RECOMMENDATIONS TO EXPEDITE SPARTINA ERADICATION IN WILLAPA BAY

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Eradicating Spartina. An Overview.

Eradicating Spartina requires that (1) there are no new introductions of Spartina plants; (2) that all the plants in a given area are found; and (3) the elimination of those plants by spray is 100% successful.

Fortunately, based on our seed collection and germination studies over the past two years, it is unlikely there will be any significant new infestations coming from viable seed production.

A more significant obstacle arises from the interaction of both search success and control success. Searchers are able to find about 63% of the plants, on average, in areas that they search. The spray kills about 75% of the plants treated. Both are impressive figures. However, the probable fraction of plants found and killed during a search is the product of these two numbers. After a search, the likely fraction of plants found and killed in an area is 0.63 x 0.75 = 0.4725 or about 47% -- less than half of the plants initially living in the area.

Table 1 shows the fractions of plants likely to be found and killed in an area during one search if the probability of discovery of each plant is as shown at the left and the fraction of sprayed plants killed by the spray is shown at the top. The lower right corner of the Table shows that, in order to find and kill 90% of the plants in an area, searchers must be able to find 95% of them and the spray must kill 95% of plants sprayed. Those very high levels of search and control efficacy are essential to wiping out the plants within the next few field seasons.

Table 1. Probability of success (P) of a combined search and spray effort

	Spray success P value			
Search success P value	**0.65**	**0.75**	**0.85**	**0.95**
0.65	0.42	0.49	0.55	0.62
0.75	0.49	0.56	0.64	0.71
0.85	0.55	0.64	0.72	0.81
0.95	0.62	0.71	0.81	0.90

Based on our data, search success ranges from 50 to 85% and spray efficacy from 65 to 95%. Ultimate eradication is therefore predicated on having a program where crews are highly effective at both search and spraying.

Table 2 shows the numbers of searches needed to clear all of the Spartina plants growing at various average densities on 95% or more of the ground searched, at various combinations of search efficacy and spray efficacy. (This Table is produced by a model described in Appendix A of Willapa Bay Spartina seed production and eradication models for the upper tidal flats and salt marshes. Patten, K. & D. Milne. 2009.)

If the observed search and kill rate probabilities are used (0.63 and 0.75, respectively) on ǂ ground with 20 plants per acre, it will take10 search/spray efforts to reduce the population to 1 plant per acre (or, in equivalent wording, to eliminate all of the plants in 95% of that area), compared to only 3 search/spray efforts if both their success rates are 0.90.

Unless both searching and spraying are significantly improved over current practices, achieving the end game of eradication in the Willapa within the next decade will be unlikely. To help achieve incremental increases in search efficiency and improve spray efficacy, a series of research-based recommendations are provided in the rest of this report.

Table 2. Reduction in number of search and spray efforts needed to clear Spartina from a site as a function of search and spray effort efficiency.

Mean # of plants/ ac	Number of searches/sprays needed to result in > 95% Spartina-free ground.				
	63% find rate & 75 % kill rate	70% find rate & 75 % kill rate	63% find rate & 90 % kill rate	70% find rate & 90 % kill rate	90% find rate & 90 % kill rate
5	4	4	3	3	2
10	6	5	5	4	2
20	10	9	8	6	3

Search Strategy Recommendations.

It is clear from our data and our analysis of search efforts that the key limiting factor in achieving eradication is the lack of efficacy in finding plants in areas of the bay where they can be easily overlooked, such as in the salt marsh. As long as the probability of finding any given Spartina in these sites is only p=0.63, the timeframe to kill the last Spartina is greatly amplified. Numerous suggestions and strategies are provided that can be used by resource agencies conducting control programs to improve the odds of finding 95% or more of the plants in fewer searches.

1) Search strategy will obviously vary by site type. Spartina on open mudflats are highly visible and are relatively easy to find compared to Spartina on the tidal salt marshes. Spartina on the mudflats usually develop later than those in the marsh. This means a search and spray effort would be much more effective if it was delayed until later in the season, after the initial higher marsh sites have been searched and sprayed. Since mudflats are mainly accessed by airboats or tracked vehicles, grid patterns are somewhat problematic. This means that there will likely be a problem of skipped sections and plants as machines go from one infestation to another. One possible means to minimize skips and help with the find efficiency is to have a dedicated

spotter with binoculars, who is on constant vigilance and assures that the search is systematic.

2) Spartina in the tidal marsh or marsh fringe are more difficult to see and thus the search process should be much more systematic. Observations made of state and federal agencies' teams spraying in various locations throughout various Willapa sites have revealed a consistent pattern. After seeing and spraying a plant, applicators are normally distracted from their search-spray grid/transect paths. As a consequence, they veer off along another tangent and miss plants that were in their "assigned" search paths. This was particularly noted when 1 or 2 applicators were assigned to cover a large site and they walked zig-zag through the site looking for Spartina. A recommendation to improve the search pattern in salt marshes would be for 3 to 5 applicators to walk 5', 10' or 20' abreast as they transverse through a site along a specific grid line. The exact grid pattern will vary by site, as some sections of the bay have very narrow salt marshes, where a two-person grid 10' apart would suffice. Other parts of the bay have marshes ¼ to ½ mile wide and will require multiple passes with a crew spaced 5' to 20' apart.

3) Search/spray patterns tended to be habituated. Consequently, the same plants are missed year after year. To minimize this concern, searches should be as independent from any previous search pattern as is practical. That is, search and spray events should be conducted so that searchers use "new eyes" and are not influenced by the footprints, browned-down plants, or their own previous search patterns, nor are they channeled in the same way during every search by topography or other factors. More specifically, agencies should a) rotate spray teams that are used to treat each of the sites (i.e. – not have the same applicators always spraying the same site year after year), and b) alternate direction of travel through a zone (north to south with east to west). It is also important that features of the topography – channels, logs, easy walking, and difficult walking – not be allowed to subtly channel all search teams over the same paths.

4) There should be effective feedback for all spray crews to tell them how efficient their search/spray effort was on any given day or site. In other words, a crew should get feedback on what percent of the plants they are missing and if there is any particular crew member who is sloppy in his/her search effort. This will enable them to learn how to best improve their search effort efficacy. This is difficult to do after the fact. Following browndown (2-4 weeks), it is next to impossible to distinguish new Spartina plants that may have sprouted, or sprayed ones that didn't die, and which crew member(s) were missing most plants along a grid. It is recommended that immediately following a spray effort a subsequent pass be made by a crew to flag any Spartina plant that lacked spray dye or had poor coverage of dye over the entire canopy. This can be done after the tide is no longer suitable for spraying, yet still low enough to find Spartina. White or red 18" or 24" metal flags work excellently for this. A cleanup crew can be used on the subsequent day to treat all skipped plants and pick up the flags. For feedback/training purposes it would be important to maintain some level of records on sprayed/skipped plants. This should include what crew member was spraying what section of the grid, if certain sections of the grid were having a lot more flagged Spartina than other sections, if there are particular sites which are more prone to skips, and if the ratio of spray to skipped plants is reducing over time. These results/patterns will help spray bosses re-educate, re-assign or remove ineffective

crew members. The results can also be used to help develop more effective spray patterns and grids. For example if a 4-person spray crew is spaced ~25' apart along a grid and is consistently getting lots of skipped plants, then they could shorten their spacing to 15' along a grid and see if that reduced skipping. This type of a post-treatment flag method doesn't have to be repeated at all sites and times, but should be done at least once or twice at the beginning of the spray season.

5) If the above post-treatment flagging is not practical, other options would be to have a second search/spray crew follow the search/spray zone of the first crew by 15 to 30 minutes. Their purpose would be to spray any skips that were found. These follow-up searches "count," in the sense of Table 2, toward the total numbers of searches needed to clear 95% of the ground of Spartina.

6) Grid patterns are not applicable to all sites. Small, but deep, tidal drainage often dissects a longitudinal search grid and runs 1000' up into the shoreline. During the intensity of the spray effort, these sites are the ones most frequently overlooked year after year by crews. The post-spray search crews should be particularly mindful and diligent in looking for these sites. They should GPS any drainage with skipped Spartina, and not rely on flagging skipped plants in these sites. A classic example of this situation occurred in 2008. An oyster grower found a large clone, 1000' up an obscure minuscule drainage system that jetted into mowed pasture south of Oysterville. This clone had never been observed in the past 10 years. This clone would have only been found if a crew member was mindful enough to follow every tiny drainage channel to its origins.

7) Despite the best attention of a crew, they may or may not cover their entire assigned sites before heading off to another location. There is no guarantee that all sites have been searched and treated. One possible way to avoid major foul-ups is for each applicator to have their own GPS system and have it set on breadcrumbs or tracklog. These tracks could all be downloaded weekly, compiled and skips in section noted for follow-up.

8) Spray teams would be more effective in the long run if they spent more time being slow, deliberate and very zealous in finding and treating as many plants at a site as possible, as opposed to moving routinely through a zone to get done. The emphasis should be on thoroughness, not speed.

9) Search and spray efforts in difficult-to-observe areas like salt marshes should be done to correspond to times/seasons when Spartina is most visible. Search sequences during May and June in the salt marsh will be less successful than sessions in July to September, when plants are bigger. The effect is to improve the probability of plant detection, which ultimately reduces the number of searches needed.

10) Each site needs to be visited three or more times per season. A site no longer has to be visited that year if no untreated plants are found during *each* of three *consecutive* searches. For any site in which untreated plants are found, the search sequence must be reset to zero and three more visits should be employed. In other words, *three consecutive searches, each of which reveals zero untreated plants*, is the condition for ending searches of any plot for that season. Using this protocol, search agencies may

eventually be able to free up searching in some sites within a given year and focus manpower in other still-infested areas.

The benefit of multiple searches in a season cannot be over-emphasized. If a strategy is used to stop searching after the first occasion upon which no plants are found, it will take 18 growing seasons to eradicate Spartina. If there are two or three consecutive searches in a season with zero plants found per search, it will only take 3+ or 2+ growing seasons respectively to eradicate Spartina.

Spray Strategy Recommendations.

The effectiveness of a search, find and spray program to eradicate the remaining Spartina in Willapa Bay is greatly compromised if treated plants are not killed. Numerous observations year after year indicate that Spartina control is often less than perfect. Numerous suggestions and strategies are provided that can be used by resource agencies conducting control programs to improve the odds of control to 95% or greater.

1) With so few acres left to spray, the cost of herbicide is no longer a limiting factor for the Spartina control effort. The low-volume spot treatment label for Habitat states that 0.5 to 5% v/v tank mix can be used, as long as the label rate of 6 pt/ac is not violated. The amount of product taken up by the plant into the root system is the limiting factor for efficacy; thus a tank mix with >1 % of Habitat would provide better control in situations where efficacy is problematic , such as small regrowth, short dry time, or a dirty canopy. We don't have data to be able to differentiate the difference in efficacy between 1, 2 or 5% Habitat on regrowth. Based on much earlier trials, however, there are major differences in efficacy between 0.5 and 1%. In addition, data from the San Francisco Spartina program has indicate a much better control of Spartina in short dry time locations using a 3% imazapyr @ 25 gpa spray volume. These factors strongly suggest an increase in tank mix ratio for backpack treatments would be appropriate. The recommended ratio will be contingent upon spray volume used by the applicators. The lower the spray volume the higher the recommended ratio of imazapyr. Calibration training session with applicators should be standard training protocol. Two methods are advised: 1) # oz to spray $1/128^{th}$ of an acre = gpa or 2) # seconds to spray a 1, 2, 3 or $4ft^2$ with an adjustable cone nozzle ~= 172, 86, 58 or 43 gpa, respectively. Low-end to high-end range for tank mixes based on spray volume and type of Spartina treated should be 1 to 3% Habitat, 3 to 5 % glyphosate and 1% surfactant. For all sites where the majority of the Spartina has been compromised, the percentage of Habitat in the tank mix should be increased to the higher rate. A compromised site is one where plant vigor is poor and the canopy is sparse and weak, the leaves are dirty or dry time will be <5 hours. More detail is provided in table 3. Enough dye should be added to allow for easy spotting of treated plants.

2) For clean-up spot treatment, high pressure spray equipment is overkill and greatly increases the amount of product used. The minimum trigger time for a quick on/off with a high pressure gun to small plants translates to >500 gpa spray volume. Use of backpacks and low pressure spray units should be considered for all final clean up operations.

3) Applicators should be sure their spray is uniform across all sides of the canopy. Failure to control is frequently an issue of partial coverage.

4) The optimal window for timing spray applications should be after all the regrowth has occurred and the plant has adequate canopy to take up enough spray to kill the entire root system. Too early an application of imazapyr can easily compromise efficacy, and only suppress and weaken the plant, making it even more difficult to control in subsequent years. Research on control of woody perennials with imazapyr has documented that continued annual spraying of weakened plants is ineffective and a year of recovery without spraying is needed before the plant can be treated and killed. A similar situation is likely to occur with weakened, partially dead Spartina. It greatly complicates a spray program to selectively not spray weak plants. Furthermore it is likely beyond the ability of most crews to distinguish previously sprayed weak plants vs. normal healthy plants with late growth. For sites where all the plants in the area have been treated in the previous year and nothing is likely to go to seed, it would be prudent to wait as late in the season as possible before spraying. This would give previously sprayed, weakened but still alive plants time to recover and grow before re-treatment. This could be as late as mid-September. Those sites should then be flagged for missed plants on the day of treatment and retreated the following day to assure no plants are totally skipped for the year. Because most sites in Willapa will be a mix of untreated and treated plants, the above strategy might not be appropriate for 2009 and could be delayed until 2010. In contrast to these sites where later treatment might be most appropriate, some sites high in the tidal zone are likely to have large enough plants to spray by late May. It could be feasible during warm years to start spraying these sites by early to mid-June.

5) The most critical sites and plants to focus a spray treatment on are those that have the potential to go to seed. Any plant in the second year of growth can flower and produce seed. Any site with scattered large or medium size clones that went untreated last year needs to be the first focus for a spray crew, after which all other sites could be treated. In 2009 it is unlikely that any plants will be seedlings; thus every plant could potentially flower. How real is the threat of seed production from the residual Spartina plants in Willapa Bay? Based on our data in 2008, it is a minor threat. Isolated plants/clones do not appear to produce many, if any, viable seeds. This, however, could have been an anomaly due to the cool growing season in 2008. Any site with a large infestation of previously untreated Spartina should still be the first and primary focus of the 2009 control effort.

6) There are three basic Spartina habitat zones, low tidal mud, mid to upper tidal mud, and the salt marsh. For the zone with longer dry times, the treatment plan to achieve sufficient dry time is fairly intuitive, provided shorter plant heights are accommodated. The areas low in the tidal zone with the shortest dry time is the most problematic. There is only one tide window in 2009, 7/20/09 to 7/25/09, that would allow for adequate dry time on short plants on lower elevation intertidal mudflats. A higher concentration of imazapyr should be used on these sites and all crews should be focused on those areas during that time period.

7) October has been traditionally too late in the spray season to get good efficacy as fall storms compromise the canopy quality. This is especially true for areas in the mudflats or in the transition zone with the salt marsh. Good efficacy can be obtained,

however, as long the canopy is clean and hasn't been knocked down or has eelgrass on it. In addition the native salt marsh canopy senesces in the fall, providing excellent visibility of Spartina in the high marsh tidal guts. A search/spray effort should be conducted during this time in as many of the upper marsh tidal guts as possible.

8) Small Spartina plants, this year's or last year's seedlings, are easily killed with herbicide. But, as mentioned before, plants that are small because they have been herbicide-stunted are difficult to control. Differentiating between these plant types may be difficult. Applicators should be trained to distinguish the difference, and leave plants that are stunted for a later treatment.

9) Mechanical treatments that damage intact plants and reduce the integrity of the root system could possibly make subsequent control with herbicide more difficult. There is no direct data on Spartina indicating that this true. For other rhizomatous species however, this has been found to be the case. On some sites with a lot of bird use and tall dead stubble, disking, tilling, or crushing of Spartina will provide a small increase in shorebird usage in the year following treatment. This, however, has not been the case if there is little stubble remaining or if there is plenty of open terrain already present. These treatments also have not been shown to accelerate restoration of the sites back to their original bathymetry. Based on the chance that mechanical treatment of the ground could compromise efficacy, or slow the time frame of eradication, such treatments are not worth the short-term benefits they may provide to shorebirds.

10) Tables 3 and 4 summarize treatment window and herbicide ratios for different situations.

Table 3. Herbicide tank mix ratios recommended for different Spartina plants and sites*.

Plant type /site	Tank mix ratio (% v/v) of Habitat:Rodeo:Surfactant
Spartina likely to go to seed	1:3:1*
Spartina low in the mudflat	1.5 to 2:3:1*
Spartina high in the salt marsh	1:3:1*
Weak, stunted, previously treated plants	1.5 to 2:3:1*
All remaining small Spartina plants/clones	1:3:1*
Untreated meadows	3.7:10:0.25**

*For all spot treatments these value assume 100 gpa low pressure application. However, if you are using a lower gpa (30 to 50) then the ratio of imazapyr and glyphosate in the mixture should be adjusted upwards. A 3:5:1 for example would be recommend to very difficult to control Spartina.

** For any large untreated meadow use a low volume boom sprayer @ 20 gpa

Table 4. Suggested treatment windows for different type of Spartina plants/sites.					
Plant type/site	Treatment window				
	June	July	August	September	October
Spartina likely to go to seed		These should be a spray priority; at least two search and spray events should be done at sites which went to seed in 2008.			
Spartina low in the mudflat		Best or only window to treat is 7/20/09 to 7/25/09			
Spartina high in the salt marsh	First to spray since it will be tallest first.				Last to spray since most visible and maybe only plants with good canopy left
Weak, stunted, previously treated plants			Continued re-treatment will only stunt them again. Wait until plants are at least 16" to 20" high before treating.		
All remaining Spartina		Plants should ideally be at least 12 to 20" high before treatment.			

References:

Patten, K. & D. Milne. 2009. Willapa Bay Spartina seed production and eradication models for the upper tidal flats and salt marshes. 2008 Progress Report to the USFW – Willapa Wildlife Refuge.

Patten, K. & C. O'Casey 2009. Shorebird usage in Willapa Bay in response to Spartina control efforts. 2008 Progress Report to the USFW – Willapa Wildlife Refuge.