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An Overview and Management Plan of Iowa's Non-native, Invasive, Terrestrial Forbs

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Non-native, invasive forb species have been a problem in Iowa since the earliest decades of Iowa's European settlement. The history of studies of Iowa's invasive plants began with L. H. Pammel, and these studies continue to present. Three tables cite the occurrence of many of these species in the state, with Table 1 listing 93 non-native forbs reported by Pammel, Table 2 citing ten invasive forbs of natural areas, and Table 3 adding 38 observed or potential aggressive species of Iowa's anthropogenic and natural areas.

There has been a divergence of interest and research in the management of invasive species of agricultural and horticultural areas versus natural areas. The problems of applying our weed laws, in particular the Iowa Noxious Weed Law, to natural areas include both a failure to accurately identify invasive and native species, and collateral damage to desirable species in the natural areas resulting from weed control efforts. Two models for control of invasive species in natural areas are provided.

In light of changing attitudes toward invasive species and our natural areas, better education, training, and coordination are suggested as ways of improving our management of them in Iowa. Continuing efforts to restore and reconstruct natural areas and the use of native, rather than non-native, species in horticultural settings are also encouraged as possible ways to slow the introduction and spread of invasive plant species.

INDEX DESCRIPTORS: invasive plants, natural areas, conservation, weed control, Iowa flora, exotic species.

Within a few decades of the settlement of Iowa by those of European descent (beginning approximately in the 1830s), non-native invasive forbs (broad-leaved herbaceous plants) became a significant part of the state's flora. By the close of the 19th century, Louis H. Pammel (1901) recognized six "classes of weeds" in Iowa—those that immediately followed the advent of the state's settlement; weeds that came in along railroads; seed contaminants of grain and flax seeds; native species that "adapted themselves to new conditions"; seed contaminants (and arguably the desired species as well) of grass and clover seed; and weeds of dooryards, hog-lots, and similar disturbed places. These six classes encompassed, but weren't limited to, non-native invasive plants.

Pammel, his colleagues (especially Charlotte King), and others published numerous papers about Iowa's weeds in the latter quarter of the 19th century and the first half of the 20th century. For example, Pohl (1985) listed 52 papers on weeds authored or co-authored by Pammel. Pammel (1913) and Pammel and King (1926) are lengthy summaries of what was then known about Iowa's weeds and their distribution, seeds, dispersal mechanisms, harmful effects, and eradication.

Richard Pohl and Duane Isely each had an active interest in weeds in the second half of the 20th century, although this inreresr was secondary to their other research pursuits. Pohl published papers on both weedy grasses and on introduced forbs (e.g., Pohl and Gillespie 1959, Pohl and Sylwester 1963, Pohl 1984). Unpublished notes from the 1970s in Isely's files indicate that he may have taught more students in elementary weed science than anyone else in the country. He published numerous papers, books and laboratory manuals on weeds (see list in Welsh and Lewis 2001). For example, his 1980 (most recent) edition of *Weeds in the North Central States* (a laboratory and field manual) provides descriptions and illustrations of more than 200 species (Isely 1980).

These papers by Iowa academicians not only highlight an early academic interest in the weeds of the state but also point out the lack of general consensus on the meaning of the word "weed". The term is not defined in any of these papers cited from Iowa, although there have been a number of attempts to define "weed" (e.g., Baker's (1974) definition as, "Those species that not only have no detected human value but actually interfere with human activities.") These definitions suffer from imprecision and often include aggressive native species.

More recently, the term "invasive plant" has been used. It is defined by Westbrooks (1998) as, "Plants that have been introduced into an environment in which they did not evolve and thus usually have no natural enemies to limit their reproduction and spread." Executive Order 13112 (Clinton 1999) adds a component of the environmental or human impact the species may have, stating, "Invasive species means an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health." This is the definition adopted in a new federal management plan titled *Meeting the Invasive Species Challenge* (National Invasive Species Council 2001), which outlines strategies for controlling invasive species in the United States.

Invasive plants may be dispersed long distances, either by their own "natural" modes of dispersing seeds or vegetative propagules, or by transport by humans, domesticated animals or machinery. Upon reaching a new area, invasive plants often take advantage of disturbances which allow them to become established. These disturbances or "openings" that provide the opportunity for establishment may have many causes, with human activities leading the list. Obviously, the settlement of the state was not the first human impact on Iowa's vegetation, although we often tend to think of Iowa's "native" or "presettlement flora" as static. Native Americans undoubtedly influ-

enced what we call the "native vegetation" by their practices of burning, grazing, and cultivating areas. On geologic time scales, climatic changes also greatly impacted this area's flora, with cycles of ice sheets, boreal vegetation, or the more familiar grasslands largely covering the state. The effects of faunal interactions are difficult to quantify, but also undoubtedly have helped shape our so-called native flora.

Undoubtedly, the post-settlement introduction of plants (including those in cultivation), intentionally or accidentally, and the disturbances caused by human activities have caused the greatest alteration of the vegetation of Iowa in recorded history. These changes are profound, yet are easily overlooked because many invasive plant species have been assimilated into our daily environment.

The impact of invasive plants is costly. In economic terms these costs are staggering; Pimental et al. (2000) estimated that the combined control costs and losses and damages incurred by invasive plant species in the United States exceed $34 billion. Additional effects of invasive plants include impacts on human health, loss of native species diversity, and loss of aesthetic appeal. Furthermore, the negative effects of non-native species on Iowa's remaining natural areas cannot be overstated. Adding to the other impacts of habitat loss and degradation, fragmentation, lack of management and maintenance of natural processes (such as burning or grazing), such non-native invasive species have had a strongly deleterious impact on our natural areas. Non-native species not only displace native plant species by occupying space; they also change nutrient and water availability, may affect light availability by shading the native species, and may be a source of introduction of diseases and pests (Randall 1996, Westbrooks 1998). Obviously these changes then affect the fauna and other biotic components of the natural community.

Which of Iowa's Invasive Forbs Merit Our Concern?

Westbrooks (1998) claims that every new plant introduction is an experiment with an unknown outcome. Thus any introduced species may potentially become invasive, even if benign in another locality or habitat. Eilers and Roosa (1994) list the native and naturalized (including invasive) vascular plants found in the state and cite each species as native or non-native. There are 434 species listed as non-native in their checklist, which is 22% of the total flora. Looking more specifically at the forbs, their checklist includes 297 species that are not native to the United States and 27 that are native to the U.S. but not to Iowa. Obviously not all of these non-native species are invasive; in fact, quite a few may no longer even be found in the state.

Perhaps one way to ascertain which species may be invasive is to look at the non-native species that have been determined as important "weeds" in the state's floristic literature. Pammel and King's (1926) *Weed Flora of Iowa* lists and describes 253 species which the authors considered "weedy". Of these, there are 1 fern, 30 graminoids (incl. 28 grasses, 1 sedge, and 1 rush), and 222 forbs (including 2 additional monocots and 220 dicots). However, most of these (139, 55%) are thought to be native in Iowa. Table 1 is a compilation of the "weedy" forbs listed in Pammel and King (1926) that are not native to Iowa according to Eilers and Roosa (1994). Many of these species are quite familiar, especially those found in "anthropogenic areas" (created or highly modified by humans) that include cropfields, lawns, construction sites, highly disturbed pastures, and rights-of-way. Several species included in Table 1, especially those of cropfields and lawns, are specific targets of the pesticide industry (e.g., *Amaranthus retroflexus* L. (pigweed), *Cirsium arvense* (L.) Scop. (Canada thistle), *Chenopodium album* L. (Lamb's quarters), *Glechoma hederacea* L. (Creeping Charlie), and *Abutilon theophrasti* Medicus (velvet leaf)). Still others on the list (indicated by a "−"), though once considered problem species, are now rare in the state. Some of these simply never became established in great numbers, while others have become increasingly rare because of changing agricultural practices (e.g., *Camelina sativa* (L.) Crantz, *Neslia paniculata* (L.) Desv. and *Agrostemma githago* L., invasive species found mainly in the cultivation of small-grain crops).

From the prevalence of advertising for herbicides, it seems that the primary concern about invasive species in Iowa centers on those of cultivated croplands, with some advertising also promoting herbicides for use in lawns and home gardens. Species that are invasive in range and pasturelands seemingly have been of secondary concern in Iowa, although there is some concern about species that are considered of low value (or harmful, such as poisonous plants) for forage or hay. Only in recent decades has their been a serious interest in invasive species found in natural areas, perhaps because some of these species are or have been actively cultivated in other settings (e.g., *Lotus corniculatus* L. and *Lythrum salicaria* L.). Lewis (1998: table 5) tabulated 20 of Iowa's common and aggressive vascular plant species found in natural areas; of these, 10 (50%) are non-native forbs (Table 2). Some of the species included in Table 2 have long been known from the state. Canada thistle, for example, is cited as a major "pest" throughout the state in Pammel's (1913) survey of Iowa weeds. *Euphorbia esula* L. (leafy spurge) is noted almost in passing as "becoming common" in Pammel and King's (1926) treatment. The most recent obviously aggressive forb to be recorded from the state is *Alliaria petiolata* (Bieb.) Cavara & Grande (garlic mustard). Hardly known in the state prior to 1990, Eilers and Roosa (1994) cite its abundance and distribution as "rare, in scattered localities, rapidly increasing its range, " and it is now known to be present in large populations across the state.

Tables 1 and 2 do not fully account for Iowa's major invasive forbs. Table 3 includes additional species that we feel warrant attention and further study as observed (personally, anecdotally, or otherwise) or potential invasive forbs. Westbrooks (1998) has referred to the introduction of invasive plants as "the silent biological invasion." It is likely that there are many potentially invasive non-native species in the state that have not yet been discovered. For example, in an inventory of the flora of Ames, Iowa, Norris et al. (2001) found 24 naturalized forbs not native in the United States (including an orchid) that are not listed in Eilers and Roosa (1994). Several of these are included in Table 3 as potentially invasive (e.g., *Cardamine flexuosa* With. and *Duchesnea indica* (Andrews) Focke). The table also includes the non-native forb species on Iowa's primary and secondary noxious weeds lists (Iowa Department of Agriculture and Land Stewardship 1990) not already cited in Tables 1 and 2, in addition to species that have been identified as invasive in other states.

The choice of scientific and common names used in all three tables follows Eilers and Roosa (1994) whenever possible. For species more recently reported from the state, Gleason and Cronquist (1991) is used, and is also the primary source of information about the duration of each species.

MANAGEMENT OF INVASIVE FORB SPECIES

Noxious Weed Laws

The Iowa Weed Law (Chapter 317, Code of Iowa 1997) directs the board of supervisors in each county to appoint a county weed commissioner, who is mandated to supervise the control and destruction of all noxious weeds occurring on any lands within the county. While Iowa's weed law generally works well, there are situations in which it has been difficult to apply or has been inappropriately applied. Problems of identification of Iowa's noxious weeds and misidentification of similar species are infrequent, but there are disturbing examples of such misidentification (e.g., populations of blazing

Table 1. Forbs listed by Pammel and King (1926) as Iowa weeds that are either cited as non-native or are not included in Eilers and Roosa (1994). '+' = species native to North America but not Iowa; '−' = species currently rare or absent in Iowa; '#' = species not included in Eilers and Roosa (1994); '1°' and '2°' denote Iowa's primary and secondary noxious weeds. For duration, 'Ann' = annual, 'Bi' = biennial, 'Per' = perennial, 'W-Ann' = winter annual.

Species (Common Name)	Family	Anthropogenic or Natural Areas?	Duration
+ *Amaranthus graecizans* L. (Prostrate pigweed)	Amaranthaceae	A	Ann
Amaranthus retroflexus L. (Pigweed)	Amaranthaceae	A	Ann
−# *Carum carvi* L. (Caraway)	Apiaceae	A	Bi
2° *Daucus carota* L. (Queen Anne's lace, wild carrot)	Apiaceae	A, N	Bi
Pastinaca sativa L. (Wild parsnip)	Apiaceae	A, N	Bi
Anthemis cotula L. (Dog fennel)	Asteraceae	A	Per
Arctium minus Bernh. (Common burdock)	Asteraceae	A	Bi
−+ *Artemisia biennis* Willd. (Biennial wormwood)	Asteraceae	A	Ann, Bi
− *Centaurea solstitialis* L. (Yellow star thistle)	Asteraceae	A	Ann, Bi
Cichorium intybus L. (Chicory)	Asteraceae	A	Per
1° *Cirsium arvense* (L.) Scop. (Canada thistle)	Asteraceae	A, N	Per
1° *Cirsium vulgare* (Savi) Tenore (Bull thistle)	Asteraceae	A, N	Bi
Lactuca serriola L. (Prickly lettuce)	Asteraceae	A	Ann, W-Ann
Leucanthemum vulgare Lam. (Ox-eye daisy)	Asteraceae	A	Per
1° *Sonchus arvensis* L. (Perennial sow thistle)	Asteraceae	A	Per
Sonchus asper (L.) Hill (Spiny-leaved sow thistle)	Asteraceae	A	Ann
Sonchus oleraceus L. (Common sow thistle)	Asteraceae	A	Ann
− *Tanacetum vulgare* L. (Tansy)	Asteraceae	A	Per
Taraxacum laevigatum (Willd.) DC. (Red-seeded dandelion)	Asreraceae	A	Per
Taraxacum officinale Weber (Common dandelion)	Asreraceae	A	Per
− *Xanthium spinosum* L. (Spiny cocklebur)	Asteraceae	A	Ann
2° *Xanthium strumarium* L. (Cocklebur)	Asteraceae	A	Ann
Cynoglossum officinale L. (Hound's-tongue)	Boraginaceae	A, N	Bi
Lappula echinata Gilib. (Beggar's lice)	Boraginaceae	A, N	Ann
− *Lithospermum arvense* L. (Corn-gromwell)	Boraginaceae	A	Ann
− *Armoracia rusticana* (Lam.) Gaertner, Meyer, & Schreber (Horseradish)	Brassicaceae	A	Per
Barbarea vulgaris R. Br. (Yellow rocket)	Brassicaceae	A	Bi
Berteroa incana (L.) DC. (Hoary alyssum)	Brassicaceae	A	Ann, Per
Brassica juncea (L.) Czern. (Chinese mustard)	Brassicaceae	A	Ann
Brassica nigra (L.) W.D.J. Koch (Black mustard)	Brassicaceae	A	Ann
− *Camelina sativa* (L.) Crantz (False flax)	Brassicaceae	A	Ann
Capsella bursa-pastoris (L.) Medicus (Shepherd's purse)	Brassicaceae	A	Ann, W-Ann
− *Conringia orientalis* (L.) Dum. (Hare's-ear mustard)	Brassicaceae	A	Ann
− *Eruca sativa* P. Miller (Garden rocket)	Brassicaceae	A	Ann
Lepidium campestre (L.) R. Br. (Field cress)	Brassicaceae	A	Ann, Bi
− *Neslia paniculata* (L.) Desv. (Ball mustard)	Brassicaceae	A	Ann
− *Raphanus raphanistrum* L. (Wild radish)	Brassicaceae	A	Ann
2° *Sinapis arvensis* L. (Charlock, wild mustard)	Brassicaceae	A	Ann
Sisymbrium altissimum L. (Tumble mustard)	Brassicaceae	A	Ann
Sisymbrium officinale (L.) Scop. (Hedge mustard)	Brassicaceae	A	Ann
Thlaspi arvense L. (Penny cress)	Brassicaceae	A	Ann, W-Ann
− *Agrostemma githago* L. (Corn cockle)	Caryophyllaceae	A	Ann
− *Cerastium glomeratum* Thuill. (Clammy chickweed)	Caryophyllaceae	A	Ann, W-Ann
Cerastium vulgatum L. (Mouse-ear chickweed)	Caryophyllaceae	A	Per
Saponaria officinalis L. (Bouncing Bet)	Caryophyllaceae	A	Per
Silene dichotoma Ehrh. (Catchfly)	Caryophyllaceae	A, N	Ann
−# *Silene dioica* (L.) Clairville (Red campion)	Caryophyllaceae	A	Per
Silene noctiflora L. (Night-flowering catchfly)	Caryophyllaceae	A	Ann
Silene pratensis (Rafn) Gren. & Godron (White campion)	Caryophyllaceae	A, N	Bi
Stellaria media (L.) Vill. (Common chickweed)	Caryophyllaceae	A	Ann, W-Ann
− *Vaccaria pyramidata* Medicus (Cowherb)	Caryophyllaceae	A	Ann
Chenopodium album L. (Lamb's quarters)	Chenopodiaceae	A	Ann
Chenopodium ambrosioides L. (Mexican tea)	Chenopodiaceae	A	Ann, Per

Table 1. Continued.

Species (Common Name)	Family	Anthropogenic or Natural Areas?	Duration
Kochia scoparia (L.) Schrader (Summer cypress)	Chenopodiaceae	A	Ann
Salsola iberica Sennen & Pau (Russian thistle)	Chenopodiaceae	A	Ann
1° *Convolvulus arvensis* (European bindweed)	Convolvulaceae	A	Per
Ipomoea hederacea (L.) Jacq. (Morning glory)	Convolvulaceae	A	Ann
Ipomoea purpurea (L.) Roth (Annual morning glory)	Convolvulaceae	A	Ann
Euphorbia cyparissias L. (Cypress spurge)	Euphorbiaceae	A	Per
Medicago lupulina L. (Black medic)	Fabaceae	A	Ann
Melilotus alba Medicus (White sweet clover)	Fabaceae	A, N	Ann, Bi
Melilotus officinalis (L.) Pallas (Yellow sweet clover)	Fabaceae	A, N	Ann, Bi
– *Trifolium arvense* L. (Rabbit-foot clover)	Fabaceae	A	Ann
– *Trifolium aureum* Pollich (Hop-clover)	Fabaceae	A	Ann, Bi
Trifolium campestre Schreber (Low hop-clover)	Fabaceae	A	Ann
– *Vicia sativa* L. (Common vetch)	Fabaceae	A	Ann
Hypericum perforatum L. (Common St. John's wort)	Hypericaceae	A, N	Per
Glechoma hederacea L. (Creeping Charlie)	Lamiaceae	A	Per
Lamium amplexicaule L. (Dead nettle)	Lamiaceae	A	Ann, W-Ann
Leonurus cardiaca L. (Motherwort)	Lamiaceae	A	Per
– *Mentha* × *piperita* (Peppermint)	Lamiaceae	A	Per
Nepeta cataria L. (Catnip)	Lamiaceae	A	Per
2° *Abutilon theophrasti* Medicus (Velvet leaf, butterprint)	Malvaceae	A	Ann
Hibiscus trionum L. (Flower-of-an-hour)	Malvaceae	A	Ann
Malva rotundifolia L. (Round-leaved mallow)	Malvaceae	A	Ann, Bi
Sida spinosa L. (Prickly mallow)	Malvaceae	A	Ann
Cannabis sativa L. (Hemp)	Moraceae	A	Ann
2° *Plantago lanceolata* L. (Buckhorn plantain)	Plantaginaceae	A	Per
Plantago major L. (Plantain)	Plantaginaceae	A	Per
Polygonum aviculare L. (Knotweed)	Polygonaceae	A	Ann
Polygonum convolvulus L. (Black bindweed)	Polygonaceae	A	Ann
Polygonum orientale L. (Prince's feather)	Polygonaceae	A	Ann
Polygonum persicaria L. (Lady's thumb)	Polygonaceae	A	Ann
2° *Rumex acetosella* L. (Red sorrel, sheep sorrel)	Polygonaceae	A	Per
2° *Rumex crispus* L. (Curly dock, sour dock)	Polygonaceae	A	Per
– *Rumex obtusifolius* L. (Bitter dock)	Polygonaceae	A	Per
Portulaca oleracea L. (Common purslane)	Portulacaceae	A	Ann
Linaria vulgaris Hill (Butter & eggs)	Scrophulariaceae	A	Per
Verbascum blattaria L. (Moth mullein)	Scrophulariaceae	A	Bi
Verbascum thapsus L. (Common mullein)	Scrophulariaceae	A	Bi
Datura stramonium L. (Jimsonweed)	Solanaceae	A	Ann
+ *Solanum rostratum* (Buffalo bur)	Solanaceae	A	Ann
2° *Tribulus terrestris* L. (Puncture-weed)	Zygophyllaceae	A	Ann

Table 2. Invasive forbs of Iowa's natural areas, compiled from Lewis (1998). '1°' and '2°' denote Iowa's primary and secondary noxious weeds. For duration, 'Ann' = annual, 'Bi' = biennial, and 'Per' = perennial.

Species (Common Name)	Family	Habitat	Duration
1° *Cirsium arvense* (L.) Scop. (Canada thistle)	Asteraceae	Prairies	Per
Alliaria petiolata (Bieb.) Cav. & Grande (Garlic mustard)	Brassicaceae	Woodlands	Bi
1° *Euphorbia esula* L. (Leafy spurge)	Euphorbiaceae	Prairies	Per
Euphorbia × *pseudovirgata* (Schur) Soo (Leafy spurge)	Euphorbiaceae	Prairies	Per
Coronilla (Securigera) varia L. (Crown vetch)	Fabaceae	Prairies	Per
Lotus corniculatus L. (Bird's-foot trefoil)	Fabaceae	Prairies	Per
Melilotus alba Medicus (White sweet clover)	Fabaceae	Prairies	Ann, Bi
Melilotus officinalis (L.) Pallas (Yellow sweet clover)	Fabaceae	Prairies	Ann, Bi
Trifolium pratense L. (Red clover)	Fabaceae	Prairies	Per
Lythrum salicaria L. (Purple loosestrife)	Lythraceae	Wetlands	Per

Table 3. Iowa's additional observed or potential invasive forb species not included in Tables 1 or 2. '+' = species native to North America but not Iowa; '#' = species not included in Eilers and Roosa (1994); '1°' and '2°' denote Iowa's primary and secondary noxious weeds. For duration, 'Ann' = annual, 'Bi' = biennial, 'Per' = perennial.

Species (Common Name)	Family	Anthropogenic or Natural Areas?	Duration
Mollugo verticillata L. (Carpetweed)	Aizoaceae	A, N	Ann
2° *Conium maculatum* L. (Poison hemlock)	Apiaceae	A	Bi
Carduus acanthoides (Plumeless thistle)	Asteraceae	A, N	Bi
Carduus nutans L. (Musk thistle)	Asteraceae	A, N	Bi
1° *Centaurea repens* L. (Russian knapweed)	Asteraceae	A, N	Per
Centaurea spp. (Bachelor's button, knapweed, star thistle)	Asteraceae	A, N	Ann, Bi, Per
Galinsoga quadriradiata Ruiz & Pavon (Peruvian daisy)	Asteraceae	A	Ann
# *Hieracium piloselloides* Villars. (Glaucous king-devil) (rare)	Asteraceae	A	Per
Matricaria matricarioides (Less.) Porter (Pineapple weed)	Asteraceae	A	Ann
Senecio vulgaris L. (Common groundsel) (rare)	Asteraceae	A	Ann
Tragopogon dubius Scop. (Goat's-beard)	Asteraceae	A, N	Bi
# *Cardamine flexuosa* With. (Bitter-cress) (rare)	Brassicaceae	A	Ann
1° *Cardaria draba* (L.) Desv. (Hoary cress, perennial peppergrass)	Brassicaceae	A	Per
Erysimum cheiranthoides L. (Wormseed mustard)	Brassicaceae	A, N	Ann
Hesperis matronalis L. (Dame's rocket)	Brassicaceae	A, N	Bi, Per
Campanula rapunculoides L. (Rover bellflower)	Campanulaceae	A	Per
Dianthus armeria L. (Deptford pink)	Caryophyllaceae	A, N	Ann, Bi
Myosoton aquaticum (L.) Moench (Giant chickweed)	Caryophyllaceae	A, N	Per
# *Sagina procumbens* L. (Pearlwort) (rare)	Caryophyllaceae	A	Per
Commelina communis L. (Day-flower)	Commelinaceae	A	Ann
2° *Dipsacus sylvestris* Hudson (Common teasel)	Dipsacaceae	A	Bi
Lespedeza cuneata (Dum.-Cours.) G. Don (Silky bush clover)	Fabaceae	A, N	Per
Medicago sativa L. (Alfalfa)	Fabaceae	A, N	Per
Trifolium hybridum L. (Alsike clover)	Fabaceae	A	Per
Trifolium repens L. (White clover)	Fabaceae	A	Per
Prunella vulgaris L. var. *vulgaris* (Self heal)	Lamiaceae	A, N	Per
Allium vineale L. (Field garlic)	Liliaceae	A	Per
Hemerocallus fulva (L.) L. (Day lily)	Liliaceae	A	Per
Malva neglecta Wallr. (Cheeses)	Malvaceae	A	Ann, Bi
Polygonum cuspidatum Sieb. & Zucc. (Japanese bamboo) (rare)	Polygonaceae	A	Per
# *Rumex stenophyllus* Ledeb. (rare, possibly overlooked)	Polygonaceae	A, N	Per
Lysimachia nummularia L. (Moneywort)	Primulaceae	A, N	Per
Ranunculus testiculatus Crantz (Bur buttercup) (rare)	Ranunculaceae	A, N	Ann
# *Duchesnea indica* (Andrews) Focke (Indian strawberry)	Rosaceae	A, N	Per
Potentilla recta L. (Sulphur cinquefoil)	Rosaceae	A, N	Per
Veronica arvensis L. (Corn speedwell)	Scrophulariaceae	A, N	Ann
Veronica serpyllifolia L. (Thyme-leaved speedwell)	Scrophulariaceae	A, N	Per
Solanum dulcamara L. (European bittersweet)	Solanaceae	A, N	Per

star (*Liatris* spp.) have been mistaken for purple loosestrife (*Lythrum salicaria* L.)). A second problem arises when control measures for destroying noxious weeds also damage or destroy populations of desirable species. Some impact is difficult to avoid when herbicides are used in natural areas. These situations require selection of an appropriate herbicide and careful application to minimize the effects of such treatment on desirable species. State, county and local government and private landowners' active management of roadside native vegetation (often including restoration or reconstruction of natural habitats) and designation of "no spray" areas may also work to decrease this problem.

Two Integrated Pest Management Models

Agricultural and horticultural practices include models and protocols for controlling invasive species in cropfields, range- and pasture-lands, gardens, and lawns. These protocols were developed to avoid losses in crops, money, time, and aesthetic appeal. Many of these methods today are used in an "integrated pest management (IPM)" approach. Agricultural technology has advanced to providing many tactics for the control of pests; IPM promotes evaluating the particular situation for selecting the best application of any or a combination of these tactics. The Cooperative State Research, Education and Extension Service (2001) provides the following definition—"Integrated pest management is a sustainable approach that combines the use of prevention, avoidance, monitoring and suppression strategies in a way that minimizes economic, health, and environmental risks."

Developing an IPM model for control of invasive forbs in natural areas is more difficult than for agricultural settings. Like agricultural and other anthropogenic areas, natural areas may have a wide diversity of invasive species, but the species may employ different strategies for dispersal, establishment and spread in natural areas. Ad-

ditional factors must also be considered in natural areas: 1) natural areas have diverse habitat types, 2) adverse impacts to native species of flora and fauna must be minimized in natural areas, 3) management of natural areas typically has different goals and objectives, and 4) the "permanence" of natural areas precludes the use of such methods as plowing or application of pre-emergent herbicides.

Randall (1996) presented a model for non-native plant species control in "wildlands", which he called an "adaptive management strategy" for weed control. Quoting from his strategy, he states the need to:

> "a) establish and articulate management goals and objectives for the wildland; b) identify any plant species that threaten or have the potential to threaten the management objectives ("weeds") and assign priority based on the severity of their impacts; c) consider control methods available and, if necessary, re-order priorities based on likely impacts of control actions on the weed(s) and non-target species; d) develop and implement a management plan designed to move conditions toward the goals and objectives; e) monitor and assess impacts of the management actions in terms of their effectiveness in approaching the goals and objectives; and f) use this information to modify and improve control priorities, methods and plans beginning the cycle again."

The "Wildland Invasive Species Program" website developed by The Nature Conservancy and the University of California—Davis (http://tncweeds.ucdavis.edu) reiterates Randall's (1996) management strategy and further provides a template for developing a site management plan. The website also links to the *Weed Control Methods Handbook* (Tu et al. 2001), which describes weed control or eradication techniques.

Randall's (1996) management strategy has been applied at a number of natural areas, with case studies provided at the URL cited above. However, this plan may overlook some basic starting points that perhaps seem obvious to land management professionals. Thus, as we propose an alternative IPM model for control of invasive plants, we promote additional steps that may aid the manager in becoming knowledgeable about the site and more cognizant of the impacts resulting from efforts (or lack thereof) to control invasive plants. This model is intended to be a part of a broader plan of management of natural areas. Our approach, while not tested *per se,* is, on the other hand, an attempt to record in somewhat specific terms what we generally tend to do intuitively. As with Randall's (1996) strategy, ours is presented as a cycle for on-going control or eradication of invasive plants as they may occur on the site.

1) Describe or map the site not only in general terms (e.g., forest, prairie, and/or wetland), but also including more specific components. These components may include slope and aspect, open vs. shaded, hydrology (i.e., noting locations of at least surface seeps, ponds, streams, and similar bodies of water), past history, current use, historic and current disturbance, and the general nature of adjacent areas. This step is important for the development of management goals and objectives that are appropriate for the site.
2) Identify and characterize the biota as far as possible or practical. List or note the native and non-native plant species present, the fauna observed, and the species that are or potentially could become invasive (for the purposes of our paper, these would be the non-native invasive forbs). For the invasive species, consider the basic biology of each (e.g., woody or herbaceous; annual, biennial, or perennial; and modes of dispersal and spread). Both careful observation and use of references will be helpful with this step of the process, which is important for planning which control measures should be implemented on the site.
3) Determine the action thresholds or "triggers" that signify that active management may be needed. In part, thresholds may be determined by recognizing what invasive plant species are present and if those species pose a threat to native populations and the overall site integrity. Management activities may need to be prioritized, based on economic considerations, available time and personnel, safety, and other site-specific factors. Small problems (such as small populations of invasive species) may become much bigger problems if they are ignored.
4) Identify possible tactics and their potential impacts. Management may range from "benign neglect" (hopefully with on-going monitoring) to active control methods. Many techniques for control or eradication of invasive plant species are available and should be considered. Chemical control using herbicides; mechanical control such as mowing, cutting, or using grazing, burning, or other "natural processes"; introduction of biological controls; and/or nutrient or water management are all possibilities. It is also important to identify the source of introduction of invasive species, if possible, and consider means of preventing their reintroduction. Note that some of these control methods target the invasive species, while others generally promote the health of the natural community with hopes that the invasive species will be discouraged. The impact of the management system should be evaluated, with consideration of the effects on fauna, adjacent areas, and the potential for spread (of chemicals in particular) by waterways or wind. Develop a more comprehensive plan for site restoration, if needed. This plan may include control of other invasive species, reintroduction of native species to the site, and other activities that advance the goals and objectives for the site. The decision about the best tactics to employ should include consideration of the information gathered in steps one through three.
5) Implement the methods determined to be most appropriate. We stress personal safety and proper use of the selected techniques, and the consideration of the impacts of the management techniques that are used.
6) Continue site monitoring and further implement the plan for site restoration (if needed). Evaluate the success of the methods used, and keep records of methods that seem to work and those that don't. The control of many of our invasive species is difficult, and even initially "knocking them back" should be considered a positive step toward success. Frequently, trial-and-error must be used to ascertain the best control methods. Consider whether the changes to the site that have been made by the management activities necessitate going through the cycle again. On-going monitoring is necessary, even if the above-ground, visually obvious parts of the invasive plants have disappeared, as the species may reemerge from seeds in the seedbank or reintroduced onto the site or from underground rhizomes or similar structures.

Either of these invasive species management plans may seem overwhelming, even on a small site, when time, staff, or expertise are limited. However, perhaps at least consideration, if not complete implementation, of the suggested steps may help in deriving some level of improved invasive species control.

The steps of inventory, monitoring, and selecting appropriate tactics may be aided by the many available printed and electronic resources that provide information on identification and

control of invasive species. For the Upper Midwest region, a classic reference for identifying invasive species is *Weeds of the North Central States* (University of Illinois at Urbana Champaign 1981). Davis (1993) has produced a comprehensive reference for identifying the weed seeds of the Great Plains region. Hoffman and Kearns (1998) are the editors of a manual for identifying and controlling invasive plants in Wisconsin; it includes many of Iowa's most aggressive non-native plant species. The "Wildland Invasive Species Program" website (http://tncweeds.ucdavis.edu) mentioned previously also includes photographs and information about specific invasive plant species and their control. This site also has links to the general overview of control methods and the use, effectiveness, and environmental and safety precautions of commonly used herbicides presented by Tu et al. (2001). The National Invasive Species Council website (http://www.invasivespecies.gov) includes descriptions of some of the most invasive species in the United States, as well as providing access to the National Management Plan for Invasive Species that has recently been developed, state weed laws, new and pending legislation regarding invasive species, and other such information. Several Iowa State University Extension documents describe the herbicides most frequently used in Iowa. Two are of particular relevance to natural areas—*Agricultural Pesticide Impacts on Prairie Wetlands* (Iowa State University Extension 1993) and *Protecting Iowa's Rare and Endangered Plant Species* (Iowa State University Extension 1997). These are available at the ISU Extension publications website (http://www.extension.iastate.edu/pubs/).

The experiences of others who are also attempting invasive species control may also be helpful. Online discussion groups such as those for Iowa's native plants (contact via owner-iowa-native-plants@list.uiowa.edu) and prairies (contact via owner-prairie@mallorn.com) provide opportunities for sharing information and getting questions answered.

FUTURE ISSUES AND CONCLUSIONS

The problems of controlling established populations of invasive plant species and preventing their introduction into new areas in Iowa are not easily solved. These problems arise in part from the aggressive nature of invasive species and their adaptability to the changing conditions which we create for them. However, another reason the problems may persist lies in our acceprance of and tolerance for these species. Several of these species were intentionally introduced, and because we may find them beneficial in some settings, we may tolerate them in others. Perhaps a still greater problem lies in simply overlooking invasive species until their numbers and effects have reached a "point of no return".

Lack of education and training in biotic inventory methods and in understanding the need for inventory, monitoring, and control of the invasive species is another factor limiting our ability to control invasive species. We have stated elsewhere (Lewis 1998, Norris et al. 2001) the need for intensive field study of Iowa's flora. In the past, this was largely the purview of researchers at our universities and colleges. More recently, state and county government employees have been involved in such inventories (e.g., county weed commissioners, also Iowa Department of Natural Resources personnel). Budget cuts, other staff demands and interests, and a lack of education and training resources for such efforts have all taken their toll. Perhaps the general public will play a larger role in inventory efforts. Some training and certainly awareness and discussion of the issues are already underway, promoted by such organizations as the Iowa Native Plant Society and the Iowa Prairie Network. Have we also reached a turning point in the general perception for need for studies, education, and information? Within the past few years, symposia on invasive species, the interest in these species at the federal government level, the accessibility of information on websites, and new publications on invasive species have all provided positive signs that the invasive species problem is being recognized. Still, there seems to be a lack of coordination of efforts, which contributes to our inability to launch a serious attack on the problem.

Habitat loss and fragmentation and other changes to our environment that encourage the introduction and spread of invasive plant species are on-going. In a recent paper (Wilcove et al. 1998), threats to rare and imperiled species of flora and fauna were quantified. Of the five threats that were ranked in the study, the top two were habitat loss and alien species (followed by pollution, overexploitation, and disease). The slowing of habitat loss and fragmentation, the restoration and reconstruction of natural areas, and the addition of adjacent buffer zones to our natural areas may all help to prevent the loss of native species and slow the spread of invasive species. Monetary support for such efforts will hopefully continue to be available through federal "Farm Bill" programs, state agencies and programs, and private conservation organizations.

A primary source of invasive plant species is their intentional introduction for use in horticulture; the majority of woody invasive plants (and undoubtedly a large number of herbaceous ones, as well) were introduced for horticultural purposes (Reichard and White 2001). In the inventory of the Ames flora mentioned above (Norris et al. 2001), at least 6 of the 24 (25%) naturalized forbs that were not previously reported from Iowa had apparently spread from cultivation. The use of native rather than introduced species in horticultural settings has been promoted as a means of combating the introduction and spread of invasive species (e.g., Federal Interagency Committee for the Management of Noxious and Exotic Weeds 2000). This also raises some legitimate concerns, one of which is the loss of gene resources of local populations if new genotypes are introduced that "swamp out" the existing local ones. Also, currently there are relatively few native species that are readily available as either seeds or plants on the market for widespread horticultural use, and the removal of plants (and in many cases, seeds) of native species from their natural habitats should not be encouraged as a substitute. However, it should be possible to increase propagation options, and thus the availability of native species, to take these caveats into account.

The control or eradication of invasive species can be a difficult problem, especially in natural areas where some of the methods available for weed control in agricultural or other anthropogenic areas cannot be used. Research is underway on methods of biological control (such as introducing insects or fungi that impair or kill the invading species) and improved application methods and formulations of herbicides. However, such techniques require considerable field testing to ascertain their effects beyond those on the targeted species.

Given all of these challenges, we are likely never to completely eradicate invasive species from Iowa, nor even fully know the extent of their impact. However, with improved coordination of efforts for control activities, education, and research, and developing partnerships between government agencies, private organizations, and the general public, we may be better able to eradicate many infestations, slow the spread of invasive forbs in the state, and prevent the introduction and establishment of new invasive species. The economic and environmental costs of invasive species are staggering (see Pimentel et al. 2000), thus we are provided ample incentives to address these challenges.

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