APPENDIX J

Dotted and Garden Loosestrife, Giant Hogweed, and Indigobush: Distribution, Biology, and Ecology

FINAL REPORT

GARDEN AND DOTTED LOOSESTRIFE, GIANT HOGWEED, AND INDIGOBUSH: DISTRIBUTION, BIOLOGY, AND ECOLOGY

Submitted to:

Washington State Department of Ecology

Submitted By:

Ebasco Environmental

Project Manager: Jay Brueggeman
Technical Lead: Clayton Antieau

January 1993

Sources of cover illustrations: garden and dotted loosestrife (Hitchcock and Cronquist 1973); giant hogweed (Hyypio and Cope 1982); indigobush (original adaptation).

CONTENTS

ABSTRACT

Several species of Eurasian and North American plants have recently invaded freshwater wetlands in the Pacific Northwest. In general, these species form monospecific stands, have growth characteristics that displace native vegetation and affect other biological and abiotic resources, or present a human health hazard. Development of an effective management plan for these species requires thorough knowledge of their biological characteristics and ecological requirements. To assist in development of such a plan, this report summarizes applicable available information on the biology, ecology, and distribution of four of these species in Washington. Pertinent literature on these species is scant, and little or no research is being conducted to investigate essential questions focusing on the biology or management of these plants.

Garden loosestrife (*Lysimachia vulgaris)* and the closely related dotted loosestrife (*L. punctata*) are Eurasian species that have recently been located in freshwater wetlands in western Washington. Both species are rhizomatous, deciduous perennials cultivated for their ornamental characteristics, but which tend to be invasive. Little information is available on the biology and ecology of these species, particularly with reference to Washington.

Giant hogweed (*Heracleum mantegazzianum*) is a Caucasian species that causes severe phytophotodermatitis in susceptible humans and some domesticated and wild animals. Long cultivated for its unusual ornamental characteristics, this species has become naturalized in many parts of the world, including the British Isles, Europe, and North America. This species has been observed to rapidly invade wetlands, riparian areas, and disturbed wastelands, following corridors such as roads, railways, and rivers/streams. More information is known about this species than the others considered in this report due to its long history of infestation outside its native range and because of the important human health concerns caused by infestations.

Indigobush (*Amorpha fruticosa*) is a North American native species that has recently invaded shorelines of reservoirs and major rivers and creeks in portions of Idaho, Washington, and Oregon, areas considered to be outside of its native range. This species tolerates a wide variety of environmental conditions, particularly drought and periodic inundation. Little information is available on the biology and ecology of this species, especially relative to its infestations in the Pacific Northwest.

1.0 INTRODUCTION

1.1 PURPOSE

The Washington State Departments of Agriculture, Ecology, Fisheries, Natural Resources, and Wildlife, and the Washington State Noxious Weed Control Board, acting as lead agencies, have proposed to develop and implement a management plan for noxious emergent plant species occurring in Washington. The lead agencies want to determine which management alternative or combination of alternatives would provide the most effective management of noxious emergent plant species with the least environmental impacts. The ultimate goal of the proposal is to develop criteria and approaches for managing infestations of new and established weed species.

The lead agencies have determined that implementing a noxious emergent weed management program could have a probable significant adverse environmental impact. Thus, an environmental impact statement (EIS) is required under RCW 43.21C.030(2)(c). Lead agencies have identified topics to be discussed in the EIS, including biology and ecology of problem species, management alternatives, and mitigation strategies. Ebasco Environmental was contracted by the nominal lead agency, the Washington State Department of Ecology, to assemble and synthesize available information on these topics of interest for inclusion in the EIS.

Development of an effective management plan for noxious emergent weed species requires thorough knowledge of the biological characteristics and ecological requirements and interactions of those species. For purposes of developing the weed management plan and for the information-gathering aspect of the EIS, the lead agencies identified species of primary concern, which include three species of cordgrass or *Spartina* (*S. patens*, *S. alterniflora*, and *S. anglica*), and purple loosestrife (*Lythrum salicaria*) and wand loosestrife (*L. virgatum*). Several species of secondary concern, for purposes of the plan and EIS preparation, are also being considered: garden loosestrife (*Lysimachia vulgaris*), the closely related dotted loosestrife (*L. punctata*), giant hogweed (*Heracleum mantegazzianum*), and indigobush (*Amorpha fruticosa*).

To assist in plan development, this report summarizes information on the biology, ecology, and distribution of species of secondary concern in this project: garden and dotted loosestrife (*Lysimachia vulgaris*; *L. punctata*), giant hogweed (*Heracleum mantegazzianum*), and indigobush (*Amorpha fruticosa*). A summary of these characteristics for these species is provided in an appendix. Separate reports detail the biology and ecology of *Spartina* spp. and purple and wand loosestrife in Washington.

1.2 OBJECTIVES

The objectives of this report are to:

(1) summarize information on the distribution of garden loosestrife, dotted loosestrife, giant hogweed, and indigobush, including locations of infestations in Washington; and,

(2) characterize the biology and ecology of these four species. Topics discussed include taxonomy, physiology, preferred habitat, life history, modes of dispersal, and factors affecting growth, spread, and dieback.

This report is not intended to be an exhaustive treatment. Rather, discussion of biological and ecological characteristics focuses on those attributes contributing to the invasive nature of these species and that have implications for the management of infestations. Primary sources of information for this report were published journal articles, published and unpublished studies, and local and regional authorities. Information was obtained from both national and international sources.

2.0 DISTRIBUTION

2.1 HISTORICAL DISTRIBUTION

Garden and Dotted Loosestrife

Both *Lysimachia punctata* and *L. vulgaris* are native to Eurasia. It is of note that *L. punctata* is considered rare in at least parts of its range (Poland) and that *L. vulgaris* is also considered rare in a part of its range (Bulgaria) (Koeva 1977, Krzaczek and Krzaczek 1982).

Giant Hogweed

Giant hogweed is a native to the mountainous Caucasus region of western Asia and eastern Europe where it occurs in the upper forest belt of the southern slopes, mainly in meadows, clearings, and forest margins (Mladenova 1950). It is also distributed along river valleys (Grossgeim 1967).

Indigobush

Indigobush is native to eastern North America from southern Quebec south into Florida and west into northern Mexico, southern California and eastern Wyoming (Wilbur 1975). The species grows along rivers and streams, and in wetlands and moist draws.

2.2 PRESENT-DAY DISTRIBUTION

Garden and Dotted Loosestrife

Lysimachia punctata and *L. vulgaris* are native to Eurasia, but both have been occasionally cultivated in North America. Brockett and Cooperrider (1983) suggest that *L. punctata* has escaped from cultivation in Ohio and has invaded disturbed sites, and that *L. vulgaris* has invaded moist, disturbed sites in northeastern Ohio. Established populations of *L. vulgaris* are also known from Quebec, Illinois, Nebraska, Pennsylvania, and West Virginia (Churchill *et al.* 1974, Cusick 1986, Duppstadt 1977, WSNWCB 1991). Cusick (1986) notes the species seems

to be on the increase in the Ohio River valley. In Washington, *L. vulgaris* has been observed on the north, east, and west shores of Lake Sammamish and the north and south ends of Lake Washington in King County (WSNWCB 1991; Gojio 1991, pers. comm.) Taylor *et al.* (1973) report *L. punctata* from a small population along the south shore of Lake Whatcom, Whatcom County, Washington. Hitchcock *et al.* (1969) mention a collection from Multnomah Falls, Multnomah County, Oregon.

Lysimachia vulgaris is currently listed as a Class B noxious weed in Washington. *L. punctata* is not presently listed, but is of concern because it is closely related to *L. vulgaris* and has been observed to be invasive elsewhere in North American (Brockett and Cooperrider 1983).

Giant Hogweed

Giant hogweed has been cultivated as an ornamental plant for many years. Its introduction into botanical gardens and other gardens throughout the world has presumably contributed to its increasing range. The species was cultivated as early as the 1800's in England, naturalizing as early as 1862 (Wright 1984). The plant was cultivated as early as 1917 in New York (Hyypio and Cope 1982).

Giant hogweed is now established in England, Ireland, and Scotland, and parts of Europe such as Belgium, France, Germany, Czech Republic, and Sweden (Clegg and Grace 1974, D'hose and De Langhe 1990, Delaigue 1989, Dierschke 1984, Hyypio and Cope 1982, Jackson 1989, Karlsson 1977, Pyšek 1991). In the Czech Republic, the species has been reported from several localities above 1000 m a.s.l. (3,281 ft a.s.l.) (Pyšek 1991). The species is being cultivated as a silage or forage plant and as a honey plant in parts of Europe and Asia (Cwiklinski 1973, Dreher 1972, Ruskova 1973).

Giant hogweed has also become established in North America, particularly the Canadian provinces of Ontario and British Columbia (near Parksville, Nanaimo, and Victoria), and the states of New York and Washington (Dawe and White 1979, Hyypio and Cope 1982, Morton 1978, WSNWCB 1991).

In Washington, the species is thought to have been introduced in the early 1950's (Cafazzo 1992). Giant hogweed has apparently been growing on Phantom Lake (Bellevue, Washington) for more than 40 years, being originally brought to that location by German emigrants (Rahr 1992, pers. comm.). The species is now reported from Clallam, Clark, Island, King, Kitsap, Mason, Skagit, Thurston, and Whatcom counties (Hovanic 1992, pers. comm.; The Sequim Gazette undated; Missoulian 1981; WSNWCB 1991). Single populations are known from Sequim, Clallam County; Potlatch, Mason County; Vancouver, Clark County; Coupeville, Island County; and Mt. Vernon, Skagit County (Roché undated, The Sequim Gazette undated). Multiple infestations are located in King County (Seattle area) and Thurston County (Olympia and Rainier). This species is classified as a Class A noxious weed in Washington.

Indigobush

In addition to its native range, indigobush occurs in China where it is planted to improve saline/alkaline soils on forestlands (Cai and Zhong 1988, Lung and Xu 1980), and in parts of Europe such as Hungary, Yugoslavia, and Armenia (Arsenovic *et al.* undated, Bozoyan 1981, Hulina 1987, Terpo and Egyed 1983). The species is apparently cultivated as a moderately palatable forage shrub for sheep and cattle in Italy and Pakistan (Bonciarelli and Santilocchi 1980, Sarti *et al.* 1982, Sheikh 1979),

The species is also now located in areas of the western United States including Idaho (Ada, Canyon, Gem, Lemhi, Payette, and Washington counties), Oregon (Malheur, Morrow, Multnomah, Sherman, and Wasco counties), and Washington (Columbia, Franklin, Garfield, Klickitat, Skamania, and Walla Walla counties) (Halse and Glad 1992; Hovanic 1992, pers. comm.; Johnson 1991, pers. comm.; Jolley 1988). It is of note that Cusick (1986) mentions West Virginia lies near the northern limit of the natural species range as given by Fernald (1950) and that some or all of West Virginia's populations may be adventive. She also mentions that indigobush is not indigenous to Ohio but has become more frequent along the Ohio River in eastern Ohio in recent years.

Indigobush was not reported in the Pacific Northwest until the 1980's (Halse and Glad 1992). In Washington, indigobush is currently invading native plant communities along the Columbia and Snake rivers and some of their tributaries from just above Central Ferry, Garfield County, to the western part of the Columbia River Gorge. It has been observed along Deadman and Meadow Creeks near Central Ferry and upstream from Starbuck on the Tucannon River in Columbia County (Bragg 1991, pers comm.; Keeland 1985, pers. comm.). It is also known from Mill Creek near Walla Walla, Walla Walla County (Keeland 1985, pers. comm.). Keeland (1985, pers. comm.) suggests this species is present on both sides of the Columbia and Snake rivers downstream of Central Ferry. Jolley (1988) indicates it is located on Columbia River shores throughout the Columbia River Gorge. Halse and Glad (1992) indicate the species is found on the Columbia River from the Hanford Reach to the mouth of the Willamette River on the Oregon shore and to Wahkiakum County on the Washington shore. The species probably extends along the entire southern length of the Columbia River (Hovanic 1992, pers. comm.).

Indigobush is listed a class B noxious weed because it spreads from planted areas into native plant communities. The designation of this species as a noxious weed is somewhat controversial because it is native to North America; parts of its natural range (eastern Wyoming) come close to reported occurrences in the Pacific Northwest such as in Idaho and eastern Washington.

3.0 BIOLOGY AND ECOLOGY

3.1 TAXONOMY AND PHYSIOLOGY

3.1.1 Taxonomic Status of Species Present in Washington

Garden and Dotted Loosestrife

Lysimachia punctata and *L. vulgaris* (Primulaceae) are primarily distinguished by leaf and flower characteristics. Specimens located on Lake Sammamish have been identified as *L. vulgaris* by local and national taxonomic authorities (Hovanic 1992, pers. comm.).

Some confusion exists regarding the chromosome number of *L. vulgaris*. Heubl (1989) reported a chromosome number of (2n=) 84 for this species, as did Skalinska *et al.* (1976). Peev (1976), however, reported that *L. vulgaris* ssp. *glandulosa* has a diploid chromosome number of 28. Ko *et al.* (1986) found L. *vulgaris* var. *davurica* to have a diploid chromosome number of 42. Tanaka and Hizume (1980) also reported a diploid chromosome number of 42 for *L. vulgaris*. In contrast, Uhrikov *et al.* (1986) reported a diploid number of 28. Heubl (1989) indicated the chromosome number for *L. punctata* is (2n=) 30.

At least one cultivated variety of *L. punctata* is known: *L. punctata* 'Purpureum,' with purplish-green leaves (Antieau 1992, pers. comm.). No named cultivated varieties of *L. vulgaris* are known. These species and this cultivar continue to be cultivated and sold in Washington (Antieau 1992, pers. comm.; Rahr 1992, pers. comm.). There is no State prohibition on the sale of plants or seeds of these species.

Giant Hogweed

Hindakova and Schwarzova (1986) reported the chromosome number of this species to be (2n=) 22. *Heracleum mantegazzianum* (Apiaceae) is distinct from other species of *Heracleum*. No named cultivated varieties are known. This species continues to be sold and cultivated in Washington despite a State prohibition of the sale of plants or seeds of this species (Antieau 1992, pers. comm.; The Sequim Gazette undated).

Indigobush

Wilbur (1975) provided the latest taxonomic revision of *Amorpha*. In that work he described *A. fruticosa* (Fabaceae) as a wide-ranging and variable complex. He noted that variation in this complex is both environmentally and genetically induced, but that the species is mostly distinct from other species identified in his revision.

Indigobush has been cultivated since approximately 1724 (Rehder 1940). Several cultivated varieties exist, including 'Albiflora' with white flowers, 'Crispa' with crisped leaf margins, 'Corulea' with light blue flowers, 'Lewisii' with larger flowers, 'Pendula' of weeping habit, and

A. fruticosa forma *humilus* of dwarf habit (Krussmann 1984). There is a State prohibition on the sale of plants or seeds of this species.

3.1.2 Hybridization with Native and Non-native Species

Garden and Dotted Loosestrife

Lysimachia ciliata and *L. lanceolata* are native species somewhat common in wetlands and riparian areas in eastern Washington. *L. terrestris* and *L. thyrsiflora* are wetland species native to western Washington primarily. *L. nummularia* is a European species widely escaped in western Washington. No information on the potential for hybridization among introduced and native species is available.

Giant Hogweed

A hybrid between *Heracleum mantegazzianum* and *H. sphondylium*, a European native cow-parsnip, has been documented (Arora *et al.* 1982, Grace and Stewart 1978, Grace and Nelson 1981, Jackson 1989, Stewart and Grace 1984). This suggests that pollination with the Pacific Northwest species, *H. lanatum*, is possible.

Weimarck *et al.* (1979) demonstrated the existence of F_1 hybrids between *H. sphondylium* subsp. *sphondylium* and *H. mantegazzianum* in Scotland. These hybrids were morphologically intermediate and virtually sterile (segregationally and perhaps also physiologically). They indicated that backcrossing, though a rare occurrence, may take place.

Indigobush

No specific information is available. There are no native species of *Amorpha* in the Pacific Northwest, and the ability of *A. fruticosa* to hybridize with other genera in the same family is unknown.

3.1.3 Physiological Processes

Garden and Dotted Loosestrife

Flavonol glucosides extracted from *Lysimachia vulgaris* var. *davurica* are used in Asian folk medicines to treat high blood pressure (WSNWCB 1991, Yasukawa and Takido 1988). In addition, *L. vulgaris* produces triterpene saponins that have antimicrobial activity (Margineanu *et al.* 1978). No information is available as to the allelopathic properties of either of these species, if any.

Giant Hogweed

Several species of Apiaceae, including giant hogweed, produce furanocoumarins, a family of glycosides that has high phytotoxicity towards insects and fungi (Berenbaum 1981, Fischer *et al.* 1978). Many of these plant species are restricted to high-light environments. This is consistent with the presumed mechanism of phytotoxicity: ultraviolet cross-linkage of DNA (Berenbaum 1981). For insects and fungi to be affected by these phototoxic effects, these organisms need to be exposed to sunlight (a source of ultraviolet radiation).

The sap of this species has been shown to cause phytophotodermatitis in susceptible humans (Drever and Hunter 1970a and 1970b, Hyypio and Cope 1982, Ippen 1973, Morton 1975 and 1978). The clear, watery sap found in roots and shoots contains the furanocoumarins that sensitize skin to ultraviolet radiation in the wave lengths between 320 and 380 nanometers (Vanhaelen and Vanhaelen-Fastre 1974). This causes disintegration of intra-epidermal cells, resulting in severe blistering and painful dermatitis (Morton 1975, Wright 1984, WSNWCB 1991). After the blisters subside, skin may remain abnormally pigmented for several months (Wright 1984).

Andrews *et al.* (1985) report on the suspected poisoning of a goat by giant hogweed, and suggest this species may be a potential hazard for grazing ruminants. Likewise, Harwood (1985) reports giant hogweed-related severe vesication of the feet, swelling and discoloration of beak and nasal tissues, stunting, and heavy scab deposits and dark pigmentation in four one-week-old ducklings. However, Wright (1984) reports cattle and pigs eat giant hogweed without ill effects.

Knudsen (1983) reports that phototoxic substance concentrations are greatest in the leaves during the growing season, except for May when concentrations are greatest in the roots. Concentrations of furanocoumarins were observed by Pira *et al.* (1989) to be greatest in the fruit, intermediate in stems, and least in the roots.

Rahr (1992, pers. comm.) suggests the species is allelopathic.

Indigobush

Indigobush produces insecticidal, acaricidal (kills spiders and ticks), anti-microbial, and anti-viral flavenoids such as the rotenoid amorphigenin, amorphin, dehydrotoxicarol, and 11-hydroxytephrosin (Gombos and Gasko 1977; Gombos *et al.*, plant patent; Mitscher *et al.* 1979; Pancheva *et al.* 1982; Polyakov *et al.* 1977). These substances are produced primarily in the seed and seedlings (Hohmann *et al.* 1982). Fruits are poisonous to humans.

Like most legumes, this species is able to fix nitrogen at the roots. This presumably contributes to its success in colonizing sterile sands and mine spoil substrates. There is also some indication that indigobush is allelopathic (Pimpe and Vasilyauskas 1975, Zolotukhin 1980).

3.2 HABITAT REQUIREMENTS

3.2.1 Plant community types

Garden and Dotted Loosestrife

Tutin *et al.* (1972) indicate *Lysimachia punctata* inhabits marshes, river banks, and other wet places in its native range. *L. vulgaris* is noted as occurring in fens, wet woods, along lakeshores, and on river banks in its native range. Bushart (1989) indicates *L. vulgaris* occurs as a component of a sphagnum (*Sphagnum* spp.)/birch (*Betula pubescens*) community in West Germany. In western Washington, *L. vulgaris* has been observed growing with purple loosestrife along shores and associated wetlands of large lakes. Dotted loosestrife is known to grow extremely vigorously in upland conditions (Rahr 1992, pers. comm.).

Giant Hogweed

Clegg and Grace (1974) found giant hogweed in two broad categories of sites in Great Britain: (1) alluvial or fluvial riparian habitats along river and stream banks; and (2) on drier and more disturbed sites (including fill areas, and road and railway verges). They found giant hogweed was a member of a broad diversity of plants in riparian habitats, but that it formed monospecific stands on disturbed sites as a result of the ability of its large leaves to exclude competing species. The species was also found in the understories of monospecific timber stands and mixed woodlands. Williamson and Forbes (1982) report the species from the stonework of derelict buildings.

In New York, Hyypio and Cope (1982) report the species inhabits stream banks, roadside ditches, moist waste areas, and cultivated upland areas (gardens). In the Pacific Northwest, the species has been observed in wetlands or riparian areas associated with lakes and streams, along rights-of-way, in gardens, and on vacant lots (Dawe and White 1979, WSNWCB 1991). Rahr (1992, pers. comm.) has cultivated the species for many years in wetlands by Phantom Lake and in upland conditions away from the lake. She indicates the species does not grow as vigorously or produce as many sideshoots if grown in upland conditions.

Indigobush

In its native range, this species occurs in a diversity of habitat types, including shorelines of rivers, creeks, and lakes, wet meadows, swamps, and floodplain depressions. A vegetation inventory and analysis along 373 km (200 mi) of the North Platte and Platte rivers in Nebraska identified 12 major vegetation types, of which shrub habitat types (lowland and upland) were characterized by *Amorpha fruticosa* being a dominant element (Currier 1982). An analysis in Oklahoma indicated that indigobush was an important species in communities that occurred in stream channels (Petranka and Holland 1980). In the Pacific Northwest, the species is seemingly restricted to the shorelines of rivers and major streams, particularly reservoirs. Halse and Glad (1992) described the habitats of Oregon and Washington infestations as being the upper

fluctuation zone of run-of-the-river reservoirs and the upper drawdown zone of storage reservoirs. Indigobush is currently being recommended for use in afforestation and as windbreaks in the forest steppe zone of the Ukraine (Halkin 1983a).

3.2.2 Substrate

Garden and Dotted Loosestrife

Reference by Bushart (1989) suggests *Lysimachia vulgaris* occurs on organic soils in its native range. Both garden and dotted loosestrife are able to be cultivated on mineral soils (Antieau 1992, pers. comm.; Rahr 1992, pers. comm.).

Giant Hogweed

This species usually grows on deep, moist soils (Morton 1978), but can grow on a variety of soil types (predominantly mineral soils ranging from clays to sands) and frequently in disturbed situations (Clegg and Grace 1974). In Great Britain, giant hogweed was found on soils of high pH (primarily 6.5 to 8) of moderately low organic matter (3.1 to 8.7%) (Clegg and Grace 1974).

Indigobush

This species occurs naturally on a wide variety of soils, ranging from coarse to fine in texture, compacted to non-compacted, slightly acidic to highly alkaline (pH 6.1-8.5) (Ling 1981). Seeds exhibited 32% and 18% germination rates from a fall seeding on mine spoils and silt loam soils in Tennessee (Brown *et al.* 1983). In the Pacific Northwest, indigobush is frequently found on rock (including riprap) and sand (Antieau 1992, pers. comm.; Halse and Glad 1992).

3.2.3 Climate

Garden and Dotted Loosestrife

Informal observation of *L. vulgaris* at infestation sites in King County, Washington, indicates this species tolerates climatic norms of the Pacific Northwest climates. Observations of both species in cultivation indicate they are cold-hardy and somewhat drought-tolerant in the Northwest (Antieau 1992, pers. comm.).

Giant Hogweed

Informal observations indicate this species survives and reproduces in the extremes and norms of the Pacific Northwest's modified Mediterranean climate. Pyšek (1991) suggests that giant hogweed does best in cooler and more humid climates, pointing to the greater threat this species is posing in northern Britain and Nordic countries, particularly Sweden where it occurs throughout the country and as far north as 68° north latitude near Tromsö (Brondegaard 1990).

Indigobush

Little information is available on the relationship of climate to the dispersal and infestation of indigobush. However, a model has been developed that attempts to predict the time and abundance of fruiting in this species in portions of Russia (Termena and Stankevich 1983). Volkov (1981) indicates that indigobush was among the most successful revegetation species for sterile shell-sand sites near the Sea of Azov (east of Crimea) where the summer is hot and dry and the winter is short with little snow. Mean annual air temperature is 8.7 to 11°C (17.5 to 52°F) and mean annual precipitation is between 311 and 380 mm (12.5 and 15.2 in).

3.2.4 Soil Moisture/Surface Hydrology

Garden and Dotted Loosestrife

No specific information is available. The literature suggests both species inhabit wetland habitats in their native ranges. Informal observations of both species in Washington indicate both species grow and reproduce best in saturated habitats. Cultivated specimens of both species are able to withstand non-saturated conditions and even substantial amounts of drought once established (Antieau 1992, pers. comm.; Rahr 1992, pers. comm.).

Giant Hogweed

Informal observations of giant hogweed in Washington and other portions of its introduced range indicate it inhabits wetland and non-wetland environments (Antieau, pers. comm; Rahr 1992, pers. comm.). Rahr (1992, pers. comm.) indicates plants growing in upland sites are less vigorous and do not produce as many sideshoots.

Indigobush

Indigobush appears to use and transpire large amounts of soil moisture (Bragg 1991, pers. comm.), but this has not been verified or quantified. The species also appears to have a high degree of salt tolerance (Choi 1986).

3.3 REPRODUCTION

3.3.1 Sexual reproduction

3.3.1.1 Phenology

Garden and Dotted Loosestrife

Both species of *Lysimachia* are rhizomatous, herbaceous, deciduous perennials. Shoots begin to emerge in early spring. Flowering occurs in late spring through mid-summer. Fruits ripen and

begin to disperse seeds in late summer through fall. Shoots are generally completely senesced by the end of November (Antieau 1992, pers. comm.).

Giant Hogweed

Giant hogweed is thought to be primarily a monocarpic perennial, taking several years to reach flowering size or age, flowering once and then dying. The species does have a tendency to produce offsets at the crown after flowering (Morton 1978). These offsets usually continue to grow and eventually flower, thus making some individuals of this species polycarpic perennials, persisting and flowering for at least several years (Tanfil'ev 1975). Pyšek (1991) indicates the species is perennial.

Plants begin to produce leaves in early spring. During the growing season, leaves may reach a span of 1.5 m (5 ft) (Hyypio and Cope 1982). Flowers are produced between mid-June to mid-July on 5 m (16.4 ft) stalks. After flowering, green fruits appear that quickly turn brown and become dry. Seeds then separate from the plant and are either blown away or dropped to the ground or into a water body (Hyypio and Cope 1982). Plants die back in late fall, exposing the still-erect, massive fruiting stems.

Indigobush

Indigobush is a 2 to 4 m (6 to 12 ft) shrub, typically multi-branched at the base. Leaves emerge in mid-spring and become deciduous in late summer and early fall. Plants flower as the leaves reach a fully expanded condition. Seeds are ripe by mid-summer, with fruits persisting through much of the winter and well into the subsequent growing season (Antieau 1992, pers. comm.).

3.3.1.2 Pollination

Garden and Dotted Loosestrife

Both species of *Lysimachia* are probably bee-pollinated, as deduced from their production of nectar (Kapyla 1978).

Giant Hogweed

Giant hogweed is a bee-pollinated species (Corbet *et al.* 1979). More than 40 different insect species representing a wide range of orders have been associated with giant hogweed. A bumble bee (*Bombus lucorum*) and the honey bee (*Apis mellifera*) appear to be good pollinators (Wright 1984). The plant is apparently cultivated in Germany as a honey plant (Dreher 1972), and has been observed to be used abundantly by bees in western Washington (Rahr 1992, pers. comm.).

Indigobush

This species is pollinated by bees (Serbanescu and Radulescu 1985).

3.3.1.3 Seed Production/Dispersal

Garden and Dotted Loosestrife

Ridley (1930) lists garden loosestrife as being dispersed by water. He also indicates that he observed seed to float for one week or more. Ridley (1930) also refers to a study in which seeds of garden loosestrife were found in the stomach contents of a bird.

Giant Hogweed.

Each of the several large umbels formed by a flowering plant of giant hogweed may shed about 5,000 seeds (Pyšek 1991), or 27,000 seeds per plant as reported by Brondegaard (1990).

There is some evidence the species is dispersed through wind and floodwaters (Clegg and Grace 1974, Williamson and Forbes 1982). Experimental data gathered by Clegg and Grace (1974) indicate wind dispersal was slight at steady windspeeds of 0.6 m/s to 1.6 m/s (24 in/sec to 63 in/sec). Such dispersal does not account for long-distance dispersal, but may prove important in dispersal from an umbel to a water body. Bird dispersal tests failed to show any evidence that birds disperse seed (Clegg and Grace 1974). Flotation tests indicate the seed stays afloat 1.5-2 days in turbulent water and for 3 days on calm water (Clegg and Grace 1974, Brondegaard 1990).

Indigobush

No specific information is available. However, the legumes are indehiscent and buoyant (Antieau 1992, pers. comm.). Seed may be transported short distances by wind and animals (Halse and Glad 1992), potentially over long distances by water.

3.3.1.4 Seed Germination

Garden and Dotted Loosestrife

No information is available.

Giant Hogweed

Protsko and Gershunina (1990) report that seed dormancy in giant hogweed is not associated with seed coat properties. Instead, there appeared to be endogenous growth inhibitors. Cold stratification for 6 weeks induced 10-30% germination (Protsko and Gershunina 1990). Shumova (1972) demonstrated development of embryos of giant hogweed is incomplete when seeds are shed from plants, and that a lengthy after-ripening period is required for the embryo to complete its development (using food stored in the seed's endosperm). Shumova (1972) also reports germination tends to be protracted and that a sharp rise in temperature during autumn

induces secondary dormancy in some seeds. Seeds kept dry and at room temperature have been observed to be viable after seven years (Morton 1978).

Indigobush

One study found that seeds germinate after 136 days in cold stratification 5°C (41°F) (USDA Forest Service, undated). A 10-minute pre-soak at 61°C (142°F) enhances germination. In experimental germination work on different substrates, indigobush exhibited 32% germination on mine spoil and 18% germination on silt loam (Brown *et al.* 1983). As most legumes have seeds with durable and impermeable seed coats, it is probable indigobush seeds are relatively long-lived.

3.3.1.5 Seedling Survival

Garden and Dotted Loosestrife

No information is available.

Giant Hogweed

No information is available.

Indigobush

No information is available.

3.3.2 Vegetative Reproduction

Garden and Dotted Loosestrife

Both species of *Lysimachia* spread aggressively by rhizomes (Antieau 1992, pers. comm.; Rahr 1992, pers. comm.).

Giant Hogweed

Despite its growth from a persistent and large tuberous rootstock, this species does not reproduce asexually.

Indigobush

It is unknown if this species spreads vegetatively.

3.3.3 Plant Growth and Competition

3.3.3.1 Nutrient and Moisture Requirements

Garden and Dotted Loosestrife

Scant information is available. In the Ohio River valley, Cusick (1986) observed that garden loosestrife remains in a vegetative state for "some time" prior to blooming. Boller and Boller (1977) refer to a situation in a marsh where *Lysimachia vulgaris* was a component of wetland vegetation that was responding with luxuriant growth to nitrogen-rich runoff from adjacent farmland. They suggested this vegetation was effectively protecting the remaining portions of the wetland from effects of the runoff.

Giant Hogweed

Giant hogweed is a perennial, but may take several years from seed germination to flowering (Morton 1978). Pyšek (1990) indicates that giant hogweed takes 2-4 years to flower from seed. Morton (1978) also suggests that plants may be monocarpic, dying after flowering and fruiting, but may continue to produce offsets at the base of the old stems.

This species tolerates both shaded and full-sun environments (Clegg and Grace 1974, Morton 1978), and appears to prefer saturated or occasionally inundated habitats.

Indigobush

This species grows naturally in a variety of hydrologic regimes, including wetlands, periodically flooded shorelines, and uplands. Indigobush is considered heat- and drought-tolerant, and tolerates high soil alkalinities (pH 6.1-8.5). Plants grow in rock and pure sands (presumably infertile) as well as in more fertile substrates of finer texture (silts and clays).

3.3.3.2 Competition

Garden and Dotted Loosestrife

Informal observations of the *Lysimachia vulgaris* infestation at Lake Sammamish indicate this species appears to have displaced purple loosestrife (*Lythrum salicaria*) in some sites, and that it has a broad tolerance to environmental conditions (Gojio 1991, pers. comm.).

Giant Hogweed

Observations in Europe and North America indicate giant hogweed is able to successfully exclude other species due to production of massive leaves in an expansive canopy. It is both shade and full-sun tolerant (Clegg and Grace 1974).

Indigobush

Indigobush may form monospecific swards that effectively displace native vegetation, presumably due to its ability to shade-out competitors, and/or usurp soil moisture and nutrients. This species is intolerant of shade (Halkin 1983b), but competes effectively in saturated and periodically flooded habitats.

3.3.3.3 Herbivory and Diseases

Garden and Dotted Loosestrife

Braverman and Provvidenti (1977) report that *Lysimachia vulgaris* is susceptible to the cucumber mosaic virus, which causes severe stunting, malformed leaves, and chlorosis. In addition, Thibaudeau (1976) reports the butterfly *Aspitates formosaria* is specific to *Caltha palustris* and *L. vulgaris*. Ghiuta (1971) described a gall mite (*Aceria ulmicola*) infesting *L. vulgaris*. The role and importance of these pathogens in population dynamics of *L. punctata* and *L. vulgaris* have not been investigated.

Giant Hogweed

Several species of Apiaceae, including giant hogweed, produce furanocoumarins, a family of glycosides that has high phytotoxicity towards insects and fungi (Berenbaum 1981, Fischer *et al.* 1978). Many of these plant species are restricted to high-light environments. This is consistent with a presumed mechanism of phytotoxicity for these biochemicals: ultraviolet cross-linkage of insect DNA (Berenbaum 1981). For insects and fungi to be affected by these phototoxic effects, these organisms need to be exposed to sunlight (a source of ultraviolet radiation). Knudsen (1983) reported concentrations of the phototoxic substances are greatest in the leaves during growing season, except for May when concentrations were observed to be greatest in the roots. Concentrations of furanocoumarins were observed by Pira *et al.* (1989) to be greatest in fruit, intermediate in the stem, and least in the roots.

More than 40 different insect species representing a wide range of orders are known to be associated with giant hogweed (Corbett *et al.* 1979). Giant hogweed has been reported as a host for carrot fly (*Psila rosae*), a potentially damaging root pest (Hardman and Ellis 1982). Van Alphen *et al.* (1991) reported decaying petioles of giant hogweed are used as breeding sites by six species of *Drosophila*, a fly, and the drosophilid, *Scaptomyza pallida*. The role and importance of these insects in population dynamics of giant hogweed have not been investigated.

Several fungal pathogens have been isolated from the closely related *Heracleum sphondylium*, suggesting that at least of few fungal pathogens may be associated with giant hogweed in its native range (Fowler *et al.* 1991). Gray and Noble (1965) indicate giant hogweed hosts *Sclerotinia sclerotiorum*, a fungus that attacks a wide range of agricultural and horticultural crops.

Indigobush

Indigobush has been observed to be occasionally defoliated in its native range by a life stage of the *Uropyxis amorphea* rust. Additional occasional diseases include twig canker and powdery mildew. Twig galls are known to be caused by viral, mycoplasmic, and insect pathogens (Paclt 1984).

Several arthropods are known to attack seeds of indigobush, including the beetle *Acanthoscolides plagiatus*, which occurs on indigobush in several provinces of China and causes approximately 15-20% seed mortality (Fan 1981). A cottony scale was described on indigobush in Italy (Pellizari 1977), and another seed beetle (*Acanthoscolides collusus*) caused 37-87% seed destruction in Texas (Rogers and Garrison 1975). A North American species of nematode was recently documented in the rhizosphere of indigobush in Yugoslavia (Barsi 1991). It is uncertain if the nematode is pathogenic. The role of these organisms in population dynamics of indigobush has not been investigated.

4.0 BIOLOGY OF INFESTATION

4.1 HUMAN-MEDIATED MODES OF DISPERSAL AND ESTABLISHMENT

Garden and Dotted Loosestrife

Both species of *Lysimachia* are cultivated in the Puget Sound basin. Cultivation may provide the seed source leading to establishment of an infestation of either species.

Giant Hogweed

In Great Britain, an analysis of its distribution indicated the species has followed avenues of dispersal parallelling roads, railways, and waterways (Clegg and Grace 1974). Infestations in the Czech Republic have been traced back to early 19th century introductions in West Bohemia, where the species initially spread along and followed the courses of large rivers (Pyšek 1991). There is some evidence the species is dispersed in floodwaters (Clegg and Grace 1974).

These dispersal patterns are also suggested by infestations on Vancouver Island (Dawe and White 1979). Given this evidence, it seems plausible seeds are readily dispersed by human activity, including being tracked around on muddy footwear, being scattered about as people collect and transport the large umbels for decorative or other use, and being collected and grown by gardeners (Dawe and White 1979, Morton 1978).

Indigobush

Indigobush is being planted and cultivated extensively for its success in revegetating or reclaiming sterile, disturbed, and severely eroding sites. It is also an attractive, drought-tolerant

shrub useful in ornamental landscapes. In some countries, indigobush is being cultivated as a forage crop and soil improvement species.

Experimental 1992 drawdowns in Snake River reservoirs triggered the establishment of a broad diversity of native and non-native pioneer plant species in exposed reservoir shorelines (Phillips 1992). Some of these were troublesome or noxious weeds, including indigobush.

4.2 PERSISTENCE AND SPREAD

4.2.1 Growth and Rate of Spread

Garden and Dotted Loosestrife

No information is available.

Giant Hogweed

As mentioned in Section 4.1.2, the dispersal pattern for this species in Great Britain tends to initially follow roads, railways, and waterways (Clegg and Grace 1974, Dawe and White 1979, Pyšek 1991). There is some evidence the species is dispersed in floodwaters (Clegg and Grace 1974). Once established, individuals and/or populations persist for many years, occasionally for more than 90 years (Clegg and Grace 1974).

In the Czech Republic, several decades passed between the time of introduction of the species and the point at which it began to spread exponentially (Pyšek 1991). However, the species has shown an ability to become established relatively quickly after introduction. On Vancouver Island, this species became established in less than 30 years and moved a distance of 12 km (7.4 mi) within a 40-year period (Dawe and White 1979).

Pyšek (1991) compared the rate of expansion of giant hogweed in the Czech Republic with that in Great Britain. Using semilog plotting of the number of mapping squares in which the species has been recorded plotted against time, Pyšek (1991) discovered that the rates have been exponential and that regressions of almost the same slope were obtained for both regions. Pyšek (1991) mentions species abundance has decreased from the region of its original introduction, but provides no explanation.

Indigobush

Dr. David Bragg has estimated the rate of spread of this species along Meadow Creek in Garfield County, Washington, to be 1 to 2 miles per year (Hovanic 1992, pers. comm.). It has been noted that plants tend to be weak-wooded (Antieau 1992, pers. comm.).

4.2.2 Factors Affecting Recessions and Senescence

Garden and Dotted Loosestrife

No information is available.

Giant Hogweed

No information is available.

Indigobush

It has been noted that indigobush plants are relatively short-lived. This characteristic has not been quantified, thus its implications relative to senescence of stands or populations are unknown.

5.0 INFORMATION AND RESEARCH NEEDS

As illustrated by the lack of information under many of the headings throughout this report, numerous aspects of the basic biology and ecology of each of these species are unknown. No research is currently being undertaken to investigate the biology and ecology of garden loosestrife, dotted loosestrife, or indigobush. Some research is underway focusing on the autecology and biology of infestation of giant hogweed, particularly the role and importance of pathogens in the population dynamics of this species. Some research has been done on the effectiveness of chemical controls on giant hogweed.

6.0 REFERENCES

GARDEN AND DOTTED LOOSESTRIFE

Boller, E.K. and C. Boller. 1977. The influence of nitrogen fertilization of intensive grassland on marsh and fen development. Veroffentlichungen des Geobotanischen Institutes der Eidg. Techn. Hochschule, Stiftung Rubel.

Braverman, S.W. and R. Provvidenti. 1977. A mosaic of loosestrife caused by cucumber mosaic virus. Plant Disease Reporter 61:332-334.

Brockett, B.L. and T. Cooperrider. 1983. The Primulaceae of Ohio. Castanea 48:37-40.

Bushart, M. 1989. Black ash and white birch forests in the western Hunsrueck, West Germany. Tuexenia 9:391-416.

Churchill, S.P., R.P. Kaul, and D.M. Sutherland. 1974. New records of native and introduced plants from Nebraska, U.S.A. Trans. Nebraska Acad. Sci. 3:32-36.

Cusick, A. 1986. Distributional and taxonomic notes on the vascular flora of West Virginia. Castanea 51:56-65.

Duppstadt, W.H. 1977. Some new state records and other plant finds in West Virginia. Castanea 42:257-258

Ghiuta, M. 1971. Contributions to the study and distribution of Eriophyid gall mites in Bacau. Muzeul de Stiintele Naturii Bacau, Studii si Comunicari: 147-161.

Heubl, G.R. 1989. Observations on the karyology of the genus *Lysimachia*. I. Chromosome numbers and evolution. Mitt. Bot. Staatssammi Muench 28: 297-312.

Hitchcock, C.L., A. Cronquist, M. Ownbey, and J.W. Thompson. 1969. Vascular plants of the Pacific Northwest. Vols. 1-5. University of Washington Press, Seattle.

Hitchcock, C.L. and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle.

Kapyla, M. 1978. Amount and type of nectar sugar in some wildflowers in Finland. Ann. Bot. Fenn. 15:85-88.

Ko, S.C., I.T. Im, and Y.S. Kim. 1986. A cytotaxonomic study on the genus *Lysimachia* in Korea. Korean J. Plant Taxonomy 16:187-198.

Koeva, T.J. 1977. Materials and notes on Bulgarian flora. God. Sofii Univ. Biol. Fak. 68:41-

44.

Krzaczek, T and W. Krzaczek. 1982. Floristic data from the Sandomierz basin, Poland. Ann. Univ. Mariae Curie Sklodowska Sect. C. Biol. 37:377-386.

Margineanu, C., I. Hintz, V. Cucu, L. Grecu, C. Cioaca, M. Rosca, V. Hodisan, and M. Tomas. 1978. Anti-microbial action of 12 triterpene saponins obtained from indigenous plants. Clujul Med. 51:254-259.

Peev, D. 1976. Chromosome numbers and critical notes on the taxonomy of some Bulgarian Primulaceae species. Fitologiya 4:16-24.

Ridley, H.N. 1930. The dispersal of plants throughout the world. L. Reeve and Co., Ltd., Ashford, England.

Skalinska, M., A. Jankun, and H. Wcislo. 1976. Further studies in chromosome numbers of Polish angiosperms, Part 11. Acta Biol. Cracov Ser. Bot. 19:108-148.

Tanaka, A. and M. Hizume. 1980. Karyo-morphological studies on species differentiation in some species of *Lysimachia*. 2. Chromosomal interrelationships of Japanese species. Kromosomo (Tokyo) 2:515-525.

Taylor, R.J., G.W. Douglas, and L.M. Sundquist. 1973. Contributions to the flora of Washington, part 2. Northwest Science 47:169-179.

Thibaudeau, N. 1976. Discussion of some lepidopterans that have disappeared from the Poitevin Swamp in Deux-sevres, France. Bull. Soc. Lepid. Fr. 1:57-58.

Tutin, T.G., V. Heywood, N.A. Burges, D.M. Moore, D.H. Valentine, S.M. Walters, and D.A. Webb, eds. 1972. Flora Europaea. Cambridge University Press, England.

Uhrikov, A., J. Majovsky, and T. Schwarzova. 1986. Karyological study of the Slovak Czechoslovakia flora, part 15. Acta Fac. Rerum Nat. Univ. Comenianae Bot. 33:73-76.

Washington State Noxious Weed Control Board (WSNWCB). 1991. Written findings for *Lysimachia vulgaris*.

Yasukawa, K. and M. Takido. 1988. Quercetin 3-rhamnosyl (1 leads to 2) galactoside from *Lysimachia vulgaris* var. *davurica*. Phytochemistry 27:3017-3018.

PERSONAL COMMUNICATION

Antieau, Clayton J. 1992. Botanist/Horticulturist, Ebasco Environmental, Bellevue, Washington.

Gojio, Tim. 1991. King County Environmental Division. Letter to Catherine Hovanic, Washington State Noxious Weed Control Board. 23 July.

Hovanic, Catherine. 1992. Washington State Noxious Weed Board. Letter to Kari Rokstad, Washington State Department of Ecology, Olympia, Washington. October 26.

Rahr, Elfi. 1992. Resident, Phantom Lake, Bellevue, Washington. Personal communication to Clayton Antieau, Ebasco Environmental, Bellevue. November 2.

GIANT HOGWEED

Andrews, A.H., C.J. Giles, and L.R. Thomsett. 1985. Suspected poisoning of a goat by giant hogweed. Vet. Rec. 116:205-207.

Arora, K., J. Grace, and F. Stewart. 1982. Epidermal features of *Heracleum mantegazzianum, Heracleum sphondylium*, and their hybrid. Bot. J. Linn. Soc. 85:169-178.

Berenbaum, M. 1981. Patterns of furanocoumarin distribution and insect herbivory in the Umbelliferae plant chemistry and community structure. Ecology 62:1254-1266.

Brondegaard, V.J. 1990. Massenausbreitung des Bärenklaus. Naturwiss. Rundsch. 43:438-439.

Cafazzo, Debbie. 1992. Attack of the giant hogweed. Journal-American, Bellevue Washington. June 19, pp. A1 and A4.

Clegg, L.M. and J. Grace. 1974. The distribution of *Heracleum mantegazzianum* (Somm. and Levier) near Edinburgh. Trans. Proc. Bot. Soc. Edinb. 42:223-229.

Corbett, S.A., P.G. Willmer, J.W.L. Beament, D.M. Unwin, and O.E. Prys-Jones. 1979. Post-secretory determinants of sugar concentration in nectar. Plant Cell and Environment 2:293-308.

Cwiklinski, E. 1973. A rare plant: *Heracleum mantegazzianum* Somm. and Lev. Zeszyty Naukowe, Akademia Rolnicza w Szczecinie, Rolnictwo 39:53-60.

Dawe, N.K. and E.R. White. 1979. Giant cow parsnip (*Heracleum mantegazzianum*) on Vancouver Island, British Columbia. Canadian Field-Naturalist 93:82-83.

Delaigue, R. 1989. *Heracleum mantegazzianum* Somm. and Lev. (Umbelliferae) in the middle Rhone Valley, France. Bull. Mens. Soc. Linn. Lyon 58:332-334.

D'hose, R. and J.E. De Langhe. 1990. New localities of rare plants in Belgium. XVIII. Belg. J. Bot. 123:63-66.

Dierschke, H. 1984. Stand of *Heracleum mantegazzianum* in the wildlife preserve, Heiliger Hain Holy Grove, near Gifhorn, northwestern Germany. Tuexenia 4:251-254.

Dreher, K. 1972. On yield improvement: giant cow-parsnip (*Heracleum mantegazzianum*, honey plants). Biene 108:307-308.

Drever, J.C. and J.A.A. Hunter. 1970a. Hazards of giant hogweed. British Medical Journal 3:109.

Drever, J.C. and J.A.A. Hunter. 1970b. Giant hogweed dermatitis. Scottish Medical Journal 15:315-319.

Fischer, F.C., D.H. Van, and G. Dannenberg. 1978. Glycosides and glycosidase in *Heracleum mantegazzianum*: their possible role in resistance against fungi. In M. Cauwet, A. Carbonnier, and J. Carbonnier (eds), Les Ombelliferes: Contributions pluridisciplinaires a la systematique, Actes du 2 Symposium International sur les Ombelliferes, Peripignan. Pp 783-792.

Fowler, S.V., A.N.G. Holden, and D. Schroeder. 1991. The possibilities for classical biological control of weeds of industrial and amenity land in the United Kingdom using introduced insect herbivores or plant pathogens. Proceedings of the Brighton Crop Protection Conference. Pp 1173-1180.

Grace, J. and F. Stewart. 1978. Hybridization in the genus *Heracleum* in the British Isles. In M. Cauwet, A. Carbonnier, and J. Carbonnier (eds), Les Ombelliferes: Contributions pluridisciplinaires a la systematique, Actes du 2 Symposium International sur les Ombelliferes, Peripignan. Pp 773-782.

Grace, J. and M. Nelson. 1981. Insects and their pollen loads at a hybrid *Heracleum* site. New Phytol. 87:413-424.

Gray, E.G. and M. Noble. 1965. *Sclerotinia* disease. Scot. Agr. 44:265-267.

Grossgeim, A.A. 1967. Flora Caucasica. Academia Nauk SSSR.

Hardman, J.A. and P.R. Ellis. 1982. An investigation of the host range of the carrot fly, *Psila rosae*. Ann. Appl. Biol. 100:1-10.

Harwood, D.G. 1985. Giant hogweed and ducklings (correspondence). Vet. Rec. 116:300.

Hindakova, M. and T. Schwarzova. 1986. Karyological study of the Slovak Czechoslovakia flora. XX. Acta Fac. Rerum. Nat. Univ. Comenianae Bot. 34:21-26.

Hyypio, P. and E. Cope. 1982. Giant hogweed: *Heracleum mantegazzianum*. Cornell University Cooperative Extension Misc. Bull. 123.

Ippen, H. 1973. Chemical burns while bathing: a differential diagnostic report. Deutsche Med. Wochenschr 98:2048-2049.

Jackson, M.W. 1989. Observations on the Irish distribution of a plant with serious public threat. Bull. Irish Biogeographical Soc. 12:94-112.

Karlsson, T. 1977. Floristic notes. Sven Bot. Tidskr 71:185-186.

Knudsen, E.A. 1983. Seasonal variations in the content of phototoxic compounds in giant hogweed, *Heracleum mantegazzianum*. Contact Dermatitis 9:281-284.

Missoulian. 1981. Weed gone wild. Photograph. June 19, p.8.

Mladenova, I.P. 1950. Species of the genus *Heracleum* from the Caucasus. Tbilisi (in Russian).

Morton, J.K. 1975. The giant cow parsnip, *Heracleum mantegazzianum* Umbelliferae, in Canada. The Canadian Field-Naturalist 89:183-184.

Morton, J.K. 1978. Distribution of giant cow parsnip (*Heracleum mantegazzianum*) in Canada. Canadian Field-Naturalist 92:182-185.

Pira, E., C. Romano, F. Sulotto, I. Pavan, and E. Monaco. 1989. *Heracleum mantegazzianum* growth phases and furanocoumarin content. Contact Dermatitis 21:300-303.

Protsko, R.F. and L.M. Gershunina. 1990. State of dormancy in seeds of *Heracleum* species and methods of germination. Ukr. Bot. Zh. 47:58-60.

Pyšek, P. 1991. *Heracleum mantegazzianum* in the Czech Republic: dynamics of spreading from the historical perspective. Folia Geobotanica and Phytotaxonomica 26:439-454.

Roché, C. Undated. Giant hogweed (*Heracleum mantegazzianum* Somm. and Lev.). Unpublished draft.

Ruskova, V.M. 1973. Rhythms of growth and development of cow parsnips introduced in Moscow. Byull. Gl. Bot. Sada:46-49.

The Sequim Gazette. Undated. Photograph and caption showing giant hogweed.

Shumova, E.M. 1972. Dormancy of seeds of giant hogweed. Doklady T. S. Kh. A. 182:281-285.

Stewart, F. and J. Grace. 1984. An experimental study of hybridization between *Heracleum mantegazzianum* Somm. and Levier and *Heracleum sphondylium* L. subsp. *sphondylium* (Umbelliferae) (Transfers of pollen between the parent species). Watsonia 15:73-78.

Tanfil'ev, V.G. 1975. Longevity of some grasses, legumes, and some other species. Trudy, Stavropol'skii Institut Sel'skogo Khozyaistva 17:196-204.

Vanhaelen, M. and Vanhaelen-Fastre, R. 1974. Furanocoumarins from the root of *Heracleum mantegazzianum*. Phytochemistry 13:306.

Van Alphen, J.J.M., G. Nordlander, and I. Eijs. 1991. Host habitat finding and host selection of the *Drosophila* parasitoid *Leptopilina australis* (Hymenoptera, Eucoilidae) with a comparison of the niches of *Leptopilina* species. Oecologia 87:324-329.

Washington State Noxious Weed Control Board (WSNWCB). 1991. Written findings for *Heracleum mantegazzianum*.

Weimarck, , G., F. Steward, and J. Grace. 1979. Morphometric and chromatographic variation and male meiosis in the hybrid *Heracleum mantegazzianum* x *Heracleum sphondylium* (Apiaceae) and its parents. Hereditas 91:117-128.

Williamson. J.A. and J.C. Forbes. 1982. Giant hogweed (*Heracleum mantegazzianum*): its spread and control with glyphosate in amenity areas. Proceedings of the 1982 British Crop Protection Conference: Weeds. Pp 967-972.

Wright, M. 1984. Giant hogweed: time for action is now. New Scientist 101:44.

PERSONAL COMMUNICATION

Hovanic, Catherine. 1992. Washington State Noxious Weed Board. Letter to Kari Rokstad, Washington State Department of Ecology, Olympia, Washington. October 26.

Rahr, Elfi. 1992. Resident, Phantom Lake, Bellevue, Washington. Personal communication to Clayton Antieau, Ebasco Environmental, Bellevue. November 2.

INDIGOBUSH

Arsenovic, M., A. Stankovic, M. Dimitrijevic, and B. Konstantinovic. Undated. Testing efficacy of some new arboricides in the Danube-Tias-Danube. Drugi Kongres u Korovima. Zbornik Referata. Pp 423-427.

Barsi, L. 1991. First record of *Anatonchus ginglymodontus* Mulvey from Yugoslavia. Nematologia Mediterranea 19:97-99.

Bonciarelli, F. and R. Santilocchi. 1980. First results of trials with forage shrubs for pasture. Revista di Agronomia 14:21-29.

Bozoyan, A.A. 1981. Inter-relationship of woody and herbaceous plants in the green zone of Yerevan Armenian-SSR USSR. Biol. Zh. Arm. 34:487-492.

Brown, J.E., J.B. Maddox, and W.E. Splittstoesser. 1983. Performance of trees, shrubs, and forbs seeded directly in the fall on minespoil and silt loam soil. J. Environ. Qual. 12:523-525.

Cai, X.Z. and Z.K. Zhong. 1988. A preliminary study on the afforestation techniques of *Choerospondias*. J. Zhejiang Forestry Science and Technology 8: 32-34.

Choi, M.G. 1986. Characteristics of salt tolerance in tree species. J. Korean Forestry Society.

Currier, P.J. 1982. The floodplain vegetation of the Platte River: phytosociology, forest development, and seedling establishment. Ph.D. Dissertation. Iowa State University.

Cusick, A. 1986. Distributional and taxonomic notes on the vascular flora of West Virginia. Castanea 51:56-65.

Fan, Z.M. 1981. Preliminary observations on *Acanthoscolides plagiatus* Reiche and Saulcy. Insect Knowledge (Kunchong Zhishi) 18:71-72.

Fernald, M.L. 1950. Gray's manual of botany. American Book Company, New York, New York.

Gombos, M. and K. Gasko. 1977. Extraction of natural anti-feedants from the fruits of *Amorpha fruticosa*. Acta Phytopathology Acad. Sci. Hungary 12:349-358.

Gombos, M., M. Nidassy, G. Pfeifer, G. Gyula, K. Gasko, and K. Szendrei. Patent. Pesticide preparations containing toxicarol. Hungary.

Halkin, S.I. 1983a. Winter resistance of introduced woody legumes which grow in the forest steppe of the Ukranian-SSR USSR. Ukr. Bot. Zh. 40:32-35.

Halkin, S.I. 1983b. Effect of illumination on the development of introduced woody legumes in the forest steppe of the Ukranian-SSR USSR. Ukr. Bot. Zh. 40:43-46.

Halse, R. and J.B. Glad. 1992. Invasion of indigobush (*Amorpha fruticosa* L.) along the Columbia and Snake Rivers, Washington and Oregon. Abstracts of the Sixty-fifth Annual Meeting of the Northwest Scientific Association, Bellingham, Washington.

Hohmann, J., Z. Rozsa, J. Reisch, and K. Szendrei. 1982. Flavenoids of *Amorpha fruticosa* L. root bark. Herba Hungarica 21:179-183.

Hulina, N. 1987. Weeds of the drainage system in the Gornja Posavina region. Fragmenta Herbalogica Jugoslavica 16: 73-83.

Jolley, R. 1988. Wildflowers of the Columbia River Gorge. Oregon Historical Society Press, Portland.

Krussmann, G. 1984. Manual of cultivated broad-leaved trees and shrubs. Timber Press, Portland, Oregon.

Ling, C.W. 1981. Saline tolerance of *Amorpha fruticosa* and the culture technique adapted to saline-alkaline soil. Forest Science and Technology 12:14-17.

Lung, C.W. and X.Y. Xu. 1980. Studies on improving alkali-saline soils by planting *Amorpha fruticosa* (in China). Forest Science and Technology 11:17-21.

Mitscher, L., S. Ali Al, T. Haas, P.B. Hudson, and P.Young Han. 1979. Antimicrobial agents from higher plants. A new rotenoid, 11-hydroxytephrosin, from *Amorpha fruticosa*. Heterocycles 12:1033-1035.

Paclt, J. 1984. Blastomania and gall disease in hardwoods. Beitr. Biol. Pflanz. 59:367-374.

Pancheva, S., N. Manolova, I. Gagov, and V. Maksimova. 1982. Anti-viral action of some natural rotenoids and their derivatives. Acta Microbiol. Bulg. 10:11-14.

Pellizari, S. 1977. A cottony scale recently discovered in Italy: *Neopulvinaria imeretina*. Redia.

Petranka, J.W. and R. Holland. 1980. A quantitative analysis of bottomland communities in south central Oklahoma, U.S.A. Southwest Nat. 25:207-214.

Phillips, Ronald. 1992. Columbia River salmon mitigation analysis, 1992 reservoir drawdown: wildlife monitoring program, shoreline monitoring, and vegetation evaluations. Battelle Pacific Northwest Laboratory, Richland, Washington. Prepared for U.S. Army Corps of Engineers, Walla Walla District. October.

Pimpe, R. and A. Vasilyauskas. 1975. Possibilities of using the allelopathic properties of trees and shrubs. Environment Canada.

Polyakov, D.K., K.M. Khaidarov, and A.I. Shreter. 1977. The acaricidal and repellent effect of plants of the natural flora. Rastitel'nye Resussy 13:267-275.

Rehder, A. 1940. Manual of cultivated hardy trees and shrubs hardy in North America. Macmillan Publishing Co., Inc., New York, New York.

Rogers, C.E. and J.C. Garrison. 1975. Seed destruction in indigobush (*Amorpha*) by a seed beetle. J. Range Management 28:241-242.

Sarti, D.M., C. Casoli, E. Duranti, P. Pollidori, and V. Rongoni. 1982. Bromatological aspects of leaves of pasture shrubs. Zootecnica e Nutrizione Animale 8:395-405.

Serbanescu, J.G. and M.N. Radulescu. 1985. Morphology and structure of some melliferous Leguminosae. Stud. Cercet. Biol. Ser. Biol. Veg. 31:24-28.

Sheikh, M.I. 1979. *Amorpha fruticosa*: a useful shrub. (A note for tree planters). Pakistan Journal of Forestry 29:61.

Termena, B.K. and L.G. Stankevich. 1983. Predicting the abundance of fruiting of woody plants. Lesnoi Zhurnal:125-126

Terpo, A. and B.K. Egyed. 1983. Semi-natural woody plants in the Hungarian flora. Kerteszeti Egyetem Kozlemenyi 47:117-126.

United States Department of Agriculture (USDA), Forest Service. Undated. Native shrub production project. Surface Environment and Mining Program, Coeur d'Alene, Idaho.

Volkov, F.I. 1981. Tree stands in the coastal zone of the Sea of Azov. Lesnoe Khozyaistvo: 59-60.

Wilbur, R. 1975. A revision of the genus *Amorpha* (Leguminosae, Psoraleae). Rhodora 77:337-409.

Zolotukhin, A.I. 1980. Allelopathic effect of shrubs used in steppe vegetation on quackgrass. Soviet Journal of Ecology 11:203-207.

PERSONAL COMMUNICATION

Antieau, Clayton J. 1992. Botanist/Horticulturist, Ebasco Environmental, Bellevue, Washington.

Bragg, David. 1991. County Extension Chair. Letter to Bill Brookreson, Washington State Dept. of Agriculture. December 23.

Hovanic, Catherine. 1992. Washington State Noxious Weed Board. Letter to Kari Rokstad, Washington State Department of Ecology, Olympia, Washington. October 26.

Johnson, Frederic. 1991. Professor of Forest Ecology, University of Idaho, Moscow. Letter to Catherine Hovanic, Washington Noxious Weed Control Board, Kent, Washington. March 20.

Keeland, Robert. 1985. Fish and Wildlife Staff Officer, U.S. Corps of Engineers. Letter to Frederic Johnson, Professor of Forest Ecology, University of Idaho, Moscow. September 30.