Padilla Bay
National Estuarine Research Reserve

Technical Report No. 13

EFFECTIVENESS OF A WIPER APPLICATION OF GLYPHOSATE ON *SPARTINA ALTERNIFLORA* IN PADILLA BAY, WASHINGTON

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ABSTRACT

Riggs, S.R. and D.A. Bulthuis. 1995. Effectiveness of a wiper application of glyphosate on *Spartina alterniflora* in Padilla Bay, Washington. Washington State Department of Ecology, Padilla Bay National Estuarine Research Reserve, Technical Report No. 13, Mount Vernon, Washington. 20 pp.

The herbicide glyphosate (Rodeo ®, 33% solution) with adjuvant (LI-700® at 5%) was applied with hand held wipers to *Spartina alterniflora* Loisel. in Padilla Bay, Washington, in September, 1994. Treated plots appeared yellower than control plots one month after treatment. Seven months after treatment (April, 1995) there was no significant difference in density of live *S. alterniflora* shoots between treatment and control plots at either an exposed site nor at a sheltered site on Dike Island. The lack of effectiveness of hand held wiper applications of glyphosate may have been due to wetness of the leaf surface, sediment on the leaf surface, the time of year relative to flowering of *S. alterniflora*, or the concentration or type of adjuvant mixed with the glyphosate.

ACKNOWLEDGEMENTS

We would like to first thank the Dike Island and Swinomish Gun Clubs for helping to fund this project. Thanks also go to Steve Wirth for supervising the herbicide application and for helping to locate and coordinate volunteers.

Many people cooperated to make the glyphosate application phase of this project a success: Dike Island Gun Club members Russ Orrell and Ralph Beringer; our neighbor Ben Welton and his friend Bill Haines; Dan Jacobson and Kent Fagen, students from Skagit Valley College; research assistants Mike Shaw and Travis Shaw; research interns Gretchen Frankenstein and Sherri Rodgers; Anne Sidbury of the Padilla Bay Foundation and; Susan Wood and Glen Alexander who are on staff at the Padilla Bay National Estuarine Research Reserve (P.B.N.E.R.R.). Julie Thielges and Dave Henry, both of the education staff at Padilla Bay N.E.R.R., also assisted in the field in the spring of 1995. Our thanks to all of you.

INTRODUCTION

Several methods for control or eradication of *Spartina alterniflora* Loisel. (smooth cordgrass) from selected bays and estuaries in the Pacific Northwest have been attempted and evaluated in recent years. The rapid spread of *S. alterniflora* in Willapa Bay during the last ten years and the perceived threat to oyster culture, eelgrasses, waterfowl habitat, and juvenile salmon habitat in bays throughout Washington state have been the reasons for testing such methods (Mumford et al., 1991; Rokstad et al., 1993; Washington State Administrative Code, 1994). Mowing, covering, spraying with herbicide, and wiping with herbicide have been attempted (Rokstad et al., 1993; Bulthuis and Scott, 1993: Norman, 1994). The Noxious Emergent Plant Management Environmental Impact Statement addresses *Spartina* species and recommends an Integrated Weed Management approach that includes chemical methods (Rokstad et al., 1993). Glyphosate is the only herbicide currently allowed in bays and estuaries of Washington. In this paper we report the results of wiper application of glyphosate to *S. alterniflora* in Padilla Bay, Washington.

Spartina alterniflora was introduced by a gun club to Padilla Bay in the 1940's to control erosion on Dike Island. Since then it has spread vegetatively by rhizome and totals approximately 11 acres in southern Padilla Bay (Riggs, 1991). Even though flowers and seeds have been noted, it does not appear to be spreading by seed, because distribution of *S. alterniflora* remains confined to a small area of Padilla Bay and no individual shoots have been observed.

Glyphosate is a broad spectrum herbicide (Grossbard and Atkinson, 1985) that is absorbed through the leaf and translocated throughout the plant (Boerboom et al., 1994). Its mode of action includes inhibition of photosynthesis (Cole, 1985). Glyphosate is effective as an herbicide on a wide spectrum of aquatic plants (Barnett, 1985) and has been approved and recommended for control of *Spartina* spp. in Washington state (Rokstad et al., 1993; Monsanto, undated). Glyphosate (as Rodeo®)

has been applied to *S. alterniflora* with a backpack sprayer with reports of 80% to 100% control (Crockett, 1991; Crockett, undated). Pritchard (1992) and Bulthuis and Scott (1993) also used a backpack hand held sprayer and reported very little control and no effect on *S. alterniflora*, respectively. However, Bulthuis and Scott (1993) reported that application with a backpack sprayer did kill some of the adjacent native salt marsh plants. A hand held wiper can be applied more selectively than a backpack sprayer and Norman and Patten (1994) reported very good control of *S. alterniflora* using such a method. Therefore, the objective of the present study was to test the effectiveness of a hand held wiper application of glyphosate (Rodeo®) with adjuvant (LI-700®) on *S. alterniflora* on Dike Island in Padilla Bay.

METHODS AND MATERIALS

Study sites

Two sites were selected on Dike Island in southern Padilla Bay in Skagit County in a contiguous *Spartina alterniflora* salt marsh (Fig. 1). *S. alterniflora* extends approximately 300 meters into the mudflat at the west end of Dike Island. At this location, *Spartina alterniflora* is mixed with a minimal amount of *Atriplex patula* and *Salicornia virginica* and is surrounded on three sides by mudflat. One experimental site (exposed) was located on the south side of this stand and was relatively exposed to southerly winds (Fig. 1, A). The other site (protected) was located in an area on the south side of Dike Island that is relatively protected from both northerly and southerly winds. The upper edge of this protected site was bordered by native salt marsh vegetation and the lower edge by mudflat (Fig. 1, B).

PADILLA BAY, WASHINGTON

Figure 1. Locations of study sites on Dike Island in Padilla Bay. A. Exposed site. B. protected site.

Experimental design and fieldwork

Eight adjacent rectangular plots were established at each experimental site and treatments were randomly assigned to the plots (Figs. 2 and 3). Five treatment plots and three control plots were assigned at each site. The plots on the exposed Dike Island site were 8 m x 40 m (320 m^2). The plots on the protected Dike Island site were 15 m x 30 m (450 m^2).

Densities of live *S. alterniflora* stems were recorded prior to the herbicide application (0.0625 m^2 quadrats, n=3 in each experimental plot) and percent cover was recorded for native vegetation for 0.0625 m^2 quadrats (n=3) if native vegetation was adjacent to the stand.

The herbicide glyphosate (Rodeo®) was applied by volunteers (under the supervision of a licensed pesticide applicator) using a wiper method of application to treatment plots at a 33% concentration with 5% LI-700® (a surfactant/penetrant/ acidifier) on September 6 and 7, 1994. Hand-held wipers were used for the application (Red Weeders, Smucker Manufacturing). An example of the field sheet is included in Appendix 1. The wipers were not calibrated but the total amount of herbicide applied and length of time to apply herbicide were recorded for each treatment plot. The amount of herbicide applied to each treatment plot (qts/ac) was calculated post-application. A photographic record of the plots was made 1-2 weeks post-treatment.

Densities of live stems (0.0625 m^2 quadrats, n=8 in each experimental plot) were also recorded seven months (April 14, 1995) post-treatment to determine the effectiveness of the late summer glyphosate treatment. In April, the native vegetation was just starting to sprout so percent cover was not recorded but presence or absence of sprouting vegetation was noted.

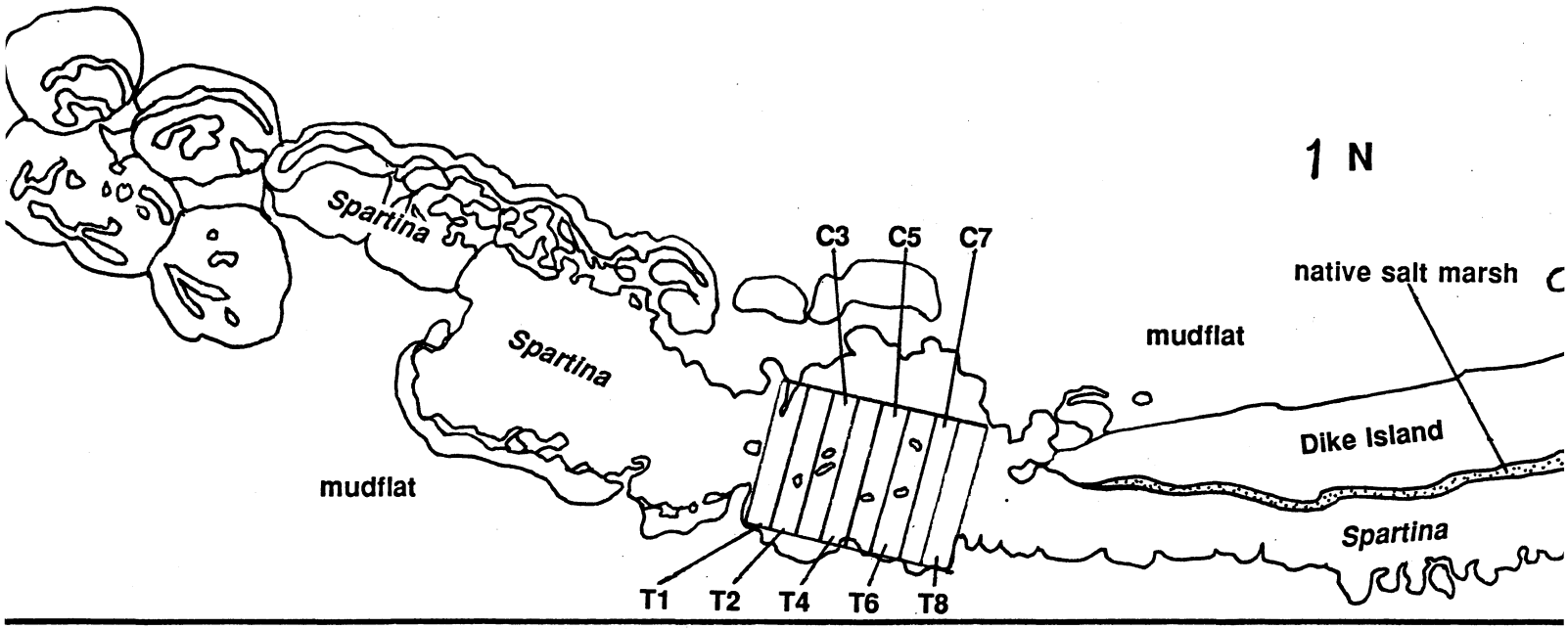

Figure 2. Experimental plots on exposed Dike Island site. Plots prefaced by "T" are plots to which glyphosate was applied. Plots prefaced by "C" are control plots. See also Figure 1, A.

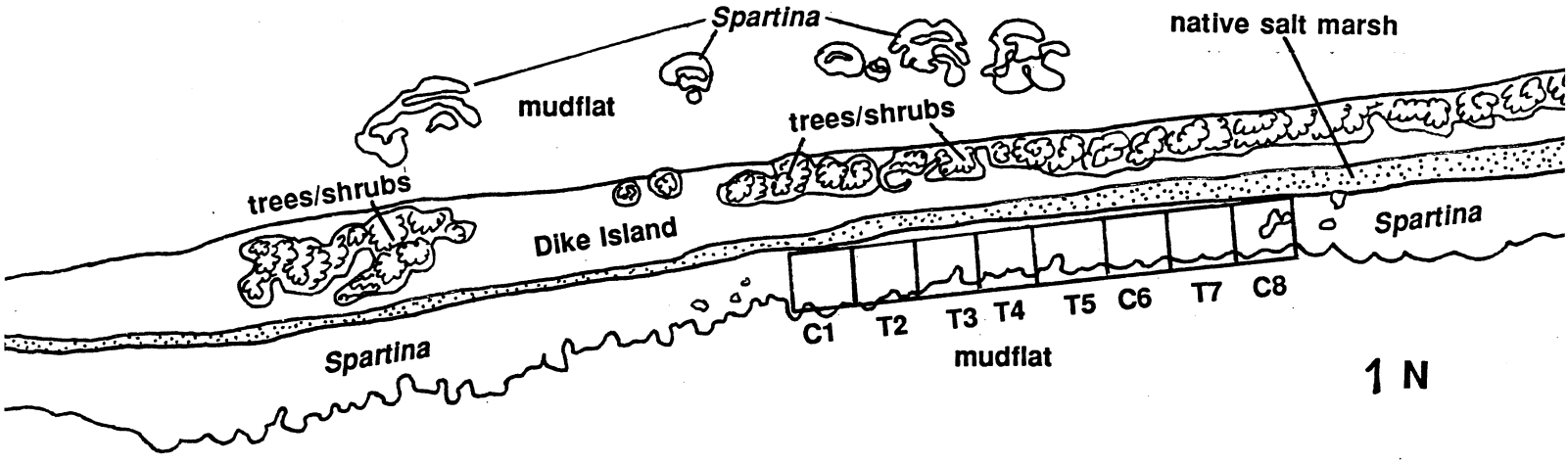

Figure 3. Experimental plots on protected Dike Island site. Plots prefaced by "T" are plots to which glyphosate was applied. Plots prefaced by "C" are control plots. See also Figure 1, B.

Statistical analysis

A student's t-test was used to compare densities of live stems for treatment and control plots at both sites ($\alpha = 0.05$) pre- and post-treatment.

RESULTS

At the exposed site, there was no significant difference between densities of live stems in treatment and control plots pre-treatment or seven months post-treatment (Fig. 4, Appendix 2). Leaves appeared to be clean and were wet with heavy dew (Table 1) the days of the herbicide application. The application rate was 11.42 qts/ac on T4, T6, and T8 (9/6/94) and the plants were not covered with water for at least 7.5 hours after application (Table 2, Appendix 3). The rate of application was 6.28 qts/ac on plots T1 and T2 (9/7/94) and plants were not covered with water for at least 7 hours after application. Mean live stem densities were not significantly different for these two rates of application, therefore a mean rate of 8.34 qts/ac is reported here. Photos were taken on 10/11/94 and yellowing of approximately 10-75% of the aboveground vegetation in treatment plots was observed. Prior to treatment, a small amount of *Salicornia virginica* was mixed with *S. alterniflora* in the experimental plots at the exposed site (Appendix 4). The presence/absence of native vegetation at this site was not recorded in April due to the low density and very small plant size.

At the protected site, there was no significant difference between densities of live stems in treatment and control plots either pre-treatment or seven months post-treatment (Fig. 5, Appendix 2). Leaves appeared to be clean and were wet with heavy dew (Table 1) the day of the herbicide application. Glyphosate was applied on 9/7/94 at a rate of 6.28 quarts/acre at this site and plants were not covered with water for at least 7 hours after application (Table 2, Appendix 3). Photographs were taken on 10/11/94 and yellowing of approximately 10-75% of the aboveground vegetation was observed in

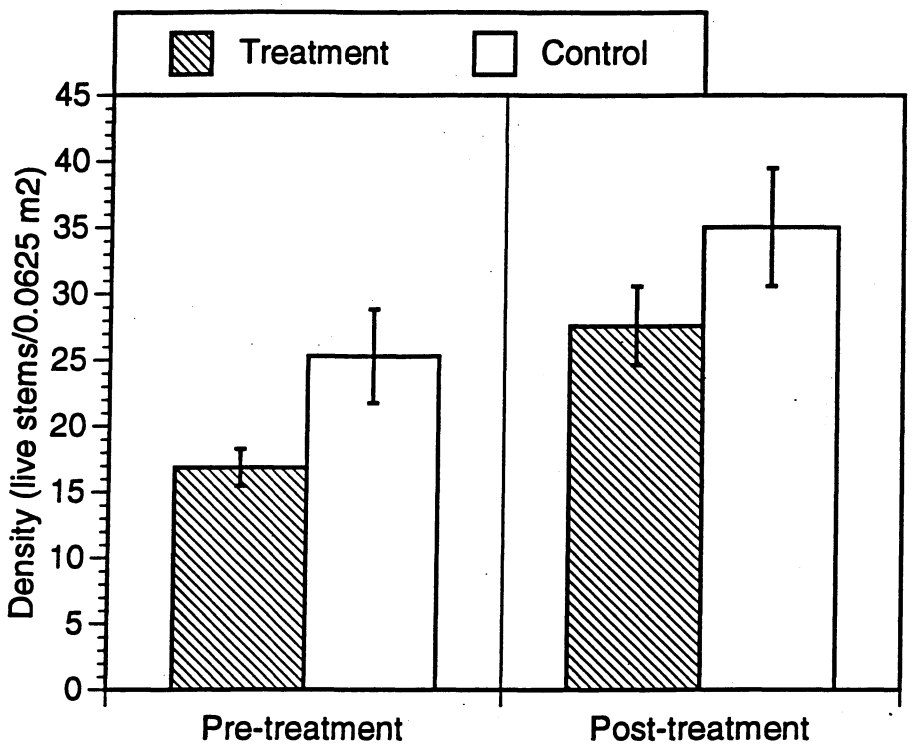

Figure 4. Mean densities (± s.e.) of live stems of *S. alterniflora* in treatment (n=5 plots) and control (n=3 plots) plots at the exposed site on Dike Island. Pre-treatment measurements (n=3 quadrats/plot) were made in August 1994, two weeks prior to treatment with 33% Rodeo® and 5% LI-700®. Post-treatment measurements (n=8 quadrats/plot) were made in April 1995, seven months after treatment.

Table 1. Weather and *Spartina alterniflora* leaf conditions on glyphosate application dates in Padilla Bay, Washington.

Date	Sites	Time	Cloud Cover	Wind	Dew	Leaf Condition	Air Temp
9/6/94	Exposed T8	0645	fog	SW, < 2 mph	heavy	clean, wet	12.5°C
9/6/94	Exposed T4, T6	0732	clear	SW, < 2 mph	heavy	clean, wet	12.5°C
9/7/94	Protected T2,T3,T4, T5,T7	0650	80%	none	heavy	clean,wet	15°C
9/7/94	Exposed T1,T2	0822	80%	S, < 2 mph	heavy	clean, wet	19°C

Table 2. Dates of Rodeo® application to *S. alterniflora* in Padilla Bay, Washington, application start and end times, and tidal sequence (feet relative to chart datum, MLLW). EXP = exposed site, PRO = protected site.

Date	Site	Plot	Application Start	Application End	High Tide	Low Tide	High Tide
9/6/94	EXP	T6	0645	0722	0536 (+7.4)	1210 (+0.8)	1823 (+8.2)
		T6	0732	0750			
		T4	0735	0805			
		T8	0645	0724			
9/7/94	PRO	T7	0650	0711	0633 (+7.5)	1250 (+1.5)	1852(+8.3)
		T5	0711	0721			
		T4	0721	0735			
		T3	0737	0747			
		T2	0747	0802			
	EXP	T2	0822	0850			
		T1	0825	0858			

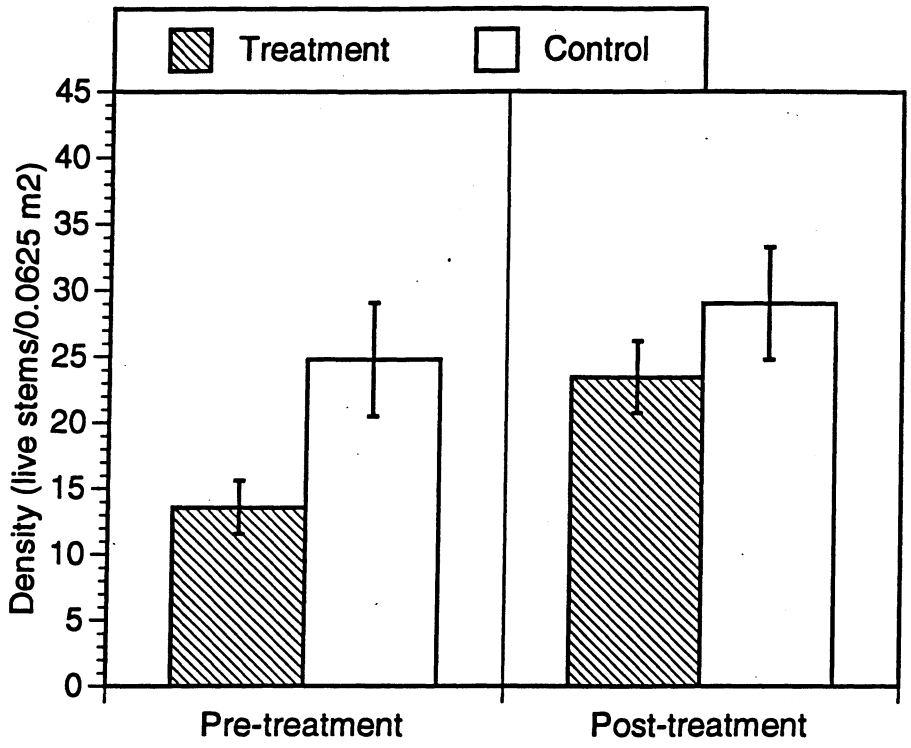

Figure 5. Mean densities (± s.e.) of live stems of *S. alterniflora* in treatment (n=5 plots) and control (n=3 plots) plots at the protected site on Dike Island. Pre-treatment measurements (n=3 quadrats/plot) were made in August 1994, two weeks prior to treatment with 33% Rodeo® and 5% LI-700®. Post-treatment measurements (n=8 quadrats/plot) were made in April 1995, seven months after treatment.

treatment plots. In adjacent native salt marsh, new vegetation was sprouting in April and presence/absence was recorded (Appendix 4).

DISCUSSION

The present study showed no effect of hand held wiper application of glyphosate (33% Rodeo®, with 5% LI-700®) on density of live *Spartina alterniflora* when applied at rates of 6.3 qts/acre and 11.4 qts/acre. These results were not expected since many aquatic plants are sensitive to glyphosate (Barrett, 1985; Lockhart *et al.*, 1989). *S. alterniflora* has been controlled with glyphosate (Monsanto, undated; Crockett, 1991) and wiper applications of glyphosate have been effective on *S. alterniflora* (Norman and Paten, 1994). The apparent lack of an effect of wiper application of glyphosate on *S. alterniflora* in the present study may be due (among other possibilities) to leaf wetness, to sediment on the leaves, to stage of plant's growth cycle, or to the adjuvant that was used. These alternatives are discussed below.

The leaves may have been too wet at the time of application. The supplemental label recommends that Rodeo® remain on the plant for at least 6 hours prior to being covered by tidewater, and that Rodeo® applications should be avoided when leaves are wet with dew. The plants in this study were exposed to glyphosate for at least 7 hours prior to inundation (Appendix 3). However, the leaves were wet with dew both days the glyphosate was applied (Table 2). Glyphosate was applied under these less than ideal conditions because: there are a limited number of suitable daytime low tides during late summer, there is less chance of rain during September than later when the plant is flowering (and when the herbicide may be more effectively translocated to the roots), and the necessary permits only allowed herbicide application within a "window" of time that was requested months earlier.

Glyphosate binds tightly to soil (Boerboom *et al.*, 1994). Therefore, if leaves are covered with sediment, glyphosate binds to the sediment on the leaf's surface and is not

available to the plant. Although the leaves appeared to be clean, the wiper applicators did become dirty as the plants were treated which indicates there was some sediment on the leaves. Wiping sediment off the leaves or washing the leaves prior to herbicide application might improve glyphosate effectiveness, but would be impractical on a large scale.

The effectiveness of herbicide applications can vary depending on the growth stage of the plant (Boerboom et al., 1994). Control of established plants such as *S. alterniflora* requires translocation of herbicide from the leaves into the roots or rhizomes. Glyphosate will move to roots and rhizomes more quickly when sugars are moving downward to the roots such as during summer or fall growth or during flowering. Therefore, the lack of effective kill of *S. alterniflora* in this study may be due to herbicide application at an inappropriate growth stage. The last appropriate daytime low tides of the year are in early September, prior to when the plant flowers in Padilla Bay. It is conceivable the herbicide could be applied in October when the plant is flowering because there are nighttime low tides that would provide the correct exposure windows, but at least three other factors must be considered: hunting season opens and most of the *Spartina* is located on property owned by gun clubs, herbicide application would be much more difficult at night, and the weather turns to rain and wind. Because of these difficulties it appears that in Padilla Bay the most likely time in the autumn when glyphosate would be effectively translocated to the roots — October/November during flowering — is not conducive to application of glyphosate.

LI-700®, the recommended adjuvant, did not appear to stay in suspension, but tended to collect above the water/herbicide mixture in the handle of the wiper. Although the wipers were agitated regularly, the LI-700® concentration on the leaf surface may not have been an effective concentration.

Thus, the lack of an observed effect on *Spartina* in the present study may have been due to: water or sediment the on surface of the leaves, application during an

inappropriate time of plant's growth stage, ineffective adjuvant, or ineffective adjuvant concentration. This study demonstrates that even though glyphosate has proven to be effective in killing *Spartina alterniflora* (Crockett, 1991; Norman and Paten, 1994), the practical control of *S. alterniflora* in Padilla Bay by herbicides will require application under less than ideal conditions and that a variety of application methods, adjuvants, and timing of application need to be used and tested before large scale application of glyphosate can be recommended. Specific methods that we recommend to be tested include:

1) mowing *S. alterniflora* early in the growing season to weaken the plant and to remove standing dead vegetation which otherwise absorbs the herbicide,
2) testing different adjuvants with glyphosate, and
3) testing several concentrations of glyphosate.

Because herbicide application outdoors involves a number of variables that are difficult or impossible to control such as weather, tides, salt and sediment on the leaf's surface, nutrients, etc. -- it would be advantageous to learn about the biology of the plant. Conducting laboratory studies where these variables can be controlled may be the key to finding a reasonable means to control the plant.

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APPENDIX 1

Example of Field Sheet

Spartina Project 1994

Field Sheet

Date:_____Air Temp:_____

Site:_____Soil Temp:_____

Tide sequence:_____

Wind: (direction/speed):_____% Cloud cover:_____

Dew: none light moderate heavy

Leaves: clean sediment mixed with dead veg dry wet

Plot # Time Start Time End	Mixed with native veg? list sp.

No. of volunteers used

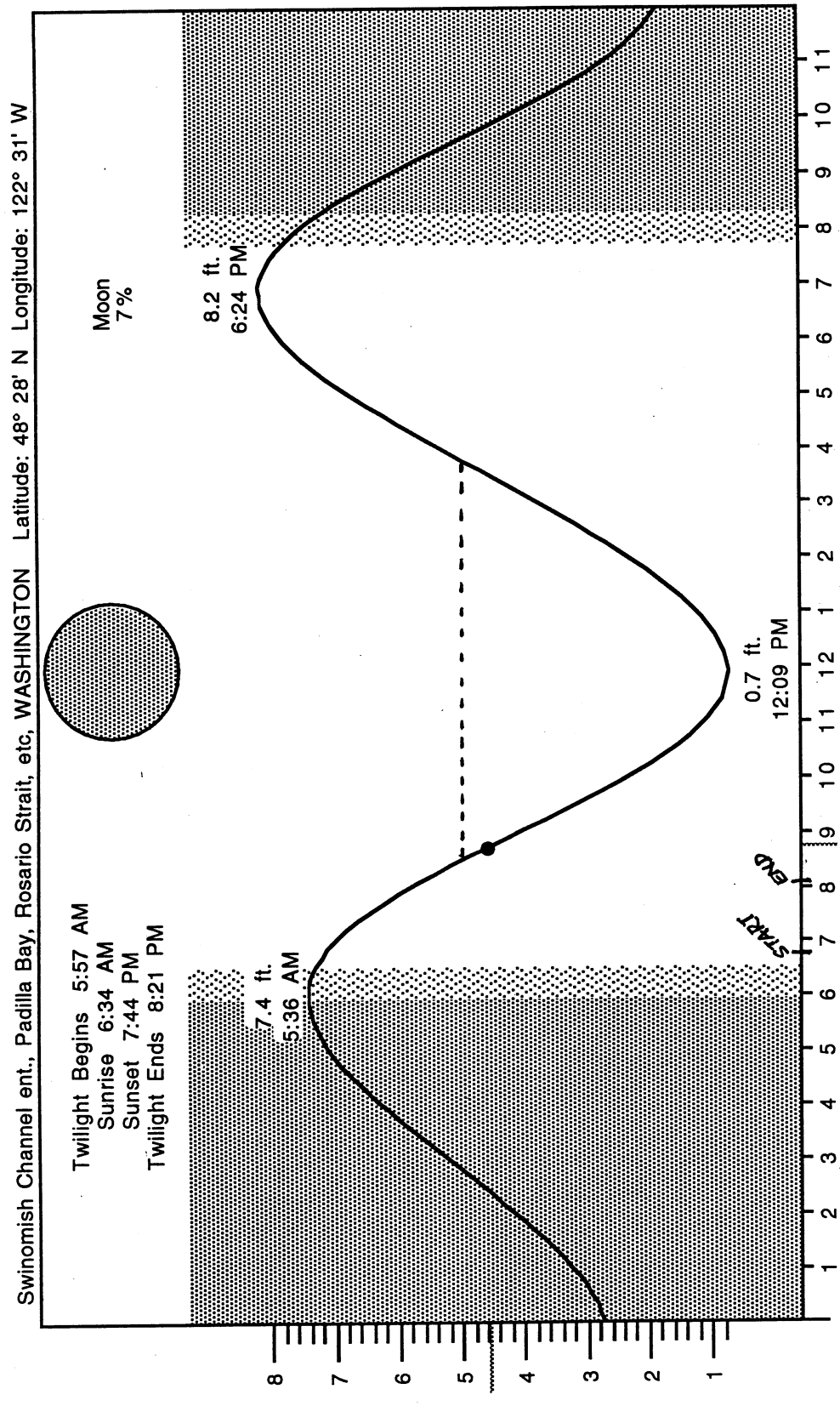
Total per day:_____
Per treatment plot:_____

Notes/Comments: (continue on back if necessary)

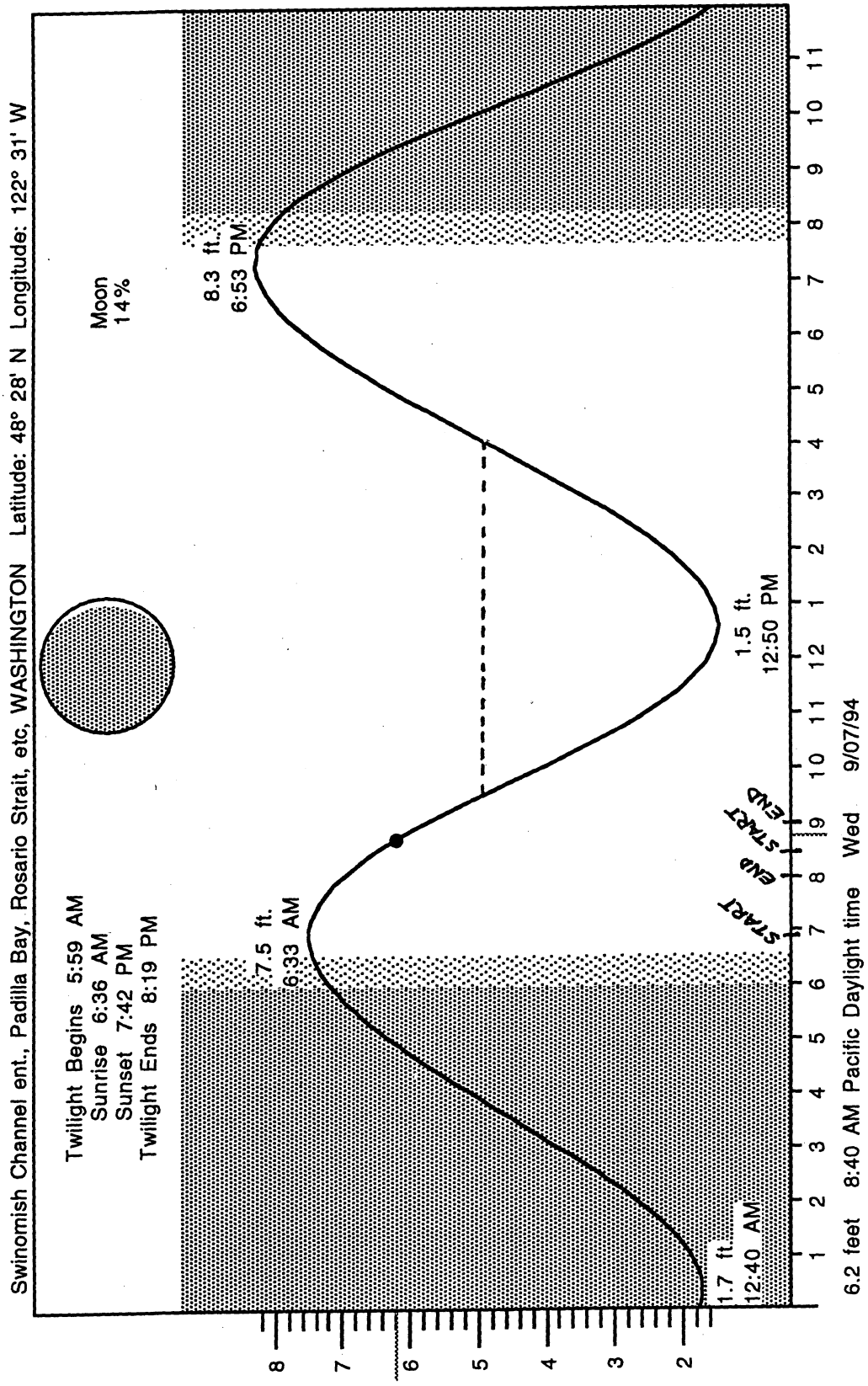
APPENDIX 2

Mean densities (± s.e.) of live *S. alterniflora* (0.0625 m^2 quadrats, pre-treatment: n=3 quadrats/plot; post-treatment: n=8 quadrats/plot.

	Plot No.	PRE (8/2//94)	POST (4/14/95)
EXPOSED SITE			
	T1	18.7 (± 3.8)	20.9 (± 6.8)
	T2	18.0 (± 3.5)	40.1 (± 9.0)
	C3	20.3 (± 5.6)	45.9 (± 7.5)
	T4	21.3 (± 12.7)	28.5 (± 7.4)
	C5	20.3 (± 4.3)	35.2 (± 4.3)
	T6	15.0 (± 5.3)	19.8 (± 8.6)
	C7	35.3 (± 6.2)	23.5 (± 10.7)
	T8	11.3 (± 1.7)	28.8 (± 6.4)
PROTECTED SITE			
	C1	12.7 (± 4.2)	18.1 (± 4.9)
	T2	8.0 (± 3.6)	15.4 (± 4.2)
	T3	29.3 (± 5.7)	29.4 (± 5.5)
	T4	7.3 (± 5.9)	22.5 (± 6.7)
	T5	17.0 (± 2.0)	29.8 (± 5.7)
	C6	31.7 (± 15.6)	30.2 (± 4.4)
	T7	16.3 (± 7.9)	27.6 (± 8.3)
	C8	30.0 (± 6.1)	38.9 (± 9.6)



Appendix 3. Tide chart for 9/6/94. Glyphosate was applied to experimental plots T4, T6, and T8 at the exposed site on Dike Island on this date. Application start and end times are indicated. The dotted line is a +5.0 tide. Inundation occurred some time after the +5.0 tide (i.e after 3:30 p.m.).



Appendix 3. Tide chart for 9/7/94. Glyphosate was applied to experimental plots T2, T3, T4, T5, and T7 at the protected Dike Island site. The first set of start/end times are for this site. Glyphosate was applied to T1 and T2 at the exposed Dike Island site as well. The second start/end times are for that site. The dotted line is a +5.0 tide. Inundation occurred some time after the +5.0 tide (i.e. after 4:00 p.m.).

APPENDIX 4

Mean (n=3) percent cover for three native species of vegetation (*Atriplex patula, Salicornia virginica* and *Distichlis spicata*) and for *Spartina alterniflora* (a non-native salt marsh grass) present pre-treatment in 0.0625 m^2 quadrats adjacent to the protected plots for this study. Percent cover was measured on 8/22/94 for these plots. As native vegetation was just beginning to sprout in April 1995, presence or absence only was recorded as percent cover estimates were not comparable to growth measured in August. Exposed plots did not border on native vegetation. However, presence or absence of native vegetation in treatment plots was recorded pre-treatment. nr = not recorded.

Plot	Sept. 1994 *Atriplex*	*Salicornia*	*Distichlis*	*Spartina*	April 1995 native vegetation (present/absent)
Protected					
C1	22	60	3	15	present
T2	4	93	1	2	present
T3	11	58	30	1	present
T4	3	76	21	0	present
T5	2.5	75	20	2.5	present
C6	16	76	2	6	present
T7	5	72	6	17	present
C8	22	48	1	29	present
Exposed					
T1	absent	absent	absent	present	nr
T2	absent	absent	absent	present	nr
C3	nr	nr	nr	present	nr
T4	absent	present	absent	present	nr
C5	nr	nr	nr	present	nr
T6	absent	present	absent	present	nr
C7	nr	nr	nr	present	nr
T8	absent	present	absent	present	nr