Table 2. A comparison of treatments to control sheep sorrel (*Rumex acetosella*) implemented in January 2007 at El Presidio, California. The mean time to implement each treatment (n = 2) was recorded, as well as the mean percent cover (± SE) before (shaded column, n = 2) and after (averaged over three-month periods, n = 6) treatment. Smother plots were included in monitoring immediately after fabric was removed on July 5, 2007.

		Labor	Percent Cover				
Soil	Treatment	(min/m²)	Jan	Feb–Apr	May–Jul	Aug–Oct	Nov–Jan
sand	Control	0	30 ± 2	50 ± 10	33 ± 13	55 ± 12	18 ± 5
	Flame	0.6	48 ± 16	35 ± 15	80 ± 2	85 ± 7	49 ± 14
	Hoe	4	42 ± 14	11 ± 6	35 ± 10	49 ± 11	35 ± 14
	Pull	2	34 ± 6	8 ± 3	35 ± 2	35 ± 9	27 ± 7
	Pick	7	40 ± 12	1 ± 1	8 ± 7	16 ± 6	3 ± 1
	Smother	4	34 ± 6	n/a	n/a	8 ± 1	16 ± 4
	7.6-cm dig	20	32 ± 4	1 ± 1	9 ± 2	11 ± 2	21 ± 6
	15-cm dig	34	34 ± 2	0 ± 0	3 ± 1	5 ± 1	2 ± 1
serpentine	Control	0	54 ± 6	43 ± 4	65 ± 8	52 ± 5	15 ± 4
	Flame	0.4	56 ± 8	26 ± 11	69 ± 2	61 ± 2	47 ± 3
	Hoe	6	46 ± 12	13 ± 7	76 ± 10	57 ± 14	50 ± 9
	Pull	9	64 ± 6	28 ± 10	54 ± 14	61 ± 6	37 ± 8
	Pick	16	74 ± 2	11 ± 6	56 ± 7	48 ± 11	41 ± 5
	Smother	6	56 ± 4	n/a	n/a	9 ± 3	29 ± 7
	7.6-cm dig	31	54 ± 4	1 ± 1	29 ± 5	25 ± 5	17 ± 3

used at the Presidio and it appears to be the best choice to provide long-term reduction in cover while taking only 25% of the time to dig the entire plot. However, further study is needed to assess the relative time costs of each option at larger scales.

Roots left on the soil surface pose a high risk of producing new plants, so practitioners are advised to remove plant fragments when implementing control techniques. Follow-up is essential because roots left on the surface are likely to produce leaves within the first month. Small root fragments left buried at 15 cm or deeper appear unlikely to produce new plants. Practitioners can improve their efficiency by focusing on the top 10 cm of soil and being most concerned about larger roots.

Roots at greater depths take longer to produce leaves, which may lead managers to favor a strategy of repeated applications. However, neither experiment assessed repeated treatments. It may be that choosing techniques that are quick to implement and repeating them at regular intervals would be more effective than any single application discussed here.

References

Fitzimmons, J.P. and L.C. Burrill 1993. Red sorrel. Pacific Northwest Extension PNW-446.

Halsted, B.D. 1889. Our worst weeds. *Botanical Gazette* 14(3):69–71.

Invasive Plant Atlas of New England (IPANE). 2004. *Rumex acetosella* (sheep sorrel, field sorrel, red sorrel). http://nbii-nin.ciesin.columbia.edu/ipane/icat/browse.do?specieId=101

Kiltz, B. F. 1930. Perennial weeds which spread vegetatively. *Journal of the American Society of Agronomy* 22:216–234. Cited in L.L. Esser. 1995. *Rumex acetosella*. Fire Effects Information System. USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). http://www.fs.fed.us/database/feis/

USDA, NRCS. 2007. The PLANTS Database (accessed 26 March 2007). National Plant Data Center. http://www.plants.usda.gov

Efficacy of Different Glyphosate Concentrations in Managing Glossy Buckthorn (*Frangula alnus*) Resprouts (Michigan)

R. Gregory Corace III (Seney National Wildlife Refuge, Seney, MI 49883, 906/586-9851 x14, greg_corace@fws.gov), Kenneth P. Leister and Erin Brosnan

Invasive species management is a high priority for many governmental agencies and nonprofit conservation groups with ecological restoration mandates. Since 2001, glossy buckthorn (*Frangula alnus*) has been intensively managed at Seney National Wildlife Refuge (SNWR) and on adjacent Michigan Department of Natural Resources properties in Upper Michigan with some success (Nagel et al. this issue). Owing to concerns for the environmental, human health, and treatment costs associated with herbicide use, utilizing the lowest possible concentration of any pesticide is desirable (Relyea 2005). Because a review of the literature yielded little in terms of the known efficacy of different glyphosate concentrations on managing glossy buckthorn resprouts and because no standard operating procedure exists for the management of this species on

National Wildlife Refuge System lands, we pursued research on the effectiveness of glyphosate (brand name *Gly Star*™) at various concentrations to manage glossy buckthorn resprouts arising from previously treated stems.

Our study area was located on an upland portion of an anthropogenic dike at SNWR dominated by glossy buckthorn. In 2003, mature glossy buckthorn shrubs were treated by first cutting stems with diameters > 2.5 cm, and then applying a 20% active ingredient (a.i.) solution of glyphosate (plus 0.05% nonionic surfactant) to the resulting stumps. However, this treatment produced vigorous resprouting from cut glossy buckthorn stems (see Nagel et al. this issue). In 2006 we set up 60 plots, each consisting of a single multistemmed cut stump, spaced at least 0.5 m apart. We recorded the total number of resprouts and their average height in each plot during initial observations. The mean (± SD) number of pretreatment resprouts was 17.1 (± 10.8). In general, resprouts arising from the same multistemmed stump were around the same height. In 48% of the plots, resprouts were 2–3 m in height, with the remaining resprouts less than 2 m in height.

Typically, glossy buckthorn plants and resprouts < 2.5 cm in diameter have been treated with a 5% a.i. solution of glyphosate at SNWR based on the anecdotal experience of colleagues in Michigan working in various ecoregions and ecosystems. Consequently, to document the efficacy of different concentration of glyphosate in managing resprouts the plots were divided evenly into four treatment groups: 0% (tap water without surfactant), 1.25%, 2.5%, and 5.0%. These concentrations were chosen based on the general experience and advice of colleagues from the State Department of Natural Resources, The Nature Conservancy, and other member organizations of the Michigan Invasive Plant Council, as well as general herbicide label recommendations. All solutions were diluted with tap water according to the label. During dry and stable weather conditions on June 9, 2006, we sprayed the resprouts once using a hand-held (low-volume) pump so that approximately 50% of the surface of all leaves was covered, but not sprayed to the point of dripping off. We monitored the study plots once a week for four consecutive weeks in 2006 (June 19, June 26, July 5, and July 13), and then followed up with approximately biweekly monitoring in April and May 2007. We noted a gradient of stress from chlorosis, to shriveled leaves, to no leaves and brittle stem and we recorded the percentage of stems determined to be dead (i.e., no leaves and brittle stems).

Within one week, the 2.5% and 5.0% glyphosate solutions produced on average 29% and 35% stem mortality, respectively, while the 1.25% solution averaged about 10% (Figure 1). Nonetheless, by the second week post-treatment most stems in most plots were dead. And by the fourth, all resprouts treated with glyphosate were dead (Figure 1). In 2007, we did not observe any change in the dead, brittle condition of resprouts and observed no new growth, providing further evidence of low-concentration glyphosate efficacy.

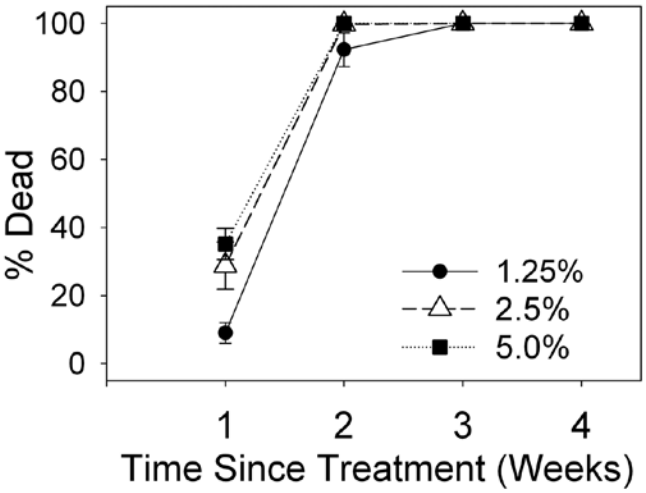

Figure 1. Average (± SE) percentage of dead glossy buckthorn (*Frangula alnus*) resprouts for three concentrations (% a.i.) of glyphosate over a four-week monitoring period in 2006. No dead stems were observed in the control plots.

Successful management of glossy buckthorn and related species likely requires a range of treatment options (Heidorn 1991), with some treatments likely more applicable to a given ecoregion. Although we are not aware of any published work pertaining to the use of glyphosate in the management of glossy buckthorn resprouts, particularly in Upper Michigan, other studies have documented using glyphosate and other chemicals (e.g., triclopyr) or other treatment methods to manage adult plants (Glass 1994, Pergams and Norton 2006), and the efficacy of dormant season herbicide treatments (Reinartz 1997). However, as stated by others (Pergams and Norton 2006, Nagel et al. this issue) eradication of glossy buckthorn and related species likely require follow-up treatments. Our research fills an important information gap by indicating that glyphosate concentrations as low as 1.25% can be effective in killing glossy buckthorn resprouts arising from mature plants previously cut and stump-treated with 20% glyphosate in Upper Michigan.

Acknowledgments

The authors wish to thank the staff and volunteers of Seney National Wildlife Refuge for financial and technical support, especially Tracy Casselman (Refuge Manager) and Laural Tansy (Administrative Technician). Dave Olson (Refuge Biologist) provided helpful edits and comments to early drafts. Field crews were provided as part of a cooperative agreement with the Michigan Department of Natural Resources.

References

Glass, S. 1994. Experiment finds less herbicide needed to control buckthorn (Wisconsin). *Restoration & Management Notes* 12:93.

Heidorn, R. 1991. Vegetation management guideline: Exotic buckthorns-common buckthorn (*Rhamnus cathartica* L.),

glossy buckthorn (*Rhamnus frangula* L.), Dahurian buckthorn (*Rhamnus davurica* Pall.). *Natural Areas Journal* 11:216–217.

Nagel L.M., R.G. Corace III and A. Storer. 2008. An experimental approach to testing the efficacy of management treatments for glossy buckthorn (*Frangula alnus*) at Seney National Wildlife Refuge, Upper Michigan. *Ecological Restoration* 25:136–142.

Pergams, O.R.W. and J.E. Norton. 2006. Treating a single stem can kill the whole shrub: A scientific assessment of buckthorn control methods. *Natural Areas Journal* 26:300–309.

Reinartz, J.A. 1997. Controlling glossy buckthorn (*Rhamnus frangula* L.) with winter herbicide treatments of cut stumps. *Natural Areas Journal* 17:38–41.

Relyea, R. 2005. The impact of insecticides and herbicides on the biodiversity and productivity of aquatic communities. *Ecological Applications* 15:618–627.

Interseeding with and without Raking (Illinois)

Stephen Packard (Audubon Chicago Region, 5225 Old Orchard Rd, Skokie, IL 60077, spackard@audubon.org) and Linda Masters (North Branch Restoration Project, Box 2154, Northbrook, IL 60062, masters2001@comcast.net)

In fall 1993 we interseeded six plots in an old field turf with a seed mix of conservative prairie species. Three plots were raked to incorporate the seeds into the soil; three plots were not raked. Ten years later, we counted individual plants of four species that appeared in good numbers in the plots. (A total of nine species appeared to be successfully established, comprising a total of 30.2% of the relative cover of the six plots in 2003. Other conservative species, already present in the area, were not well tested by this experiment.) Two of the four species seemed to benefit from soil disturbance after sowing, and two species did not.

The area chosen for the experiment was former pasture or cropland on Markham silt loam soil in Northbrook, Illinois. (An aerial photo from 1938 shows the site as a mix of pasture and cropland.) The area had subsequently been a Cook County Forest Preserve for many decades. The principal vegetation of the study plots in 1993 (listed in order of total cover in 18 random 0.25-m² quadrats) consisted of tall goldenrod (*Solidago rigida*), early goldenrod (*Solidago juncea*), hawkweed (*Hieracium caespitosum*), meadow fescue (*Festuca elatior*), sedge (*Carex hirsutella*), coneflower (*Ratibida pinnata*), dogwood (*Cornus racemosa*), and bluegrass (*Poa compressa*).

On November 21, 1993, we pounded metal bars into the ground to mark the centers of six circular 6.15 m² plots, selected because they appeared basically similar (a relatively flat surface with few shrubs and generally similar existing vegetation). Each plot was seeded with the mesic prairie turf mix as given in Table 11.1 in Packard and Mutel (1997).Our seed mix consisted of rough seed and chaff (rubbed through screens to break apart the seed heads) mixed about half and half with perlite; we applied this mix at the rate of about one cup of mix per 100 square feet. In three plots (A,C, and E), selected by coin toss after seeding, the seed was raked by hand with four-prong "potato rakes" or "cultivating rakes."

The crew was asked to "rough up" the upper half inch (1.3 cm) of the soil so as to incorporate the seeds. Given the fully vegetated and uneven (bumpy) nature of the soils in these plots (typical in this and many other old field sites in northern Illinois), the raking skipped over some areas, while occasionally raking more than a half an inch deep. Thus, following this treatment, some seeds remain on the surface while others are buried 1 mm to perhaps as much as 20 mm deep. Three plots (B, D and F) were left unraked as a control.

In summer 1994 this area withstood a severe drought. The plots received no special treatment over the subsequent ten years, but were managed as a part of the 36-ha Somme Prairie Grove. This management consisted mostly of spring and fall burning every one to three years, with a hiatus in burning between 1996 and 2001 as a result of county politics. White sweetclover (*Melilotus alba*) and wild parsnip (*Pastinaca sativa*) were pulled by hand from areas like this whenever they appeared.

In August 2003 and May 2004, we relocated the six stakes and remarked the plots. Four species were easily countable in the 6.15 m² plots. Numbers of plants of these four species in the six plots are shown in Table 1. For shooting star (*Dodecatheon meadi*a) and rattlesnake master (*Eryngium yuccifolium*), the total numbers of plants in the raked and control plots were remarkably similar. For purple prairie clover (*Petalostemum purpureum*) and prairie dropseed (*Sporobolus heterolepis*) the totals showed about three times as many plants in the raked compared to the control plots.

Although the variance from plot to plot was great, the apparent pattern was sufficiently suggestive for us to change our management practices. Raking by volunteers is a time-consuming, strenuous, tedious (and unpopular) effort; it also competes for time with work of more proven

Table 1. The numbers of four target species of plants counted, ten years after six plots (A–F) were planted with a mesic prairie turf seed mix.

	Raked Plots				Unraked Plots			
Species	**A**	**C**	**E**	**Total**	**B**	**D**	**F**	**Total**
shooting star (*Dodecatheon meadia*)	18	3	52	**73**	10	37	19	**66**
rattlesnake master (*Eryngium yuccifolium*)	14	14	1	**29**	21	4	6	**31**
prairie dropseed (*Sporobolus heterolepis*)	8	9	12	**29**	4	1	6	**11**
purple prairie clover (*Petalostemum purpureum*)	3	4	1	**8**	1	2	0	**3**