Sequential Dry Substrate/Foliar Herbicide Applications For Suppression of Flowering Rush[1]

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Flathead Lake is at low pool drawdown in late winter through May. This seasonal drawdown regime provides a dry ground treatment window for soil active herbicide uptake via roots. And in warm springs, which promote early leaf elongation additional foliar uptake. It is well established that Habitat has soil residual effects (Senseman 2007, Netherland 2009), in addition to foliar uptake in the warmer springs which promote early leaf growth. Patten and Haldeman (2012) have shown that Clearcast has aquatic weed efficacy via foliar uptake during drawdown periods (Japanese eelgrass at low tide), although the contribution via root uptake of Clearcast is uncertain (Environ 2012).

Two herbicide treatments, Clearcast (imazamox) & Habitat (imazapyr), both with 2 qt/ac Competitor MSO were applied as "dry ground" treatments during the spring (May) drawdown in East Bay of Flathead Lake. Flowering rush leaf tips emergence ranged from just about ½ to 2 inches out of the lakebed substrate and were still purple at the times of spraying. The treatments were repeated for five sequential years (2014-2018). Clearcast was used at 4 qt/ac in 2014 through 2016 and at 3 qt/ac in 2017 and 2018. The Habitat rate was 3 qt/ac for all five treatment years. Depending on the year the total herbicide and water spray mix volumes ranged from 87 to 105 gallons per acre. The randomized complete block experimental design included no-spray control plots. Each of the three treatments was replicated 5 times. The individual plots were 140 x 30 ft.

Post spray assessments of suppression of flowering spring leaf tip emergence was done by counting the number leaf tips in 20 Daubenmire frame (10 x 20 in.) per plot. Canopy cover measurements were done by point intercept (100 to 120 points/plot).

A summary of the five years of percent control of spring leaf tip emergence and summer or fall canopy cover is presented in Table 1. The block 5 plots were at a lower lakebed elevation and were inundated by water much sooner than the other four blocks. Control tended to be less on the block 5 plots in most years. Without including the early flooded block 5 the 2018 annual control of canopy cover after 5 sequential years of herbicide treatments was 91.1% for Habitat and 78.5% for Clearcast treatments. Including the block 5 data the canopy cover suppression was 88.1% for Habitat and 66.3% for Clearcast treatments. Habitat was consistently more efficacious than Clearcast. A graphic summary for leaf tip emergence and canopy cover control from sequential spraying for 5 years is presented as Figure 1.

The percent canopy cover control obtained by Habitat in most years would be commercially acceptable for the summer season recreational uses. The percent control of spring emerging leaf tips after having sprayed the previous year range from 70% to 94% for Clearcast and 92% to 99% for Habitat. However there are still very large numbers of new leaf tips emerging in the following spring (Table 3). This persistent emergence of leaf tips from the rhizomes allows the new top growth to replenish the carbohydrate reserves of the rhizomes and maintain the perennating buds.

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Table 1. Summary of % control of flowering rush obtained over 5 years with Habitat and Clearcast herbicides applied during the spring drawdown (May) period.

Sampled		% Control	
Date	**DAFT***	**Clearcast**	**Habitat**
8/13/2014	**107**	61.8	95.6
10/8/2014	**163**	46.1	88.2
4/20/2015	**357**	93.7	97.4
7/13/2015	**441**	64.1	77.7
4/19/2016	**722**	62.1	87.3
8/1/2016	**826**	85.2	90.5
5/2/2017	**1100**	89.4	95.4
7/25/2017	**1166**	62.2	77.8
4/30/2018	**1462**	76.4	93.0
7/27/2018	**1533**	66.3	88.1

*Days After First Treatment

Without Block 5:		% Control	
Date	**DAFT***	**Clearcast**	**Habitat**
8/13/2014	**107**	62.0	96.0
10/8/2014	**163**	55.3	98.5
4/20/2015	**357**	94.3	98.6
7/13/2015	**441**	69.5	95.2
4/19/2016	**722**	65.9	91.1
8/1/2016	**826**	96.4	98.2
5/2/2017	**1100**	91.8	98.0
7/25/2017	**1166**	74.5	91.6
4/30/2018	**1462**	77.8	96.6
7/27/2018	**1533**	78.5	91.1

*Days After First Treatment

**Block five has wetter soil conditions resulting in later flowering rush maturity that likely affects efficacy. Block 5 had much denser flowering rush at the beginning of the trial five years ago.

Figure 1. Graphic summary of increasing flowering rush canopy cover suppression obtained by sequential spraying with Habitat and Clearcast herbicides from May 2014 through July 2018.

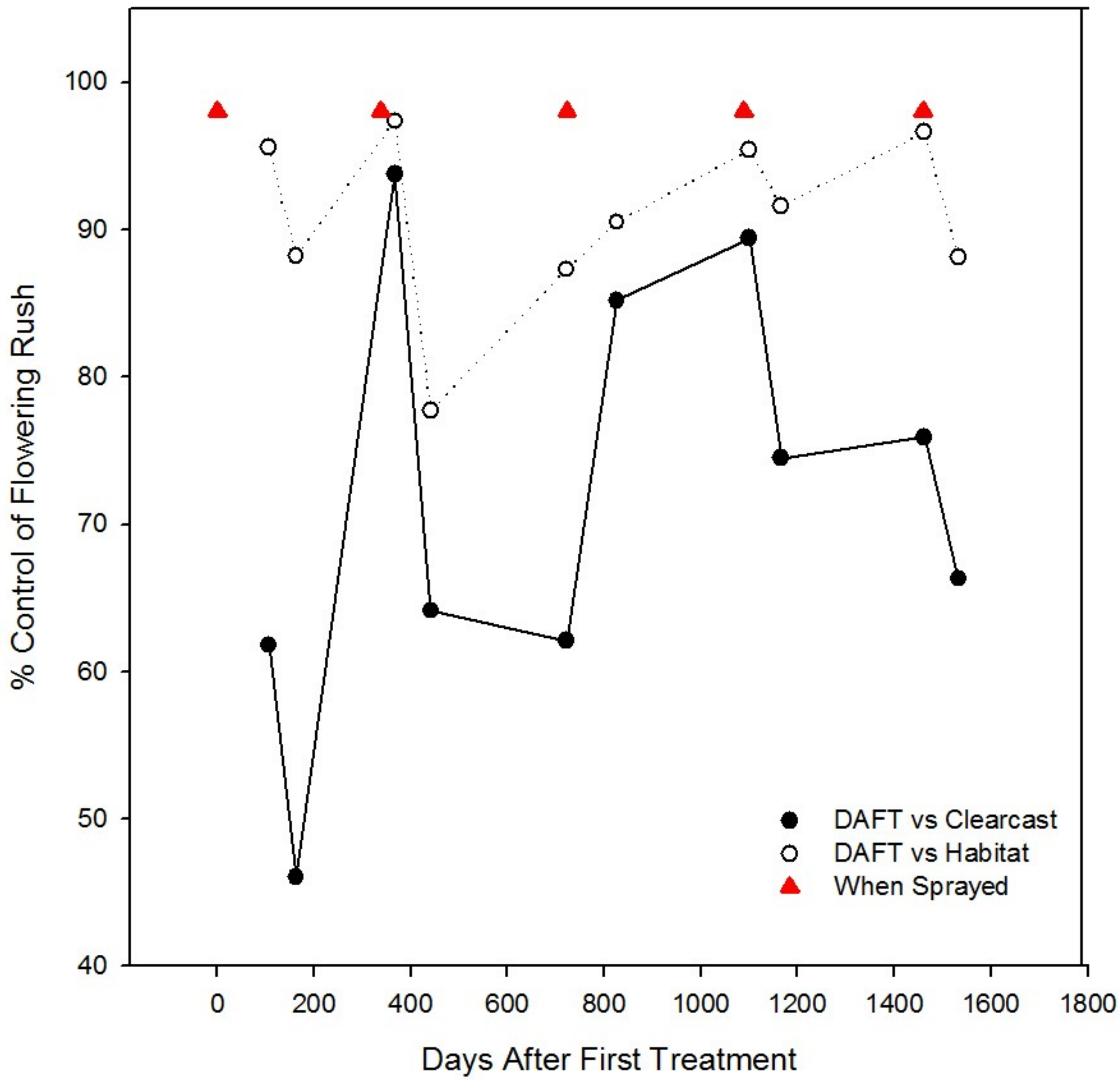

Table 2. Percent control of leaf tips emerging in late April-early May for blocks 1-4.

% Control	2015	2016	2017	2018
Clearcast	94	70	92	76
Habitat	99	92	98	97

Table 3. Density (#/acre) of late April-early May emerging leaf tips for blocks 1-4.

Treatment	2015	2016	2017	2018
Control	6,616,610	3,302,235	3,334,610	3,136,314
Clearcast	382,428	975,292	270,128	757,774
Habitat	88,019	253,434	66,773	106,230

Lakebed substrate cores (6 per plot) were taken in April of 2017 and April 2018. The cores were washed to free the flowering rush rhizomes and fine roots. Viable rhizome buds were counted and rhizome wet weights were taken. Fine root wet weights were also determined in 2018. After the initial set of measurements were completed the April samples of washed rhizome fragments were planted in pots and allowed to grow in the greenhouse through the summer and the same measurements made in August. Standard deviations of the response measurements were approximately equal to the means (Table 4) and most of the data sets included one or more outliers. So in most cases the variances did not meet Levene's Test for Homogeneity of Variances. We did not find an appropriate transformation that could be applied to all cases. Accordingly the nonparametric ranked Kruskal-Wallis Test for Independent Samples was applied. Overall differences for the three treatments were very highly significant ($p \leq 0.001$, but not tabled) for all measurements and assessment dates. Accordingly pairwise comparisons were warranted. In the Kruskal-Wallace pairwise comparisons the individual herbicide treatments were always very highly significant compared to the no-spray controls ($p \leq 0.001$, but not tabled). Pairwise comparisons of Habitat versus Clearcast by the Kruskal-Wallis Test and Tamhane's T2 for unequal variance indicate the trend for Habitat to be more suppressive of rhizomes. The Habitat versus Clearcast p. values were <0.05 in five of the ten possible pairwise comparisons, marginally significant ($p=0.079$) in one case, and the test specific minimum p values ranged from 0.117 to 0.291 in the other four pairwise herbicide comparisons (Table 4). Given the small number of cores and heterogeneity of the response measurements this assessment does indicate a trend for rhizome depletion from Habitat treatments.

Environ. 2012. Screening-Level Ecological Risk Assessment of the Proposed Use of the Herbicide Imazamox to Control Invasive Japanese Eelgrass (Zostera japonica) in Willapa Bay, Washington State. Washington State University Pullman, Washington.

Netherland, M.D. 2009. Chemical Control of Aquatic Weeds. Chap. 11. Biology and Control of Aquatic Plants. Aquatic Ecosystem Restoration Foundation.

Patten, K. & Haldeman, N. 2012. Post-treatment water, sediment and eelgrass concentrations of imazamox following a spray to control Japanese eelgrass in Willapa Bay, WA and an assessment of non-target impacts to native eelgrass. State University Long Beach Research and Extension Unit. Washington State University Long Beach Research and Extension Unit. 11p.

Senseman S.A. (editor). 2007. Herbicide Handbook. Ninth Edition. Weed Science Society of America. p 84-86.

Table 4. 2017 & 2018 rhizome leaf sprout counts and rhizome wet weights (grams); and 2018 fine roots wet weights (grams) (without block 5).

		Sprout Count	Sprout Count	Rhizome Weight*	Rhizome Weight*
Herbicide	**Mo. & Yr.**	**Apr 2017**	**Aug 2017**	**Apr 2017**	**Aug 2017**
Clearcast	Mean	10.7	28.6	18.1	18.3
	n	24	24	24	24
	Std. Dev	9.35	27.43	14.98	15.38
Habitat	Mean	2.4	13.6	10.9	10.1
	n	24	24	24	24
	Std. Dev	2.92	16.56	12.26	11.26
No-Spray	Mean	30.7	113.8	51	80.4
	n	24	24	24	24
	Std. Dev	9.79	26.22	22.22	26.27
[Y]Pairwise Clearcast vs. Habitat					
	Kruskal-Wallis p.	**0.029**	0.168	0.172	0.159
	Tamhane's T2 p.	**0.001**	**0.079**	0.211	0.117
		Sprout Count	**Sprout Count**	**Rhizome Weight***	**Rhizome Weight***
	Mo. & Yr.	**Apr 2018**	**Aug 2018**	**April 2018**	**Aug 2018**
Clearcast	Mean	10.3	15.6	13.3	15.5
	n	24	24	24	24
	Std. Dev	15.75	16.38	17.6	16.36
Habitat	Mean	4.4	4.1	7.8	5.8
	n	24	24	24	4.1
	Std. Dev.	9.17	5.13	9.1	5.13
No-Spray	Mean	39.5	94.5	73.6	94.5
	n	24	24	24	24
	Std. dev.	19.94	23.96	21.36	23.96
[Y]Pairwise Clearcast vs. Habitat					
	Kruskal-Wallis p.	0.189	0.090	0.291	0.090
	Tamhane's T2 p.	0.338	**0.009**	0.417	**0.009**
				Fine Root Weight*	**Fine Root Weight***
	Mo. & Yr.			**April 2018**	**Aug 2018**
Clearcast	Mean			30.4	11.9
	n			24	24
	Std. Dev			24.78	7.4
Habitat	Mean			19.8	5.3
	n			24	24
	Std. Dev.			12.16	6.46
No-Spray	Mean			51.4	43.3
	n			24	24
	Std. dev.			18.15	11.49
[Y]Pairwise Clearcast vs. Habitat					
	Kruskal-Wallis p.			0.127	**0.028**
	Tamhane's T2 p.			0.191	**0.006**

[Y]Kruskal-Wallis tests (not tabled) for overall differences for the three treatments were very highly significant ($p \leq 0.001$) for all measurements and assessment dates justifying pairwise comparisons.

*weights are grams wet weight