CURRENT STATUS AND MANAGEMENT OPTIONS OF EXOTIC AND INVASIVE WEEDS OF FORESTRY IN COASTAL BRITISH COLUMBIA, CANADA

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Exotics that cause the greatest share of forest damage are invasive insects and plant diseases. However, some introduced flora (woody species, ornamentals and weeds) are also proving to be damaging and highly competitive for space, light, nutrients and water with useful forest vegetation. Two such major invasive species are Scotch broom (*Cytisus scoparius*) and gorse (*Ulex europaeus*) and another two minor species are Daphne spurge (*Daphne laureola*) and English ivy (*Hedera helix*). Together, they pose threats to the coastal forest ecosystems, and to the fragile Garry Oak (*Quercus garryana*) – Arbutus (*Arbutus menziesii*) ecosystem on southeastern Vancouver Island and the southern Gulf Islands of British Columbia, Canada (Prasad, 2004). Clearly, not all introductions become pests, but when they do, their impacts can be devastating.

Both Scotch broom and gorse have expanded their range along the coasts of British Columbia and have evolved pockets of infestations from the southern tip of Vancouver Island to Queen Charlotte Island, including some of the mainland of British Columbia. Gorse possesses volatile oils, giving it a higher fuel load and creating a fire hazard in suburban and forested areas (Clements *et al* 2001). Daphne spurge and English ivy, on the other hand, have restricted their range of expansion on many federal lands, public parks, and suburban areas in the Garry Oak – Arbutus ecosystem. The geographical distribution of these exotic plants on coastal British Columbia is shown in Figure 1. Scotch broom inhabits a larger area (*ca*. 10%) of the landscapes than the other three invasive species.

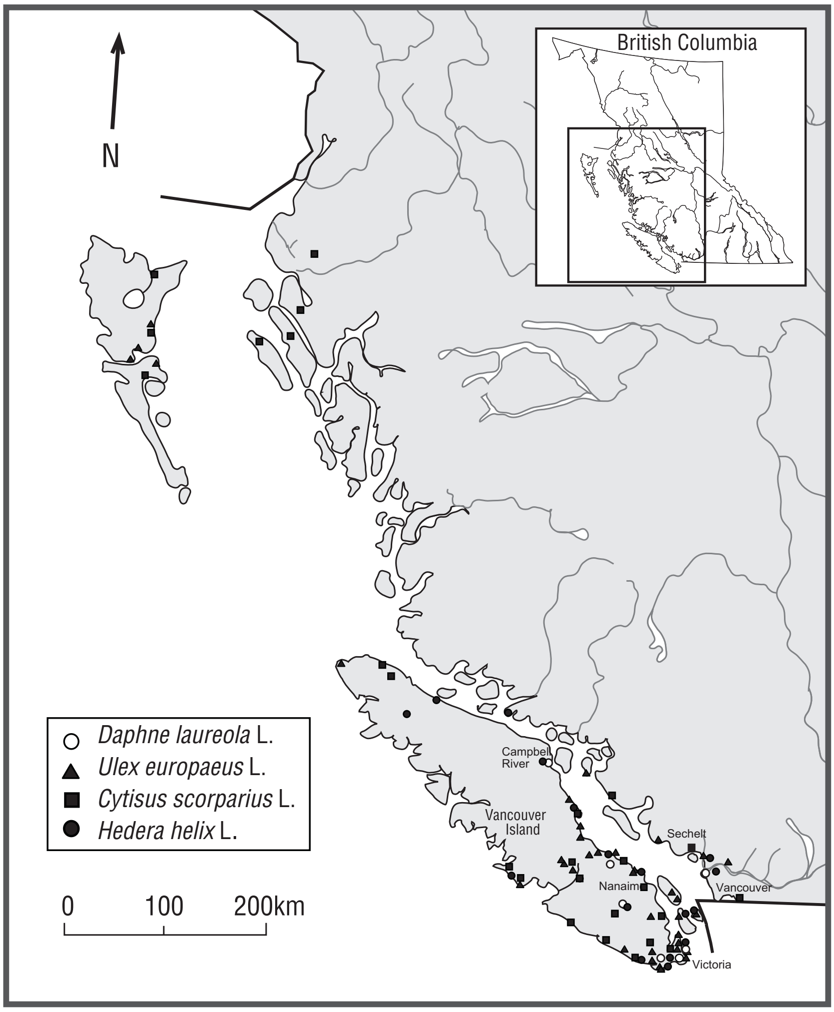

Figure 1. **Distribution of four invasive species, *Cytisus scoparius* (Scotch broom), *Ulex europaeus* (Gorse), *Daphne laureola* (Daphne) and *Hedera helix* (English ivy) in British Columbia, Canada.**

Impact and Ecological Concerns

All four invasive species (Scotch broom, gorse, Daphne and English ivy) have developed mechanisms and ecological traits to colonize disturbed areas rapidly; persist for a long time and pose difficult problems for eradication; suppress and inhibit native vegetation and associated ecosystems by forming dense, mono-specific stands or thickets; alter habitat structure; and arrest successful forest succession. Detailed characteristics of each species are described below:

1. Scotch broom: is an exotic, leguminous shrub (from the Family Leguminosae: Fabaceae), it is a native of Europe (Spain to Portugal) and North Africa; it has become distributed along Pacific/Atlantic coasts, where it is an aggressive coloniser of disturbed sites, and it is able to photosynthe-

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Figure 2. ***Cytisus scoparius* in flower**

size during winter months and fix nitrogen in its roots. (Figure 2).

2. Gorse: is an exotic shrub (from the Family Leguminosae: Fabaceae), it possesses conspicuous spines, is a native of Central/Western Europe/North Africa, and is only found in British Columbia, where it is classified as a noxious weed by the Agriculture Department of British Columbia. It is not found in the rest of Canada. It is highly successful in disturbed sites and thrives on drier sites than Scotch broom, but it has been found to share similar ecological niches as Scotch broom. (Figure 3).

Figure 3. ***Ulex europaeus* in flower and replacing Garry oak ecosystems**

3. Daphne spurge: is an exotic invasive evergreen shrub (from the Family Thymelaceae), is reported to have originated in Southern Europe/North Africa, and was first introduced into southwest B.C. from Washington State, USA. It is slow-growing, shade-loving and long-lived and is found ranging on federal lands (Department of National Defence, Indian Affairs, Fisheries and Oceans, Parks Canada, Environment Canada) around the Victoria district. (Figures 4a and 4b).
4. English ivy: is an alien invasive plant with a climbing vine that belongs to the ginseng family (from the Family Araliaceae), is a native of Europe, and was introduced into North America in the 18th century. It was widely cultivated as an ornamental plant in urban areas and it is an opportunistic weed, often associated with some form of land disturbance. (Figure 5).

Management Options

Several methods for management of all four species were evaluated in a field trial at Victoria. Four methods were employed:

(a) Manual and mechanical cutting: Stems of all four species were excised at the root collar region during

Figure 4. **(a) *Daphne laureola* in flower**
(b) *Daphne laureola* colonizing a Garry oak ecosystem

Figure 5. ***Hedera helix* impacting on native trees (Douglas-fir).**

Figure 6. ***Daphne laureola* dying in the field**

July – August and the plots were left, but monitored for two years. Results demonstrated that cutting was not a very effective or successful tool as all four species re-sprouted profusely. However, some investigators (Peterson & Prasad, 1998; Prasad, 2000) have noted that cutting broom and gorse stems before flowering (when they have exhausted the supply of internal carbohydrate reserves) reduces the frequency of re-sprouting. The onset of this differs with each species, but, in general, occurs before flowering. Mature plants cut during hotter months, July – August, may be prone to drying and desiccation and, thus, may eventually die. Manual cutting is labour-intensive and often not a very efficacious method, but nevertheless it is still widely used.

(b) Herbicide application: cut stumps of all four species were treated with 5 ml of sterile water to serve as the check (control) or with 5ml of the chemical herbicide triclopyr (Release) at 180 g a.i./litre. The herbicide was applied with a plastic bottle sprayer and the entire cut surface area was covered with the herbicide spray.

(c) Bioherbicide application: cut stumps of all four species were treated with 5 ml of a bioherbicide formulation (*Chondrostereum purpureum*) or with 5 ml of the bioherbicide formulation without mycelium to serve as the check (control). The fungal formulation contained mycelial slurry, in 5% vegetable oil + 0.2% sticker (Bond™*) and applied through squeeze bottles immediately after cutting according to a standard method (Prasad & Kushwaha, 2001). Additional field trials were conducted with another mycoherbide (*Phomopsis* sp.) for control of Daphne plants.

This fungus was isolated and purified from a stand of dead/dying Daphne colony (Figure 6) near Albert Head (Victoria). Forty-five healthy plants (3 years old, with 5–7 leaves on a single stem) were selected from an adjacent site and tagged. Their stems were quickly washed with sterile water before an incision (5 × 5 mm) was made with a sterile scalpel, above the soil region. Fifteen incised stems were treated with a blank (sterile water), fifteen with PDA agar and fifteen with the same agar containing the mycelial mass of *Phomopsis*. To prevent desiccation and infection by microbes, each incision on the stems was covered with waxy paper. All plants were fenced off and left for 12 weeks for observation. A scoring technique, given below, was developed to assess the response:

1. as healthy and vigorous plants with green leaves
2. as plants with slight chlorotic leaves
3. as plants with distinct patches of chlorotic leaves
4. as plants with completely chlorotic and desiccated leaves
5. as plants completely dead, all leaves dry or detached

(d) Mulching: cut stumps of all four species were treated with 5 ml, sterile water and then covered with a black plastic garden mulch. The garden mulch was obtained locally and, to ensure all samples were covered, the entire plots containing the cut stumps were covered with two thick layers of the mulch. The mulch was nailed into the ground to prevent removal by wind, rainfall or wild animals.

The experiments were laid in a randomized block layout, fully replicated (10 plants/treatment; mean value of 30 plants) and installed at three different sites to minimize variation of edaphic factors. Observations on resprouting behaviour (number, height and vigour) were recorded for 2 consecutive years. Data were analysed statistically by least significance difference (LSD) method.

Result and Discussion

Of all the four methods of control investigated, only two were found to be successful in inhibiting resprouting in all four species tested. Triclopyr herbicide was the most efficacious completely arresting re-sprout growth. The mulching treatments were the next best. Initially, under the

* Bond is synthetic latex 45%, aliphatic oxyalkyalyated alcohol 10% manufactured by Loveland Industries, Colorado, USA.

Table 1: Influence of various treatments on re-sprouting of four exotic weeds in British Columbia after 2 years.

Treatment	Scotch broom	Gorse	Daphne spurge	English Ivy
		(% re-sprouting)		
Cutting alone	80.0	85.0	95.0	98.0
Cutting and herbicide	0.0	0.0	0.0	0.0
Cutting and bioherbicide-Cp	49.0	51.0	90.0	95.0
Cutting and mulches	0.0	0.0	0.0	0.0

Table 2: Comparison of control options.

Options	Methods	Comments
1. Mechanical	Cutting Pulling	Labour intensive Labour intensive Promotes re-sprouting and new emergence of seedlings
2. Mulching	Black plastic	Labour intensive Not practical on large scale
3. Chemical herbicides	Triclopyr	Very efficaceous, cost-effective Environmental concerns
4. Biological		
(a) Bioherbicide-Cp	Native fungal pathogen Treatment of cut stumps	Slow to act Variable results
(b) Bioherbicide-*Phomopsis*	Patch treatment on Daphne stems	Very efficacious but needs further testing

mulch, re-sprouts emerged from the cut stumps of all four species, but, due to lack of light, they deteriorated and eventually died such that this treatment was completely effective after 3 – 6 months. It was also observed that under the mulches, no new seedlings were established from the seed bank meaning that, long-term, it was a better control measure than the other treatments. However, mulching is cumbersome and unpractical to use over larger areas under the field conditions.

The response of the use of the bioherbicide (*Chondrostereum purpureum* (Cp)) turned out to be highly variable. Whereas Cp prevented resprouting in the cut stumps of Scotch broom under glasshouse conditions, being similar to the triclopyr treatments, its efficacy was variable under field conditions. For instance, when gorse stumps were subjected to Cp applications under field conditions (Table 1), the number and height of new regrowth was suppressed by only 50%, but most re-sprouts remained stunted and the onset of flowering and seed production were delayed. Therefore, the biological treatment was partially effective and reduced the total number of flowers, pods and seeds produced. On the other hand, Cp failed to arrest re-sprout growth from cut stumps in Daphne spurge and English ivy. This may be due to copious exudates produced by the cut stumps of Daphne spurge and English ivy which may block the penetration of live mycelia contained in the Cp formulation or it is possible that these exudates may contain phytoalexins and be inhibitory to these mycelia, since both species are noted for forming fruit berries that are toxic to birds (Howard *et al*., 1974; Russell *et al*., 1997) – the argument being that these are non-specific toxins that would inhibit the growth of the mycoherbicide.

On the other hand, mycelia of the new fungus *Phomopsis* sp., when applied to incised stem surfaces (patches) of Daphne plants, were found to be extremely inhibitory and lethal to seedling growth (Figure 7). It could be that this fungus (*Phomopsis*) can overcome the toxic effects of exudates by metabolizing them.

A similar situation is known for the relationship between monarch butterfly larvae (Family Danaidae) and plants in the milkweed family (Asclepiadaceae). The larvae are specialist herbivores on milkweed plants and are capable of sequestering toxic steroids, known as cardenolides, without causing negative effects to themselves, but rendering them unpalatable and toxic to predators (Brower, 1969; Brower & Glazier, 1975; Malcolm, 1991, 1995).

The data presented in Figure 7 also show that *Phomopsis* was very infective four weeks after treatment and killed all 15 plants by week 10 or 11. On the contrary, the untreated and blank plants showed no chlorosis, necrosis, desiccation or death. A similar experiment was carried under glass and in a growth chamber with controlled conditions of light, temperature and relative humidity and similar results were found. However, the rate of infection and killing were faster under the constant growing conditions (25°C; 2000 foot candles; 70% relative humidity) of the growth chamber. More research is needed to exploit the potential of this native fungus as a biological control agent for Daphne.

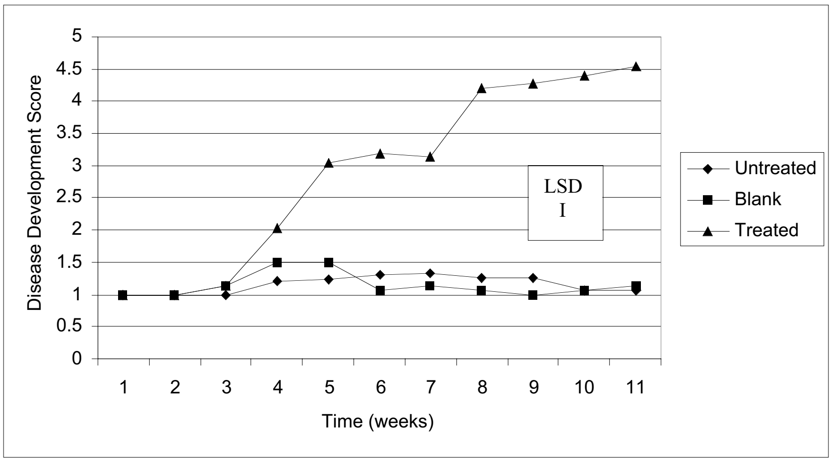

Figure 7. **Progress of disease development in healthy (untreated control), blank and treated (infected with *Phomopsis sp*.) plants of *Daphne laureola* under field conditions.**

Conclusion

Four exotic and invasive plants (Scotch broom, gorse, Daphne spurge and English ivy) are threatening the native ecosystems and biodiversity of the fragile and unique Garry Oak – Arbutus ecosystems in British Columbia. Precise data on the extent of incursion are not readily available, but Scotch broom has been found on about 10% of the landmass of Vancouver Island (Prasad, 2003). These alien plants were originally introduced as ornamentals, but have now escaped from the original habitats of gardens and parks and are invading and expanding their ranges into urban, semi-urban, industrial, rights-of-way and forested landscapes. They are destroying the critical habitat of native species by competing for space, light and nutrients. Great concern has been shown by land, forest, and real estate managers to contain them so as to arrest their prolific invasions. Experiments conducted in the laboratory, glasshouse and under field conditions demonstrate that it is possible and feasible to do so. Four methods of control (manual/mechanical cutting, treatment with a herbicide (triclopyr), bioherbicide (*Chondrostereum purpureum*) and a plastic mulch) reduced resprouting from the cut stumps. While the applications of the herbicide and the mulch proved to be most efficacious, the manual cutting and biological control methods with (*Chondrostereum purpureum*) were found to be variable. Mulching can be achieved by using synthetic materials, saw dust, biomass of cut materials of these exotic species or by sowing another aggressive plant (grasses) to cover, displace or arrest new seedlings/germinants of invasive species on priority sites, but it cannot be practised on large scales because of the associated costs. However, mulching can be effectively employed in smaller gardens.

Chemical herbicides (triclopyr), even though very effective and safe to use, arouse public concerns near urban and aquatic sites and caution is needed in choosing a particular control method. Glyphosate has been tried on Scotch broom and gorse but was found to be less efficacious than triclopyr (Peterson & Prasad, 1998). Both herbicides are registered for use in forestry but there is a public misconception that their adjuvants may have adverse impacts on children or salmon and other fish. For this reason, manual cutting and disposing of the biomass is widely practiced. An integrated approach employing manual cutting at the appropriate time, together with the application of chemical herbicides has been found to be a better option for knocking down the emerging seedlings from the seed banks (Prasad, 2003). A new mycoherbicide (*Phomopsis* sp.) has been shown to kill Daphne spurge completely. Further research is required to investigate the potential of such native biological control agents. Finally, no single method of control (save rapid killing of Daphne spurge by *Phomopsis*) was considered to be a satisfactory tool and an integrated approach might be more successful.

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