PARROTFEATHER MILFOIL (*MYRIOPHYLLUM AQUATICUM*) – ASSESSMENT OF MANAGEMENT ALTERNATIVES

Final Progress Report to Washington State Department of Ecology
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INTRODUCTION

Parrotfeather milfoil (*Myriophyllum aquaticum*) is an introduced and widely distributed aquatic weed, infesting drainage canals and shallow lakes and ponds. In Washington State the infestations are primarily in the southwest corner, extending from the Chehalis River to the Columbia River (Gibbons et al. 1999). Additional small infestations are also found in the eastern side of the state (Parsons et al. 2003). An infestation of parrotfeather results in a degraded aquatic ecosystem with significantly reduced flow and drainage. Management of parrotfeather has been problematic, with both herbicides and dredging only providing temporary control (Sytsma).

The goal of this project was to evaluate a range of control alternatives for parrotfeather milfoil that could be used in a management plan. Specifically, our objectives were to determine 1) which treatment protocols are most effective, 2) how long they need to be implemented to eliminate an infestation of parrotfeather milfoil, and 3) how these treatment protocols should be incorporated into a management plan.

MATERIALS AND METHODS

Study Areas: Eighteen studies at three locations were conducted from 2004 through 2006 to determine herbicide efficacy on parrotfeather milfoil. These studies were located in Seaview, Longview and Skamokawa, Washington, comprising an estimated total surface area of 3.95 acres over the 3 years of work; 2004 (1 acre), 2005 (2.2 acres), 2006 (0.75 acres). All studies were conducted in drainage canals or ponds with relatively turbid water conditions with a slow flow of 0.05 m/s or less.

Herbicide Field Trials: Five herbicide field trials were conducted in 2004 to compare efficacy of injection application of triclopyr, and foliar application of imazapyr, triclopyr, and imazapyr with triclopyr and glyphosate. In 2005, one injection study and six foliar studies were conducted. These studies focused on refining our efficacy data on imazapyr and triclopyr, plus an assessment of imazamox, diquat, and 2,4-D amine. In 2006, five foliar studies were conducted to further help refine our efficacy data for glyphosate, imazapyr, imazamox, and triclopyr. In all studies, applications were made when the parrotfeather canopy extended 6-18 inches out of the water. Foliar treatments were made using an AA43 GunJet® at 310 kPa and 19 l/min 12V pump at 100 gpa (spray to wet), unless otherwise noted.

Experimental design was usually a randomized complete block. Experimental treatments (herbicide rates and timings), plot size and replications are provided in detail for each study in the table. Efficacy was assessed based on initial canopy kill (browndown rating 1=none, 10=100% of canopy brown/black); percent of canopy resprouting after initial canopy kill, percent of plot covered by parrotfeather, and percent control (percent of plot free of all parrotfeather). These assessments were taken after various durations (months to years) after the initial treatment. Percent control in the year(s) following the initial treatment should be viewed as the best assessment of efficacy. In some cases, however, owing to plots being destroyed by flooding or dredging or being re-infested with new fragments of parrotfeather, these data were not available. Treatment differences were determined by analysis of variance, with mean separation by Student-Newman-Keuls test at $P \leq 0.05$. Assumptions of normality and homogeneity of variance were tested with Bartlett's test for homogeneity of variance.. When variances were not normal, we transformed the data using arcsine square root transformation.

Insect Herbivory by *Galerucella nymphaeae:* During our trials we were observant for any natural herbivory. *Galerucella nymphaeae* was noted feeding on parrotfeather at the Julia Butler Hansen Wildlife Refuge in Skamokawa, Washington, in 2004. The following summer we observed this same extensive damage on the emergent portion of parrotfeather in September 2005. In August 2006 we observed *Galerucella nymphaeae* feeding in sites in Longview and Seaview, WA in addition to repeated observations in Skamokawa, WA. Observations were made on how this predation might affect herbicide efficacy, and detailed sampling was done at several sites to gather more data on *Galerucella's* herbivory potential for parrotfeather milfoil.

RESULTS

Experiment 1: A complex experiment was initiated to evaluate both injection and foliar application of herbicides (Table 1). All rates of foliar-applied imazapyr and injected or foliar-applied triclopyr burned back parrotfeather milfoil, limited resprouting and provided control in the year following treatment. Unfortunately, because of water movement between plots, there was enough interaction between treatments within the ditch complex that inferences were difficult to make. Conducting replicated experiments with injection treatment of herbicides proved to be an unfeasible experiment protocol.

Experiment 2: Mid-summer foliar treatments of imazapyr, glyphosate and triclopyr were compared (Table 2). All treatments showed good efficacy four months after treatment (MAT), with a trend for imazapyr applied twice to show the best efficacy. The population of parrotfeather milfoil in the year following treatment was affected by dredging, predation, and flooding, making data collection at the site impossible.

Experiment 3: October foliar treatments of imazapyr and triclopyr were compared in a deep drainage system (Table 3). Only imazapyr significantly reduced the resprouting that occurred following treatment. The resprouting that occurred with triclopyr was similar across all rates. The addition of triclopyr to imazapyr did not improve the efficacy of imazapyr. Flooding destroyed the sites preventing better follow-up assessments.

Experiments 4 &5: The long-term efficacy of multiple-season foliar application of imazapyr and triclopyr was assessed for several years in drainage ditches in Skamokawa and Seaview (Tables 4 & 5). In September 2004, and continuing into 2006 in Seaview, the two most promising herbicides, imazapyr and triclopyr, were found to effectively control parrotfeather. One month after treatment, imazapyr provided superior control to triclopyr with 5% resprouting compared to triclopyr with 78% resprouting, respectively. One month following the third and final application, percent resprouting was 1 and 4% respectively. It is important to note that imazapyr was applied only once in 2004 while triclopyr was applied a second time nine weeks following the first application. Both were reapplied twice in 2005. Both of these herbicides demonstrated efficacy on parrotfeather; however, imazapyr proved far more effective than triclopyr with percent control at 92 and 73%, respectively, 22 MAT (Table 5).

Experiment 6: The efficacy of foliar applications of imazapyr, triclopyr, glyphosate, 2,4-D amine and imazapyr + glyphosate were compared in a drainage ditch in Skamokawa (Table 6). There was not a statistical difference between herbicide treatments for any of the rating times. There were, however, some non-significant trends. The least effective treatment was glyphosate, where control had dropped to 63% just prior to the second year application. Treatments with imazapyr (6 pt/ac, 3 pt/ac twice, or 6pt/ac with glyphosate) had the highest level of control just prior to the second season application and at the end of the second treatment year.

Experiment 7: The efficacy of imazapyr at 6 pt/ac was compared to imazamox at 2 pt/ac (Table 7). Based on the amount of canopy mat that had regrowth in the spring following the initial treatment, there were no differences between products. By early summer, one month after the second treatment, imazapyr was a superior treatment. That difference had disappeared by July. The treatment site was too cross-contaminated to follow longer term observation.

Experiment 8: The efficacy of imazapyr at 6 pt/ac was compared to imazamox at 2 pt/ac and imazapyr at 6 pt/ac plus glyphosate at 5 gal/ac (Table 8). In the spring following treatment there were no differences between treatments. Because of site disturbance, longer observations were not feasible.

Experiments 9, 10 and 11: The efficacy of various herbicides on a mixed aquatic weed canopy of waterprimrose (*Ludwigia peploides* ssp. *Montevidensis*) and parrotfeather was evaluated (Tables 9, 10 and 11). Because of the mixed canopy it was difficult to assess percent control of each species. Percent cover was used instead. For both species imazapyr at 3 or 6 pt/ac was more effective than imazamox up to rates of 2 pt/a (Table 9) and/or triclopyr (Table 10). Data for percent cover of parrotfeather are confounded when there was a heavy cover of waterprimrose, since the waterprimrose masked assessment of parrotfeather cover. The level of control of parrotfeather was surprising considering the amount of canopy that was covered by waterprimrose. In 2006, imazapyr, imazamox, glyphosate and triclopyr all provided good initial control of waterprimrose (Table 11). Although not significant, there was a trend for imazapyr and glyphosate to provide the best reduction in canopy cover of waterprimrose. The amount of parrotfeather that was released and grew after the waterprimrose canopy was treated was lowest for the imazapyr and glyphosate treatments.

Experiment 12. The efficacy of two rates of imazapyr was compared in 2006 (Table 12). There was no treatment difference between rates, based on the same season evaluation. There was a trend, however, for the higher rate to provide better control.

Experiments 13 and 14. The efficacy of equal rates of imazapyr and imazamox was compared in 2006 (Tables 13 and 14). In both experiments there was no treatment difference between herbicides, based on the same season evaluation. There was a trend, however, for the imazapyr to provide better control than imazamox.

Experiment 15. Diquat, 2,4-D, imazamox and triclopyr were assessed for their efficacy applied into the water body (by injection) (Table 15). Since each herbicide was applied in a separate site to avoid confounding and the experiment was not replicated, only limited inferences can be made from these studies. Nevertheless, it was apparent that imazamox, triclopyr and diquat had only limited to no short-term or long-term efficacy. 2,4-D, however, provided excellent control at the site. Several other experiments were conducted with injecting imazamox, but are not reported because of protocol problems.

Experiment 16. The efficacy of imazapyr and triclopyr on parrotfeather which had been grazed by *Galerucella* was studied (Table 16). This was not an intentional study, as the grazing occurred immediately after the first treatment application. Under these conditions, control was marginal (80% with two imazamox treatments) and it is suspected that the reduction in above water canopy volume at the time of the second application markedly reduced herbicide uptake.

Experiment 17. Galerucella herbivory was studied by making repeated observations at several sites in 2005 and 2006 (Table 17). The damage inflicted by the native chrysomelid beetle, *Galerucella nymphaeae,* had a "burndown" appearance and occurred almost entirely in August and early September. In September 2005 this beetle had defoliated approximately 75% of the emergent parrotfeather throughout the drainage canals of the Refuge site. This beetle is able to complete its life-cycle on this host plant with larvae, pupae, and adults observed (eggs masses were not observed in 2005, but were observed in 2006). The distribution of *Galerucella* on parrotfeather appeared to be wide-spread. Parrotfeather has not been previously recorded as a host for *Galerucella nymphaeae*; however, due to the plastic host range of this beetle it should not be surprising.

DISCUSSION

Herbicide efficacy: All evaluated herbicides were reasonably effective in killing back the exposed canopy; none provided 100% systemic kill of the entire plant with one application.

Diquat: Trials with the contact subsurface-injected herbicide, diquat, were limited. The results indicated temporary suppression of parrotfeather, but not enough to provide any lasting control.

Glyphosate: Broadcast application of glyphosate, browned and temporarily suppressed parrotfeather canopy, but on the average it provided less canopy suppression than other herbicides. Repeat application within the year and across years will be necessary to achieve lasting control. Adding glyphosate to the tank mix with imazapyr did not enhance the overall treatment efficacy.

Imazamox: At broadcast rates of 32 and 64 fl oz/acre imazamox, provided good canopy suppression of parrotfeather. Repeated applications were necessary within the same season and in subsequent years to achieve long-term suppression. Control was minimal at rates less than this. Injection of imazamox, based on our limited experiments, provided little control. Further use of imazamox will be contingent on it obtaining an aquatic label in Washington.

Imazapyr: Based on these trials, imazapyr consistently provided superior control of parrotfeather compared to all other evaluated herbicides. The differences in efficacy between rates (3 to 6 pt/ac) were usually minor and not significant. Without a follow-up treatment in the subsequent season(s), however, permanent control with imazapyr was not achieved.

Triclopyr: Canopy knockdown with broadcast or injection application of triclopyr was excellent. Regardless of the rate or method of application, regrowth occurred relatively quickly. Repeated applications were necessary within the same season and in subsequent years to achieve long-term suppression. These results are similar to treatments in New Zealand (Hofstra et al. 2006), where they report it triclopyr being a superior herbicide to glyphosate for parrotfeather.

2,4-D amine: Broadcast application of 2,4-D amine resulted in similar canopy control as other herbicides (good, but re-treatment was required). Based on only one unreplicated trial, injection of 2,4-D amine resulted in excellent control, with no follow-up treatment required.

Factors affecting parrotfeather control. Four factors played a significant role in the level of our success in controlling parrotfeather: amount of exposed canopy at time of treatment and depth of water (amount of unexposed canopy), thoroughness of treatment coverage, treatment follow-up, and site re-infestation.

Exposed/unexposed canopy: For broadcast applied herbicide, the best control was achieved when herbicides were applied to sites in shallow water (<1-2’) when there was ample canopy (>12-18”) exposed for herbicide absorption. How much canopy needs to be exposed to herbicide relative to the amount of below water plant biomass is uncertain. This inference was not based on definitive experiments to test this hypothesis, but was based on comparative treatment efficacies across different sites (Tables 11 & 13), or when removal of canopy by the herbivory *Galerucella* affected canopy density (Table 15).

Thoroughness of treatment coverage: Broadcast spraying herbicides along ditch banks is not without technical difficulties. Achieving 100% herbicide coverage is made difficult by riparian weeds like blackberries, or bank undercuts hiding the parrotfeather canopies, or a strong wind preventing the spray from always reaching the full distance of the plot. In these circumstances, control was not achieved and parrotfeather quickly re-infested the treated area. Even with special effort to minimize this effect, our experiment plots were often fraught with this issue. A spot retreatment was often necessary at these sites. Under a regular control effort, thoroughness of coverage would be an especially critical concern.

Treatment follow-up: No treatment was 100% effective in permanently removing parrotfeather. Without re-treatment in the same year and/or subsequent year, the treated sites eventually became re-infested and any pretense of control was lost. Treatments varied as to their need for re-treatment in the same year, with imazapyr needing the least. Often when our plots were scheduled for re-treatments there were only a few small sprigs of live parrotfeather. They took minimal chemical to retreat. However, if we skipped those re-treatments, the site became thoroughly re-infested.

Site re-infestation. Without an effort to prevent upstream re-infestation, treated sites were re-infested in the subsequent year. This was not feasible in replicated plots with untreated controls spaced throughout the sites. Thus it was difficult to rate long-term treatment efficacy not knowing what was a new infestation or an old infestation. In a real control program every effort would need to be made to prevent re-infestation from upstream sites.

Management plan: A parrotfeather management plan based on chemical control should be area-wide and consider herbicide selection, timing, and re-treatment.

Area-wide management plan: To effectively control and possibly eradicate parrotfeather from a body of water or water system, such as the drainage ditch system, an area-wide control effort is essential. Any parrotfeather left upstream will merely fragment, drift downstream, reroot and begin a new stand. Parrotfeather should be first controlled from upstream working downstream.

Herbicide selection: If there are no restrictions on water use, such as irrigation, imazapyr is the product of choice. It provided the best efficacy, with the least need for same season re-treatment. Differences between rates were minor, as long as canopy exposure was adequate. If no re-treatment was planned for the season, however, then a 6 pt/ac rate would be a better choice. Alternatively, two 3 pt/ac imazapyr treatments, a 4 pt/ac and a 2pt/ac imazapyr treatment, or a 6 pt/ac imazapyr treatment followed by a second alternative herbicide would be suitable.

- If there are restrictions on water use then labels should be carefully reviewed and a choice made on what provides the most margin of safety. For example, glyphosate has only a 1 day restriction prior to irrigation. A more complete re-treatment effort, however, will need to be made if glyphosate is used.

- Herbicide cost should only be a minor variable in dictating herbicide selection. Some herbicides, like imazapyr, are an order of magnitude more expensive per gallon than others, like glyphosate. Some herbicides require only a few pt/ac for efficacy; others require several gallons. Re-treatment in subsequent years may be less expensive, because it will only be on a spot basis. Regardless of cost per gallon or rate per acre, the price of product per acre is minor compared to labor cost.

- Consideration also needs to be made for application method. If an injection treatment is an option, based on our data, 2,4-D amine might be an appropriate choice.

- Finally, change in labels may change over time. Any management plan must be compliant with current state and federal labels.

Treatment timing: Herbicide timing when the water level is at its lowest and the canopy has greatest exposure is ideal. This is often late summer. Mid-summer canopy herbivory by *Galerucella* , however, could foil that effort. Therefore, herbicide timings should consider the impact of *Galerucella*. A mid-summer treatment also provides a chance for a late season follow-up treatment of any regrowth. Treatment timing in subsequent years should be based on the need to prevent parrotfeather from re-infesting and/or building up storage reserves. Thus early, middle and late season treatments would be preferred.

Retreatment plan: Without a plan for follow-up treatment to prevent new infestations or suppress regrowth, any effort to control parrotfeather will meet with eventual failure. The number of retreatments per year and their timings are contingent on the amount of previous treatment(s) success.

SUMMARY

Numerous herbicides were screened for their efficacy in management of parrotfeather milfoil. Although all herbicides showed effective activity, no herbicide provided complete control with only one application. Imazapyr was the most effective broadcast herbicide evaluated, with triclopyr, imazamox, glyphosate, and 2,4-D amine being generally less effective. 2,4-D amine was the most effective injected herbicide evaluated; triclopyr, diquat and imazamox were less effective. All herbicides required follow-up treatments to assure success.

LITERATURE CITED

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Table 1. Efficacy of injected and foliar-applied triclopyr and foliar-applied imazapyr on parrotfeather milfoil in 2004.[1]

Treatment[2]	Resprout rating (1= none; 10=100%) 3 MAT	% control 12 MAT
Control	10 a	33 a
Triclopyr 0.25 ppm Injection	3 a	70 a
Triclopyr 0.25 ppm Injection + foliar 2 qt/a (3 WAT)	3 a	73 a
Triclopyr 0.25 ppm Injection + Imazapyr 4 pt/a Foliar (3 WAT)	3 a	54 a
Triclopyr 0.5 ppm Injection	4 a	87 a
Triclopyr 1 ppm Injection	3 a	75 a
Triclopyr 4 pt/a Foliar	6 a	77 a
Imazapyr 4 pt/a Foliar	3 a	67 a
Imazapyr 6 pt/a Foliar	3 a	88 a
LSD (P=0.05)	2	29
CV	32	30

[1]Means followed by same letter do not significantly differ according to Student-Newman-Keuls test. LSD, least significant difference. CV, Coefficient of Variability. MAT, months after treatment. LSD, least significant difference. CV, coefficient of variability. MAT, months after treatment.

[2] Study was conducted at the Julia Butler-Hanson Wildlife Refuge for the Columbia Whitetail Deer in Skamokawa, WA. Plots were 500 square feet each with 3 replications. Injection amounts are in parts per million of product. Application was made in late June, 2004 with an additional treatment 3 weeks following the first application. Water depth was approximately 4.5 feet deep with the bottom 18 inches a watery organic muck. Parrotfeather was approximately 12" tall at all applications. Foliar applications contained 1 % v/v Competitor. Because there was water flow through the ditch, although very slow, there was cross contamination between injection treatments. This confounded our ability to separate out treatment effects between plots.

(milfoil 1 2004 applied)

Table 2. Efficacy of imazapyr, glyphosate, and triclopyr on the control of parrotfeather milfoil in 2004.

Treatment[2]	% Resprout 4 MAT
Control	100 a
Imazapyr 6 pt/a	7 b
Imazapyr 3 pt/a (2x)	0 b
Glyphosate 5 gal/a (2x)	12 b
Triclopyr 4 pt/a (2x)	2 b
LSD (P=0.05)	12
CV	29

[1] Means followed by same letter do not significantly differ according to Student-Newman-Keuls test. LSD, least significant difference. CV, Coefficient of Variability. MAT, months after treatment.

[2] Study was conducted at the Julia Butler-Hanson Wildlife refuge for the Columbia Whitetail Deer in Skamokawa, WA. Applications were made in early July, 2004. Plots receiving a second application were reapplied in Late September, 2004. Plots were 480 square feet and 2-3 feet deep each with 4 replications. All treatments contained 1 % v/v competitor. Parrotfeather had 12''of exposed canopy at times of treatment. (milfoil 2 2004).

Table 3. Efficacy of imazapyr and triclopyr on the control of parrotfeather milfoil in 2004.

Treatment[2]	% resprout 1 MAT
Imazapyr 6 pt/a	5 b
Triclopyr 4 pt/a	43 b
Triclopyr 6 pt/a	38 b
Triclopyr 8 pt/a	41 b
Triclopyr 2 pt/a + Imazapyr 6 pt/a	4 b
LSD (P=0.05)	13
CV	27

[1] Means followed by same letter do not significantly differ according to Student-Newman-Keuls test. LSD, least significant difference. CV, Coefficient of Variability. MAT, months after treatment.

[2] Study was conducted at Longview, Washington. Applications were in early October 2004. Plots were 1000 square feet and 8 feet deep each with 4 replications. All treatments contained 1 % v/v competitor. Parrotfeather had 6''of exposed canopy at times of treatment. The site was destroyed by severe flooding in the winter following treatment and no follow-up assessments were possible. (milfoil 9 2004).

Table 4. Efficacy of imazapyr, imazapyr plus triclopyr, and triclopyr on the control of parrotfeather milfoil in 2004.[1]

Treatment[2]	% Resprout		% Control	
	2 MAT	15 MAT	20 MAT	25 MAT
Control	100 a	100 a	0 c	0 b
Imazapyr 4 pt/a, reapplied at 2 pt/a 2 MAT	3 b	0 b	100 a	85 a
Imazapyr 4 pt/a + Triclopyr 3 pt/a, reapplied at imazapyr 2 pt/a + Triclopyr 3 pt/a 2 MAT	0 b	3 b	98 b	84 a
Triclopyr 3 pt/a, reapplied 2 MAT	2 b	1 b	98 b	83 a
LSD (P=0.05)	5.7	6.5	1.2	17
CV	13	16	1	17

[1]Means followed by same letter do not significantly differ according to Student-Newman-Keuls test. LSD, least significant difference. CV, Coefficient of Variability. MAT, months after treatment.

[2] Study was conducted at the Julia Butler-Hanson Wildlife refuge for the Columbia Whitetail Deer in Skamokawa, WA[1]. All treatments were applied at four timings: July and September 2004; July and September 2005. Plots were 300 square feet each with a depth of 1-2 feet with 4 replications. Parrotfeather had 6-12''of exposed canopy at times of treatment applications. Imazapyr treatments contained 1% v/v of competitor as a surfactant, while triclopyr used 1% v/v Agridex. (milfoil 6 2004)

Table 5. Efficacy of imazapyr and triclopyr on control of Parrotfeather milfoil in 2004 and 2005[1.]

Treatment[2]	% Control			
	1 MAT	13 MAT	20 MAT	22 MAT
Imazapyr	95 a	99 a	98 a	92 a
Triclopyr	72 b	96 b	80 b	73 b
LSD (P=0.05)	11	6	15	19
CV	17	49	12	15

[1]Means followed by same letter do not significantly differ according to Student-Newman-Keuls test. . LSD, least significant difference. CV, Coefficient of Variability. MAT, months after treatment.

[2] Study was conducted in Seaview, WA. Both treatments contained 1% v/v of Competitor as a surfactant. Plots were 150 square feet with 3 replications. Parrotfeather had 12''of exposed canopy at times of treatment in approximately 2-3 feet of water. Imazapyr was applied at 6 pt/a September 2004; reapplied at 3 pt/a in June and August 2005 and again in late April 2006 at 3 pt/a. Triclopyr was applied in September and October 2004 at 2 qt/a; reapplied in June and August 2005 at 1 qt/a and again in late April, 2006 at 1 qt/a. (milfoil 8 2004)

Table 6. Efficacy of imazapyr, triclopyr, imazapyr with glyphosate, glyphosate, 2, 4-D, and reduced rate of imazapyr on control of parrotfeather milfoil in 2005

Treatment[2]	% control		
	8 MAT	9 MAT	11 MAT
Control	0 b	0 b	0 b
Imazapyr 6 pt/a	96 a	83 a	99 a
Triclopyr 4 pt/a	92 a	75 a	95 a
Imazapyr 6 pt/a+ Glyphosate 5 gal/a	99 a	93 a	98 a
Glyphosate 5 gal/a	87 a	63 a	83 a
2,4-D 1 gal/a	89 a	70 a	88 a
Imazapyr 3 pt/a*	96 a	83 a	99 a
LSD (P=0.05)	15	21	12
CV	15	25	12

[1]Means followed by same letter do not significantly differ according to Student-Newman-Keuls test. LSD, least significant difference. CV, Coefficient of Variability. MAT, months after treatment.

[2] Study was conducted at the Julia Butler-Hanson Wildlife refuge for the Columbia Whitetail Deer in Skamokawa, WA. Imazapyr 3 pt/a was applied September and October 2005. All other treatments were applied September 2006 and June 2006. All treatments contained 1 % v/v Competitor except 2, 4-D. Plots were approximately 210 square feet. Canal depth was <6", dry, and 1' to 2' for the September 2005, October 2005 and June 2006 applications, respectively. Parrotfeather had 6-12''of exposed canopy at times of treatment. (milfoil 8 2005)

Table 7. Efficacy of imazapyr and imazamox on control of parrotfeather milfoil in 2005 and 2006.

Treatment[2]	% control		
	7 MAT	10 MAT	11 MAT
control	0 b	0 c	0 a
Imazapyr 6 pt/a	100 a	98 a	99 b
Imazamox 2 pt/a	98 a	76 b	98b
LSD (P=0.05)	3	16	4
CV	2	12	1

[1]Means followed by same letter do not significantly differ according to Student-Newman-Keuls test.

[2]A Study conducted in Seaview, WA. Applied in August 2005 and retreated in May 2006. Both treatments contained 1 % v/v Competitor. Plots were 150 square feet with 3 replications. Water depth at applications varied from 2.5-4 feet. Raptor vs. habitat 2005 (2006)

Table 8. Efficacy of imazapyr with and without glyphosate and imazamox on the control of parrotfeather milfoil in 2005.

Treatment[2]	% Resprouting 2 MAT	% Control 8 MAT
Imazapyr 6 pt/a	2 a	99 a
Imazapyr 6 pt/a + Glyphosate 5 gal/a	3 a	99 a
Imazamox 2 pt/a	3 a	98 a
LSD (P=0.05)	6	2
CV	104	1

[1]Means followed by same letter do not significantly differ according to Student-Newman-Keuls test. LSD, least significant difference. CV, Coefficient of Variability. MAT, months after treatment.

[2] Study was conducted in Seaview, WA. All treatments contained 1 % V/V of Competitor. All treatments were applied in September, 2005 and sites were not retreated. 2006 assessment was difficult because the site was dredged by the landowner. Plots were 600 square feet with an average water depth of 4 feet with 3 replications. Parrotfeather had 12''of exposed canopy at times of treatment. (milfoil 9 2005)

Table 9. Efficacy of imazamox and imazapyr for control of a mixed canopy of parrotfeather and waterprimrose in 2005.

	Waterprimrose % Cover		Parrotfeather % Cover	
Treatment[2]	2 MAT	11 MAT	2 MAT	11 MAT
Imazamox 0.5 pt/a	37 b	73 ab	1 a	5 bc
Imazamox 1 pt/a	10 bc	53 bc	25 a	18 a
Imazamox 1.5 pt/a	12 bc	36 cd	12 a	1 c
Imazamox 2 pt/a	17 bc	25 de	20 a	2 bc
Imazapyr 3 pt/a	7 bc	10 de	5 a	0 c
Imazapyr 6 pt/a	0 c	5 e	3 a	0 c
Control	96 a	95 a	3 a	8 ab
LSD (P=0.05)	33	8	17	9
CV	74	66	65	66

[1]Means followed by same letter do not significantly differ according to Student-Newman-Keuls test. LSD, least significant difference. CV, Coefficient of Variability. MAT, months after treatment.

[2] Study was conducted in Longview, WA. Parrotfeather was treated as an understory of waterprimrose. All treatments contained 2 qt/100 gal of competitor. All were applied in July, 2005 and misses were retreated in August, 2005. Plots were 1000 square feet with 3 replications and a water depth of >10 feet. PF height was 12". The main weed canopy was waterprimrose. Parrotfeather canopy was 18-24'' at time of application, but was not clearly visible at the time of application, as it was occluded by the waterprimrose canopy. Percent cover data reflects difference between treatments and not overall control. (milfoil 1 longview 2005)

Table 10. Efficacy of imazamox, imazapyr, and triclopyr for control of a mixed canopy of parrotfeather and waterprimrose in 2005.[1]

Treatment[2]	% Control of Waterprimrose and Parrotfeather		% Cover of Waterprimrose	% Cover of Parrotfeather
	1 MAT	9 MAT	10 MAT	10 MAT
Imazamox 1.5 p/a	57 c	75 ab	52 ab	11 a
Imazapyr 3 pt/a	80 b	92 a	9 b	27 a
Triclopyr 4 pt/a	98 a	43 b	77 a	23 a
LSD (P=0.05)	10	34	36	25
CV	7	22	37	54

[1]Means followed by same letter do not significantly differ according to Student-Newman-Keuls test. LSD, least significant difference. CV, Coefficient of Variability. MAT, months after treatment.

[2] Study was conducted in Longview, WA. Parrotfeather was treated as an understory of water waterprimrose. All treatments contained 0.5 % V/V of competitor. All were applied in August, 2005 and retreated in late June, 2006. Plots were 2000 square feet with 3 replications and a water depth of ~8 feet. The main weed canopy was waterprimrose. Parrotfeather canopy was 18-24'' at time of application, but was under the waterprimrose canopy and therefore poorly exposed to herbicide. At the time of second treatment there was 2-14" clearly exposed canopy. (milfoil 5 2005)

Table 11. Efficacy of imazapyr, imazamox, triclopyr and glyphosate for control of a mixed canopy of parrotfeather and waterprimrose in 2006[1].

Treatment[2]	% Waterprimrose control 2.5 MAT	% plot filled in by understory Parrotfeather milfoil canopy 2.5 MAT
Control	0 b	NA
Imazapyr 3 pt/aa	100 a	3 b
Imazamox 2 pt/a	88 a	90 a
Imazamox 3 pt/a	96 a	70 a
Glyphosate 3 gal/a + Agridex 1 % v/v	71 a	3 b
Triclopyr 1 pt/a (no surfactant)	73 a	63 a
LSD (P=0.05)	31	49
CV	23	57

[1]Means followed by same letter do not significantly differ according to Student-Newman-Keuls test. LSD, least significant difference. CV, Coefficient of Variability. MAT, months after treatment.

[2] This study was conducted in Longview, WA. Parrotfeather was treated as an understory of water waterprimrose. Plots were 525 square feet applied July, 2006 with 3 replications. Water depth >10 feet. Used boom buster nozzle. All treatments were made with 1 qt/a of competitor except were noted. The main weed canopy was waterprimrose. Parrotfeather canopy was 18-24'' at time of application, but was under the waterprimrose canopy and therefore poorly exposed to herbicide. (waterprimrose 2 2006)

Table 12. Efficacy of two rates of imazamox on parrotfeather control in 2006. [1]

Treatment[2]	% control 2 MAT	Resprout shoots # uprights/300 ft^2 2 MAT
Imazamox 2 pt/a	92 a	144 a
Imazamox 3 pt/a	98 a	43 a
LSD (P=0.05)	12	288
CV	6	134

[1]Means followed by same letter do not significantly differ according to Student-Newman-Keuls test. LSD, least significant difference. CV, Coefficient of Variability. MAT, months after treatment.

[2] This study was conducted in Seaview, WA. Treatments applied in late July, 2006 with a follow-up spot treatment (missed sections) in mid-August, 2006. Plots were 300 sq feet each with 3 replications; water depth was approximately 5 feet, Parrotfeather canopy was 6-12'' at time of application. (milfoil 3 2006)

Table 13. Efficacy of imazapyr and imazamox on parrotfeather control in 2006[1].

Treatment[2]	% control 1 MAT	Resprout shoots /M^2 1 MAT
Imazapyr 3 pt/a	99 a	7 a
Imazamox 3 pt/a	97 a	17 a
LSD (P=0.05)	3	13
CV	2	45

[1]Means followed by same letter do not significantly differ according to Student-Newman-Keuls test. LSD, least significant difference. CV, Coefficient of Variability. MAT, months after treatment.

[2] Study was conducted in Longview, WA Treatments applied in August, 2006. Plots were 200 square feet with 3 replications and a water depth >10 feet. Parrotfeather canopy was 12'' at time of application. All treatments contained 1 qt/a competitor and were applied using boom buster nozzle (milfoil 8 2006).

Table 14. Efficacy of imazapyr and imazamox on control of parrotfeather milfoil in 2006[1].

Treatment[2]	% control		
	1 MAT	2 MAT	4 MAT
Imazapyr 2 pt/a	72 a	100 a	95 a
Imazamox 2 pt/a	78 a	99 a	74 a
LSD (P=0.05)	38	1.4	72
CV	14	0.4	24

[1]Means followed by same letter do not significantly differ according to Student-Newman-Keuls test. LSD, least significant difference. CV, Coefficient of Variability. MAT, months after treatment.

[2] Study was conducted in Seaview, WA. Treatments applied in May, 2006. Plots were 60 square feet with 3 replications and a water depth of 3-4 feet. Parrotfeather canopy was 6" at time of application. All treatments contained 0.5 % v/v of competitor. (milfoil 7 2006)

Table 15. Efficacy of imazamox, diquat, 2, 4-D amine, triclopyr applied with injection on control of parrotfeather milfoil in 2006[1].

Herbicide/Injection rate[1]	% control (Mean± Std.Err) 20 days after treatment	% control (Mean± Std. Err) 7 MAT
Diquat 0.37 ppm	86±3	24±6
Imazamox 100 ppb	0±0	18±08
2, 4-D amine 4 pt/ac	98±1	100±0
Triclopyr 1 ppm	15±2	0±0

[1] Study was conducted at the Julia Butler-Hanson Wildlife refuge for the Columbia Whitetail Deer in Skamokawa, WA. Each treatment was applied in a separate water system as a directed spray in the open water. Final rates achieved in the water are approximations, since water samples were not analyzed. Application made in October, 2005. Plot size varied from 0.1 to 0.7 acres in size. Water depth varied, but ranged from 1-5 feet. Flow rate varied at each site, from almost none to slight. Parrotfeather canopy was 6-12'' at time of application depending on site. Visual assessments of control were made from 10 sites along the body of water to determine treatment mean and standard error. (milfoil 15 2005)

Table 16. Efficacy for two applications of imazamox and triclopyr with interaction of herbivory by *Galerucella nymphaeae*[1].

Treatment[2]	% control 10 MAT
Imazamox 0.5 pt/a	53 ab
Imazamox 1 pt/a	80 a
Triclopyr 4 pt/a	33 ab
Control	0 b
LSD (P=0.05)	46
CV	70

[1]Means followed by same letter do not significantly differ according to Student-Newman-Keuls test. LSD, least significant difference. CV, Coefficient of Variability. MAT, months after treatment.

[2] Study was conducted at the Julia Butler-Hanson Wildlife refuge for the Columbia Whitetail Deer in Skamokawa, WA[1].). All treatments contained 0.5 % v/v of competitor. All treatments were applied in August, 2005. Second applications were applied in October, 2005. Plots were 225 square feet with 3 replications and a water depth of 2-4 feet. PF height was 12" at first application. Second application had approximately 4" regrowth following heavy herbivory by *Galerucella nymphaeae.* (milfoil 4 2005)

Table 17. Mean number of *Galerucella nymphaeae* per upright in 2005 and 2006.

Date	Location	Number Samples	% damaged uprights	Larvae per upright	Pupa per upright	Adults per upright	Egg Masses per upright
September 2005	Skamokawa	4*	n/a	0.2	0.8	0.4	n/a
October 2005	Skamokawa	24**	n/a	0.1	0	0.2	n/a
August 2006	Skamokawa	4*	83	0.5	0.3	0.1	0.1
August 2006	Longview	1*	33	0.2	0	0.2	0.2
September 2006	Seaview	12***	n/a	2.2	1.5	0	0

*Samples collected by using a rake to collect several uprights. The number of uprights varied in each sample.

**Samples were collected using a 310 cm^2 ring as the sample area.

***Samples were from individual uprights taken from the center of a moderately fed upon parrotfeather mat. Area was approx 9 m^2.