0	0	0	0	0	0	2	0	0	5	0	0	7	0	0	4	0	0	10	0	6	18	0	10	24	0
Saltmarsh Vegetation	P3	0	0	0	0	0	0	1	0	0	0	2	0	0	5	0	0	7	0	0	4	0	0	10	0	8	21	0	20	28	8
Weeds	P3	0	0	0	1	0	0	4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0
Juncus acutus	P4	84	95	100	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Sarcocornia quinqueflora	P4	9	5	0	10	14	0	7	13	0	8	6	0	10	13	0	12	13	0	12	11	0	10	16	0	10	27	0	17	25	0
Sporobolus virginicus	P4	0	0	0	0	0	0	0	0	0	1	64	9	0	0	0	0	0	3	0	0	5	0	0	0	0	0	0	0	0	0
Suaeda australis	P4	0	0	0	7	0	3	4	0	1	1	0	7	9	0	8	19	1	14	21	0	18	46	2	31	84	3	94	83	2	70
Saltmarsh Vegetation	P4	9	5	0	17	14	3	11	13	1	10	70	16	19	13	8	31	14	17	33	11	23	56	18	31	94	30	94	100	27	70
Weeds	P4	0	0	0	12	20	29	13	47	33	1	2	0	0	29	8	3	7	0	0	21	0	0	2	3	0	22	6	0	43	15

Appendix II: Raw Data of Percentage Coverages of *J. acutus*, saltmarsh vegetation and weeds in Glyphosate-based Plots

Sampling Date	**Trial**	**13/12/00**			**30/08/01**			**27/09/01**			**25/10/01**			**29/11/01**			**20/12/01**			**17/01/02**			**1/08/02**			**24/06/03**			**10/09/03**		
Plot		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Juncus acutus	G1	92	72	96	2	0	0	5	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sarcocornia quinqueflora	G1	0	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	0	0	0	0
Suaeda australis	G1	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	15	0	0	31	42	0
Saltmarsh Vegetation	G1	0	28	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	15	45	0	31	42	0
Weeds	G1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	18	2
Juncus acutus	G2	87	87	73	84	87	98	91	96	99	96	100	92	96	100	100	97	100	100	96	100	100	96	100	100	100	98	100	100	95	100
Sarcocornia quinqueflora	G2	8	0	9	0	3	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Suaeda australis	G2	0	3	0	7	0	2	9	0	0	4	0	0	4	0	0	3	0	0	4	0	0	4	0	0	0	2	0	0	5	0
Tetragonia teragonioides	G2	0	3	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saltmarsh Vegetation	G2	8	6	9	16	3	2	9	4	1	4	0	0	4	0	0	3	0	0	4	0	0	4	0	0	0	2	0	0	5	0
Weeds	G2	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juncus acutus	G3	84	58	81	24	22	19	32	12	17	32	24	17	26	22	12	27	19.5	19	27	17	16	38	30	21	21	45	27	19	44	27
Sarcocornia quinqueflora	G3	0	28	19	3	18	0	1	21	9	0	15	0	2	17	0	3	28	0	4	21	0	9	26	0	11	50	0	28	49	0
Suaeda australis	G3	14	14	0	0	13	5	1	17	0	2	12	9	1	18	4	3	20.5	7	6	18	6	1	18	13	9	5	22	7	7	22
Saltmarsh Vegetation	G3	14	42	19	3	31	5	2	38	9	2	27	9	3	35	4	6	48.5	7	10	39	6	10	44	13	20	55	22	35	56	22
Weeds	G3	0	0	0	0	0	0	0	2	1	0	0	0	0	0	1	0	0	7	0	0	3	0	0	0	0	0	0	0	0	0
Juncus acutus	G4	93	94	99	22	33	29	23	35	22	28	14	32	11	14	28	11	17	22	15	8	26	19	13	28	19	8	31	33	15	43
Atriplex semibaccata	G4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Sarcocornia quinqueflora	G4	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	0	0	3	0	0	1	0	0	8	0
Suaeda australis	G4	0	6	0	0	0	1	0	4	5	0	2	1	0	2	6	0	4	12	0	7	21	0	14	49	0	41	60	0	36	46
Tetragonia teragonioides	G4	0	0	0	0	0	0	0	0	1	3	0	1	10	0	0	9	0	0	10	0	0	17	0	0	13	0	0	9	0	0
Triglochin striata	G4	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saltmarsh Vegetation	G4	0	6	1	0	1	1	5	4	6	3	2	2	10	2	6	9	7	12	10	8	21	17	17	49	14	42	60	9	44	46
Weeds	G4	0	0	0	0	0	0	1	3	5	1	0	0	2	0	0	6	5	1	4	5	0	0	0	0	0	0	0	0	0	0

Appendix II Continued: Raw Data of Percentage Coverages of *J. acutus*, saltmarsh vegetation and weeds in Glyphosate-based Plots

Sampling Date	**Trial**	**13/12/00**			**30/08/01**			**27/09/01**			**25/10/01**			**29/11/01**			**20/12/01**			**17/01/02**			**1/08/02**			**24/06/03**			**10/09/03**		
Juncus acutus	G5	95	87	100	24	19	18	24	16	30	31	13	36	30	9	50	11	8	55	17	10	47	25	22	64	29	17	72	51	29	61
Sarcocornia quinqueflora	G5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	2	0	2	0	0	6
Suaeda australis	G5	0	8	0	0	0	0	0	0	1	0	0	0	3	0	1	4	0	0	9	0	9	28	0	12	19	0	4	33	0	8
Tetragonia teragonoides	G5	0	0	0	5	0	0	13	0	0	14	0	0	18	0	0	17	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Saltmarsh Vegetation	G5	0	8	0	5	0	0	13	0	1	14	0	0	21	0	2	21	0	0	12	0	9	28	0	14	21	0	6	33	0	14
Weeds	G5	0	5	0	5	1	0	8	2	0	0	10	0	1	26	0	3	38	0	0	37	0	0	0	0	2	14	0	5	17	0