ELEMENT STEWARDSHIP ABSTRACT
for

Cytisus scoparius and *Genista monspessulanus*

Scotch Broom, French Broom

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The Nature Conservancy
Element Stewardship Abstract
For *Cytisus scoparius* and *Cytisus monspessulanus*

I. IDENTIFIERS

Common Name: Scotch Broom and French Broom

General Description:
Scotch broom: Also referred to as Sarothamnus scoparius, this weed is a perennial shrub of the Fabaceae (Leguminosae) family. The shrubs are 1-2 meters high and deciduous. The green branches (Robbins et al. 1951) are strongly angled (Hitchcock and Cronquist 1973) and appear naked or almost so (Munz and Keck 1973). The leaves are trifoliolate with petioles 2-10 mm long. The leaflets are obovate to oblanceolate, entire, strigose and 6-12 mm long.

Unlike French or Spanish broom, the yellow flowers of Scotch broom are usually borne solitary in axils, blooming between April and June. The glabrous banner is ovate to rounded; wings are oblong to ovate; and the keel is straight or curved. Petals are about 2 cm long. The flaring calyx is glabrous, about 7 mm long and is two-lipped with short teeth. The brownish black pods, 3.5 to 5 cm long, are villous on the margins only. These pods are compressed, several seeded, with a callous appendage or strophiole near the base (Munz and Keck 1973).

French broom: Perennial shrubs, 1-3 meters high with villous branchlets. The leaves are trifoliolate with petioles 3-5 mm long. The leaflets are more or less obovate, entire and 1-2 cm long. They are subglabrous above, pubescent beneath.

Flowers are borne in subcapitate racemes, unlike Cytisus scoparius. These racemes terminate short lateral branches, each raceme containing 3-9 flowers. The light yellow flowers open between March and May. Petals are 10 mm long. The mostly glabrous banner is ovate to rounded; wings are oblong or ovate; and the keel may be straight or curved. The pubescent calyx, 4-5 mm long, is two-lipped with short teeth. In comparison, Spartium junceum has one-lipped calices. The pods, 2-2.5 cm long, are densely villous. These pods are compressed, several seeded, with a callous appendage or strophiole near the base (Munz and Keck 1973).

II. STEWARDSHIP SUMMARY

III. NATURAL HISTORY

Habitat:
Scotch broom: This broom is native to the British Isles as well as central and southern Europe. The common name "broom" may have been given to the plant because of its growth habit. Its upright dense mass of ascending stems were once cut and made into floor brooms (Wyman 1971). Scotch broom first became naturalized in North America on the East Coast (Mountjoy 1979) and is found in Nova Scotia and from New York to Georgia (Gill and Pogge 1974). It was sold as an ornamental in California in the 1860s following introduction of Spanish broom (Spartium junceum) (Butterfield 1964). By the turn of the century it had become naturalized on Vancouver Island (Bailey 1906) and was probably planted throughout the Pacific Northwest as an ornamental.

The rapid spread of Scotch broom was accentuated by frequent planting of the shrubs in gardens and as a soil binder along highway cuts and fills. Its weedy tendency in California was noted as early as 1925 in Sonoma and San Mateo counties (Jepson 1925). By 1930 the citizens of El Dorado County had become so concerned by Scotch broom infestation that they had an uninfested part of the county declared a Weed Free Area (Mobley 1954).

In the West, Scotch broom has now become established along the inland valleys of the Pacific Northwest, from British Columbia to central California (Hitchcock and Cronquist 1973). Its northern limits are probably due to low winter temperatures, the southern limits due to summer drought (Williams 1981). Although it is primarily found west of the Cascades, it has been found growing on the eastern slopes as well (Gilkey 1957).

In California the distribution of Scotch broom has been mapped by the California State Department of Food and Agriculture, which considers the shrub a pest weed. This map shows two major concentrations of Scotch broom. Along the coast broom is found concentrated in Sonoma, Marin, Contra Costa, San Mateo, Santa Cruz and Monterey counties. In the Sierran foothills, Scotch broom grows in Sierra, Nevada, Placer, El Dorado and Calaveras counties. It has a much more scattered distribution in northwestern California, including Siskiyou, Del Norte, Humboldt, Trinity, Shasta and Mendocino counties (Mountjoy 1979). A survey of county agricultural commissioners throughout California (Koehler 1965) revealed the additional presence of Scotch broom in Lake, Amador, Butte, Plumas and Yuba counties, though it is only of minor importance in these counties.

Scotch broom grows best in dry sandy soils in full sunlight and will grow well in soils with pH values ranging from 4.5 to 7.5 (Gill and Pogge 1974). In Europe it is found on moderately leached soils in heathlands, acidic grasslands and inland dunes (Bicher and Larsen 1958). Scotch broom can also do well on soils high in boron (Vergnano 1957). The subspecies C.s. maritimus is found on exposed sea cliffs, unlike Cytisus scoparius ssp. scoparius which grows in more sheltered habitats (Davies et al. 1978).

Where it has been introduced, Scotch broom invades pastures and cultivated fields, dry scrubland and "wasteland", native grasslands and along roadsides, dry riverbeds and other waterways (Gilkey 1957, Johnson 1982, Williams 1981). It does not do well in forested areas but invades rapidly following logging, land clearing and burning (Mobley 1954, Williams 1981).

In California Scotch broom is common along roads and paths near towns (Howell 1970) and sometimes forms pure stands for miles along highway and country roads (Gilkey 1957). By the late 1970s the California Department of Transportation assured concerned citizens that it was no longer planting broom along highways (Mountjoy 1979). In Marin County broom has become extensively naturalized in the grassland areas of open hills and is invading the lower border of the chaparral (Howell 1970). Although broom is difficult to grow in the "hot valleys" of California (Mobley 1954), its occurrence in dry habitats and value for stabilizing sand dunes (Smith et al. 1947, Rikli 1943) implies a certain degree of drought resistance.

French broom: This broom is native to the Mediterranean region, the Azores (McClintock 1979) and the Canary Islands (Munz and Keck 1973). French broom was offered for sale at California nurseries as early as 1871 (McClintock 1985). By the mid 1940s it had escaped cultivation and was naturalized in central California (Abrams 1944).

Of the three brooms naturalized in California, the most widespread is French broom. It is presently found in at least 23 counties from Del Norte southward to San Diego and from the coast eastward to Butte, Yuba, Nevada, Placer, Sacramento and San Bernardino counties (McClintock 1985). It is also reported from Santa Catalina Island (Mountjoy 1979).

No information was available describing the optimal physical environment for French broom.

Broom has been used for a variety of purposes throughout European history, beyond its use for sweeping floors. An infusion of the leaves was used as a diuretic. Bark shavings were used to stanch blood in the 14th century. An unguent was made from the blossoms. The tops of broom were put in beer to give it a bitter taste. Some people have used the seeds to "adulterate" coffee. The flowers in bud are pickled like capers. It is cathartic and the seeds emetic. Broom has been used for thatching, fence rows

and cattle fodder. The woody plant was once used for tanning leather and the old wood for veneering. Cloth has been manufactured with the fiber.

Ecology and Reproduction:
Both Scotch and French broom may reproduce vegetatively or by seed. It has been purposefully propagated from cuttings (Gill and Pogge 1974) and it sprouts back after cutting (Mountjoy 1979).

Scotch broom bushes can produce up to 60 seed pods per bush by their second year. Each pod usually contains 5-8 seeds (Waloff and Richards 1977). Years of heavy pod production are cyclical and are generally followed by years of lighter pod production. In a recent study the timing of these cycles varied between plots, and Waloff and Richards (1977) concluded that seed production was independent of climactic conditions and reflected more the physiology of individual plants.

Broom seeds have hard seed coats which can survive transport in river gravels (Williams 1981). They may remain viable for over 80 years if properly stored (Turner 1933). For horticultural purposes Gill and Pogge (1974) recommend several types of treatment to induce germination. These include soaking the seeds in hot water and mechanical scarification (piercing, chipping or filing the seed coat) followed by a three hour soak in water. Such treatment is easily accomplished when seeds are transported by water for any distance. Only about 45-50% of the seeds produced will actually germinate (Gill and Pogge 1974, Williams 1981).

Broom pods often open explosively, especially in a drying wind, and the seeds may be widely scattered (McClintock 1985). In the Sierran foothills the most rapid spread of the plant has occurred along waterways where the seed is distributed by water. In this same area there has also been a rapid spread, often for long distances, along roads where the seed is distributed by passing vehicles and in gravel hauled from river bottoms. Seeds may also be transported by birds and other animals to isolated areas (Mobley 1954).
Seedlings buried more than 10 cm deep fail to emerge. The fastest emergence occurs when seeds are buried less than 3 cm deep in a fine textured substrate (Williams 1981). Seedlings may be damaged by frost, but this has little direct effect on their total height growth in their early years. Tips are soon replaced by growth from lateral buds (Williams 1981). Young broom plants can tolerate a wide range of growth habits. In open river beds young plants may be almost prostrate, with no single leading shoot. Shaded plants may have only a single upright shoot (Williams 1981).

Williams (1983) reported that broom can regenerate only where the canopy is disturbed by fire, substrate instability (as on steep bluffs or river beds) or by sheep and, particularly, cattle grazing.

Within the first year broom plants can grow over a meter tall (Waloff and Richards 1977). The initial rapid growth during the first 4-5 years is succeeded by 2-3 years of relative stability (Waloff 1968). Broom can tolerate low soil temperatures and can fix nitrogen throughout the year in regions with mild winters (Wheeler et al. 1979).

Miller's (1883) description of the pollination mechanism of Scotch broom has been briefly summarized by Gill and Walker (1971). Since it does not appear to be greatly different from other legumes in general, the interested reader is referred to these two papers for further discussion.

Six to eight years of growth is followed by degeneration accompanied by an increase in the ratio of woody to green material, reduction in seed production and finally death. Bushes rarely die in one year, but as "the habitat begins to disintegrate", a mosaic of dead, partly dead and living plants is formed. Broom bushes rarely live more than 10-15 years (Waloff 1968).

Broom has photosynthetic tissue dispersed throughout the crown in long twigs and small lancet-shaped leaves. This makes it well adapted to the open environments of early succession. In later seral stages in New Zealand, shrubs with photosynthetic tissue mostly on the outer crown readily shade out broom. In

tall mixed scrub, many broom bushes have single stems clear of branches until 1.5 meters above the ground, further suggesting intolerance to shade (Williams 1983).

Williams (1983) suggests that broom stands provide a more suitable environment for later successional species than gorse. Broom is leafless from late summer to early spring, allowing light to reach seedlings of later seral species. It produces a sparse, readily decomposable litter, unlike the acidic litter of gorse.

There is almost no information available about seed production, dispersal, viability, germination, or seedling establishment for French broom. The only specific information found was that it copiously produces hard coated seeds which may remain viable for many years.

IV. CONDITION

V. MANAGEMENT/MONITORING

Management Threats:
Scotch broom: The success of Scotch broom is due to 1) its wide tolerance of soil conditions; 2) its ability to fix nitrogen and grow for most of the year given adequate precipitation and a mild climate and 3) its abundant production of long lasting viable seeds. Its aggressive spread and establishment away from planted areas into stands of native vegetation causes it to be of serious concern. The California State Department of Food and Agriculture (CDFA) has declared broom to be a Class C pest species. Class C is the lowest CDFA pest rating for noxious weed species. Species of this rating will be eradicated only when found in a nursery. Spread outside of nurseries it will be retarded only at the discretion of the State Agricultural Commissioner (CDFA 1986). It endangers open grasslands and hillsides throughout California (Mountjoy 1979).

Mobley (1954) summarizes Scotch broom's "many objectionable qualities" as follows:

"It is very aggressive, spreads rapidly, growing so dense that it is often impenetrable. It prevents reforestation, creates a high fire hazard, renders rangeland worthless and greatly increases the cost of maintenance of roads, ditches, canals, power and telephone lines...Even wildlife suffers...as the growth becomes too dense for quail to thrive and there is no forage left for deer...They must move to new ranges or starve. Being slightly toxic and unpalatable it is browsed very little by livestock."

In 1965 and 1982 the USDA Biological Control Laboratory in Albany, California sent letters to all of the county agricultural commissioners throughout the state requesting information on the extent of broom infestation. Responses were varied and occasionally vague. The 1982 survey reflected surprise at the lack of French broom mentioned. It was implied that some commissioners may have failed to distinguish between the three dominant broom species, so conclusions from the following should be treated in this context. Of interest are the changes in the following counties (the 1965 approximations are followed by the 1982 acreage counts which are in parentheses): El Dorado 25,400 acres (760,000 acres); Glenn 0 acres (710 acres); Nevada 15,100 acres (76,800 acres); San Francisco 0 acres (20 acres); Shasta 3 acres (10,850 acres); Yuba 50 acres (35,200 acres). It is emphasized that this is hardly a scientific census and possibly misleading, but it is the only statewide survey indicating the rate of spread of broom.

Thomas (1985) reports Scotch broom as a moderate pest in the Santa Monica Mountains. It was nominated for this research by preserve managers at Ring Mountain, Santa Cruz Island, and the Northern California Coast Range Preserve.

French broom: This is the most widespread and damaging of the weedy brooms, in some places forming dense, almost impenetrable thickets and invading native vegetation (McClintock 1985). French broom is also classified by the California State Department of Food and Agriculture as a Class C pest species.

Management Recommendations:
With proper management, areas infested with the weedy brooms may be restored to more desirable vegetation. Soil disturbance should be kept to a minimum, as it provides bare soil which is very conducive to broom seedling establishment. Improper use of broadcast burning may contribute to a re-invasion of broom. Research by Williams (1983) suggests that broom stands are early successional in nature and can be replaced by later seral stages if left undisturbed. Planting of tall growing shrubs or trees in or near broom stands may aid in reducing photosynthesis in broom plants and possibly lead to their demise. Goats are also effective in controlling re-establishment of broom.

Monitoring is needed to determine the effectiveness of management practices.

Detailed observations focused on the vegetational change of the affected area over time will help to determine what method of control would be most efficient.

From a practical viewpoint, methods of weed management are commonly categorized as follows: physical, thermal, managerial, biological, and chemical (Watson 1977). Physical methods include both manual and mechanical methods. Thermal methods include both broadcast burning or spot treatment with a flame thrower. Managerial methods include the encouragement of competitive displacement by native plants and prescribed grazing. Biological control is usually interpreted as the introduction of insects or pathogens which are highly selective for a particular weed species. Chemical control includes both broadcast and spot application.

The most desirable approach for controlling weeds is that of an integrated pest management plan. This involves the optimum use of all control strategies. This approach is generally accepted as the most effective, economical, and environmentally sound long-term pest control strategy (Watson 1977). In cases where more than one control technique is used, the various techniques should be compatible with one another. Broadcast herbicide application, for example, may not work well with certain managerial techniques (i.e. plant competition).

PHYSICAL CONTROL:

The physical control methods discussed below, manual and mechanical, produce slash (i.e. cutting debris) that can be disposed of by several techniques. If cut before seeds are produced it may be piled and left for enhancement of wildlife habitat (i.e. cover for small mammals).

Debris may be fed through a mechanical chipper and used as mulch during revegetation procedures. Care should be taken to prevent vegetative reproduction from cuttings. Burning the slash piles is also effective in disposing of slash.

MANUAL METHODS

Manual methods use hand labor to remove undesirable vegetation. These methods are highly selective and permit weeds to be removed without damage to surrounding native vegetation.

The Bradley method is one sensible approach to manual control of weeds (Fuller and Barbe 1985). This method consists of hand weeding selected small areas of infestation in a specific sequence, starting with the best stands of native vegetation (those with the least extent of weed infestation) and working towards those stands with the worst weed infestation. Initially, weeds that occur singly or in small groups should be eliminated from the extreme edges of the infestation. The next areas to work on are those with a mixture of at least two natives to every weed. As the native plant stabilizes in each cleared area, work deeper into the center of the most dense weed patches. This method has great promise on nature reserves with low budgets and with sensitive plant populations. More detailed information is contained in Fuller and Barbe (1985).

Since manual removal is labor intensive, a ready supply of cheap labor is the first obstacle to overcome for manual control programs. The Marin chapter of the California Native Plant Society has been

successful in getting volunteers on weekend days to form broom pulling parties (Bravo 1985). Youth groups and civic organizations might also be willing to form work parties (Mounjoy 1979). More work is accomplished proportionately in a short period, such as from 10 a.m. to 1 p.m., than in a long period with a lunch break. In addition to being short, the 10 a.m. to 1 p.m. work period also allows volunteers to hike in the afternoon, a factor that results in increased participation.

Handpulling: This method may be used to destroy seedlings or plants up to 1-1/2 meters tall. Handpulling is most easily done after a rain when the soil is loose. This facilitates removal of the rooting system, which may resprout if left in the ground. Plants should be pulled as soon as they are large enough to grasp but before they produce seeds.

Hand Hoeing: Plants can be destroyed readily while they are still small by hand hoeing, either by cutting off their tops or by stirring the surface soil so as to expose the seedlings to the drying action of the sun. The object of hoeing is to cut off weeds without going too deeply into the ground and doing damage to the roots of desirable vegetation.

Plants with a large tap root may not be completely removed by hoeing and may resprout afterwards. For plants up to 4 meters tall a claw mattock is effective. The dirt around the root is loosened by the claw and the plant is then pulled out in the same way a claw hammer is used to pull out nails.

Cutting: Manually operated tools such as brush cutters, power saws, axes, machetes, loppers and clippers can be used to cut Scotch broom. This is an important step before many other methods are tried, as it removes the above ground portion of the plant. For thickly growing, multi-stemmed shrubs such as Scotch broom, access to the base of the shrub may not only be difficult but dangerous where footing is uncertain. Cutting the above ground portion and leaving the root intact is only partially successful; about half the remaining roots will resprout. Bravo (1985) suggests cutting plants before the seeds are set. this prevents seed production and dispersal for that plant.

Hand Digging: The removal of rootstocks by hand digging is a slow but sure way of destroying weeds which resprout from their roots. The work must be thorough to be effective. Every piece of root that breaks off and remains in the soil may produce a new plant. Such a technique is only suitable for small infestations or around trees and shrubs where other methods are not practical.

The manual methods discussed above were used to control broom in Marin County. The result has been the return of at least some of the native plants. Success may be somewhat limited because manual techniques do not totally eradicate broom. The resurgence of broom seedlings with

time suggests that manual removal must be regularly repeated. One strategy may be to re-seed the area with fast growing, non-weedy natives in hopes of reducing broom seedling survivorship.

MECHANICAL METHODS

Mechanical methods use mechanized equipment to remove above ground vegetation. These methods are often non-selective in that all vegetation on a treated site is affected. Mechanical control is highly effective at controlling woody vegetation on gentle topography with few site obstacles such as rocks, stumps or logs. Most mechanical equipment is not safe to operate on slopes over 30 percent. It is also of limited use where soils are highly susceptible to compaction or erosion or where excessive soil moisture is present.

Chopping, Cutting or Mowing: Scotch broom may be trimmed back by tractor-mounted mowers on even ground or by scythes on rough or stony ground. Unwanted vegetation can be removed faster and more economically in these ways than by manual means and with less soil disturbance than with scarification. However, these methods are non-selective weed eradication techniques and cut plant species which do not need control. They reduce potential for biological control through plant competition and open up new niches for undesirable vegetation. In addition, wildlife forage is eliminated. Broom plants usually require several cuttings before the underground parts exhaust their reserve food supply. If only a

single cutting can be made, the best time is when the plants begin to flower. At this stage the reserve food supply in the roots has been nearly exhausted, and new seeds have not yet been produced. After cutting or chopping with mechanical equipment, broom may resprout from root crowns in greater density if not treated with herbicides (Amme 1983).

THERMAL CONTROL

Flame Thrower: A flame thrower or weed burner device can be used as a spot treatment to heat-girdle the lower stems of shrubs. This technique has the advantages of being less costly than basal and stem herbicide treatments and of being suitable for use during wet weather and snow cover.

Although burning will remove the shoot portions of broom plants, it probably stimulates broom seed germination. A few years after hot fires in El Dorado county there is a noticeable solid stand of broom in burned areas (Mobley 1954). In New Zealand lowland scrub areas which are periodically burned contain both broom and gorse (Johnson 1982).

Broadcast Burning: Large areas of weed infestation may be burned in order to remove the standing mature plants. This may be accomplished with a pre-spray of herbicides to kill and dessicate plants, or without such spraying for notably flammable species. Used alone, this method will not prevent resprouting from root crowns. Burning is best followed by 1) herbicide treatment of stumps, 2) subsequent burning to exhaust soil seed bank and underground food reserves, and/or 3) revegetation with fast growing native species. Other considerations for the use of prescribed burning include the time and cost of coordinating a burn, and the soil disturbance resulting from firebreak construction.

BIOLOGICAL CONTROL:

Biological Competition: Sowing native plant species which have the potential to out-compete weedy exotics for important resources is usually a preventive method of weed control. In some cases later successional plants may be encouraged to take root among the unwanted vegetation. Williams (1983) suggested that broom stands provide good environment for the establishment of other broadleaved shrubs or trees.

Such seedlings should be looked for in broom stands and encouraged. In addition, seeds of taller growing plants should be sown among the broom.

The seeds and seedlings may establish sufficiently to eventually shade out the broom (Williams 1983). Such an approach is recommended in shrub or tree-covered areas in national parks in New Zealand (Green 1976).

In most cases broom prevents the establishment of other native plants and must be initially removed. Following physical or thermal removal of mature plants, root crowns must be treated to prevent resprouting. Seedlings of native plant species usually cannot establish fast enough to compete with sprout growth from untreated stumps.

Some plant species inhibit the establishment or growth of other plants through the effects of allelopathy (i.e., biochemical interference by metabolic products). Native species with such properties may be propagated in treated areas to control re-establishment of broom.

Allelopathic noxious weeds should of course be avoided. Prescribed Grazing: The continued removal of the tops of seedlings and resprouts by grazing animals prevents plant development and seed formation and gradually weakens the underground parts. Grazing must be continued until the seed bank is eliminated, as the suppressed plants return quickly after livestock is removed.

Livestock grazing as a control measure may be effective, although Scotch broom is slightly toxic and unpalatable to most livestock (Mobley 1954, Long 1938). An attempt to control broom in New Zealand failed, even though grazing commenced when broom plants were only a few inches high (Allo 1960).

In many areas of California the use of Angora and Spanish goats is showing promise as an effective control for Scotch broom (Daar 1983). In the Cleveland National Forest goats are herded for firebreak management of brush species on over 79,000 acres of land. Goats are less costly to utilize than mechanical and chemical control methods. They can negotiate slopes too steep to manage with machines and do not pose the environmental dangers inherent with herbicides (Andres 1979).

A pioneer in the use of goats for weed control in urban settings is Richard Otterstad, owner of Otterstad's Brush Clearing Service in the San Francisco Bay Area (Otterstad's Brush Clearing Service, 718 Adams St., Albany, CA 94706 (415) 524-4063). The primary weed control "tools" utilized by Otterstad's company are Angora goats and light-weight flexible fencing reinforced with electrified wire. Angoras are preferred over Spanish goats because their smaller size makes them easier to transport (Otterstad uses a pickup truck). Dairy goats were abandoned when Otterstad found them to be "goof-offs" when it came to eating (Daar 1983).

Goats prefer woody vegetation over most grasses or forbs, although Angoras have a higher tolerance for non-woody species. Since goats will trample or browse virtually any vegetation within a fenced area, any desirable trees or shrubs must be protected. Experience has shown that goats are most cost-effective when used to clear or suppress one to four year old regrowth of brush rather than to do initial clearing of dense, tall, mature stands of vegetation. When faced with mature brush, goats will defoliate twigs and strip off bark, but will leave standing the plant's main superstructure which is too old and tough to tempt them.

Sheep are more selective than goats in their food choices but function well in grazing down a variety of plants. Thus sheep grazing may be practical alternative to mowing. It is important to properly manage sheep grazing to prevent soil compaction problems which may occur when sheep are allowed to graze an overly damp area. Sheep are valuable not only for weed control but also for additional income from the sale of their wool and their contribution of fertilizer to the soil. However, it is possible that seed re-introduction may occur from the sheep droppings.

Chickens, suprisingly enough, are known to effectively digest (and destroy) all weed seeds passing through their crops and they can thoroughly graze back vegetation in areas up to one acre in size. Releasing chickens into an area after the mature plants are removed allows them to scratch and peck out weed seeds and potentially reduce the weed seed bank in the soil (Andres 1979).

INSECTS AND PATHOGENS:

The introduction of exotic natural enemies to control plants is a complex process and must be thoroughly researched before implementation to prevent biological disasters. Such tools are not normally suitable for preserve managers to implement.

In the 1950s it was suggested that the spread of broom was becoming so extensive that biological control was the only economically feasible solution (Mobley 1954). In 1960 and 1961, 6,750 twig mining moths (Leucoptera spartifoliella) were brought in from France and released in El Dorado, Sonoma and Mendocino counties (Frick 1962, Holloway 1961, Andres 1979). As of 1979 it had become well established along the Pacific Coast, up to Washington.

The small white moth is 1/4-1/2" long and can be seen flying around the broom at dusk in May and June when it lays its eggs on the new vegetative growth. The Leucoptera larvae mine directly from the eggs into the stems, tunnel throughout the stem and complete development in April or May the following year. Emerging from their tunnels, they spin white silken cocoons on the underside of twigs (Andres 1979).

Moth-infested broom plants bear a number of dead and dying twigs. The overall effect is rather subtle, making it difficult to measure the full impact of the insect on the weed. The plants suffer damage, but the moth has not solved the Scotch broom problem (Andres 1979).

Another insect, the seed weevil Apion fuscirostre, was introduced from Italy (Julien 1982) to the U.S. in 1964 and has become established in both coastal and Sierran broom infestations. Although there are high populations of the weevil in the coastal mountains, only small populations survive on Sierran plants. This is probably due to mortality of immatures in pods exposed to high temperatures (Julien1982). Despite damage to as much as 60% of the seed at some sites, the weevil has only limited impact on controlling Scotch broom. Both the moth and the seed weevil are specific to Cytisus scoparius and will notfeed or develop on French broom (Cytisus monspessulanus), Spanish broom (Spartium junceum) or gorse (Ulex europaeus) (Andres 1979).

In 1978 the California Department of Food and Agriculture proposed to fund joint biological control research on Scotch broom with its Oregon counterpart. The Oregon Department of Agriculture politely declined, as broom is looked upon as a "desirable ornamental." A similar earlier proposal had run into strong objections from nursery men and landscapers (Kosesan 1978).

Research on the insect fauna on Scotch broom in England has shown that there are 9 Lepidoptera, 5 Diptera, 1 Hymenoptera, 7 Coleoptera and 13 Hemiptera which regularly feed on broom (Waloff 1968). At present only 10 of these European broom insects are found in North America and only 5 are present in California (Andres 1979). Given such a diverse insect fauna, there is still potential for introducing other species to help control broom.

No studies are available on the effects of insect herbivory on French broom. The introduced twig-mining moth, Leucoptera spartifoliella and the seed weevil Apion fuscirostre are specific to Cytisus scoparius and will not feed or develop on French broom (Andres 1979).

Please notify the California Field Office of The Nature Conservancy of any field observations in which a native insect or pathogen is seen to have detrimental effects on broom. These reports will be used to update this Element Stewardship Abstract. Management techniques which encourage the spread of such species-specific agents may be desirable in controlling broom.

CHEMICAL CONTROL

Detailed information on herbicides are available in such publications as Weed Science Society of America (1983) and USDA (1984), and will not be comprehensive here. The Weed Science Society publication gives specific information on nomenclature, chemical and physical properties of the pure chemical, use recommendations and precautions, physiological and biochemical behavior, behavior in or on soils and toxological properties for several hundred chemicals.

Herbicides may be applied non-selectively (as in broadcast treatments) or selectively (i.e. spot treatments). Both types of treatments have advantages and disadvantages and will be discussed separately.

Broadcast Herbicide Application: Broadcast application of herbicides has become the mainstay of most weed control efforts today. This may be due to the illusion that it is a "quick fix" method of eradicating undesirable vegetation. Most herbicides so applied are non-selective and will kill most, if not all, of the vegetation sprayed. Those species that survive the treatment may, after repeated sprayings, form an herbicide-resistant vegetation cover, thus creating a more difficult problem to deal with. Such broadcast spraying may also kill off native plants, which have the ability to outcompete exotic weeds.

Broadcast herbicide application may be most effective where the weed infestation is very dense and needs to be killed and dessicated prior to burning. It may also be useful following the removal of mature plants so as to reduce the soil seed bank.

The most commonly mentioned herbicides for broom are 2,4-D, alone or with additives. These additives include diquat, picloram, dicamba, and sodium chlorate (Watt and Tustin 1976, Balneaves 1981, Allo 1960, Elliott 1976).

Broom proved to be very susceptible to picloram, regardless of the form of picloram - (Upritchard 1969;Moffat 1965). The 0.5 lb/acre ester formulation gave control equal to the 0.751 lb/acre amine formulation, both rates being clearly superior to the 0.5 lb/acre amine formulation. Moffat (1966) recommends rates twice this amount. Such a rate resulted in complete death of plants 2-3 meters high within 9 months (Patterson 1964).

Broom has been eliminated using 8 lbs of sodium chlorate in 80 gallons of water per acre (Anonymous 1934). McCavish (1980) concluded that triclopyr ester was particularly effective in controlling broom, superior to glyphosate and fosamine ammonium. Triclopyr amine or triclopyr ester also controls broom (Gilchrist 1980;McCavish 1979). Glyphosate did not satisfactorily control broom (McCavish 1980).

Paraquat and diquat result in only short term (3-6 weeks) control of stump sprouting and seedlings(Balneaves 1981). Hexazinone (Issaly 1980) or atrazine may provide control of germinating and very young broom seedlings but are generally ineffective against established plants and resprout material. Also, other competing vegetation would be eliminated, allowing ideal conditions for re-infestation (Balneaves 1981).

The potential for herbicide damage to native plants must be considered when deciding which herbicide to use. Pines are sensitive to triclopyr, spruces and firs are damaged by glyphosate. Douglas fir and Western hemlock growth was stunted by fosamine ammounium. Herbicides cause less damage to conifers if applied in July and August, after they have laid down a waxy cuticle on their needles (McCavish 1980).

Both *Cytisus scoparius* and *C. monspessulanus* react in the same way to hormone weedkillers. Plants in the seed-leaf stage are resistant. When 4 to 6 inches high they are quite susceptible to emulsifiable esters of 2,4-D at 1 lb. acid equivalent per acre (Matthews 1960).

In general, when using the broadcast application method, plants should be sprayed only in full leaf. Results are poor if plants are sprayed when the leaves are developing and when plants are in full flower before leaf development. The best results have been obtained when plants are in the seed head stage in late summer and early autumn (Matthews 1960).

Spot Chemical Methods: Spot chemical methods consist of various techniques for manually applying herbicides to individual plants or small clumps of plants (such as stump resprouts). These methods are highly selective as only specific plants are treated. They are most efficient when the density of stems to be treated is low. In applying herbicides it is recommended that a dye be used in the chemical mixture to mark the treated plants and thus minimize waste.

Jones and Stokes Associates (1984) reviewed a variety of spot chemical techniques. The following is an excerpt from this report, listing techniques in order of increasing possibility of herbicide exposure to the environment or to humans in the vicinity of treated plants.

1) Stem injection: Herbicides are injected into wounds or cuts in the stems or trunks of plants to be killed. The herbicide must penetrate to the cambial tissue and be water-soluble to be effective. The chemical is then translocated throughout the tree and can provide good root-kill, which is important in order to prevent resprouting.

2) Cut stump treatment: Herbicides are directly applied to the cambial area around the edges of freshly cut stumps. Application must occur within 5-20 minutes of cutting to ensure effectiveness. McHenry (1985) suggests late spring as the best season to do this. In early spring sap may flow to the surface of the cut and rinse the chemical off. At other times of the year translocation is too poor to adequately distribute the chemical. Applications may be made with backpack sprayers, sprinkling cans, brush and pail, or squeeze bottles. Picloram should not be used for this technique as it is known to "flashback" through root grafts between treated and untreated plants and may damage the untreated individuals.

3) Basal/Stem sprays: This technique involves the use of backpack sprayers in applying high concentrations of herbicides in oil or other penetrating carriers to the basal portion of stems to be killed. The oil carrier is necessary for the mixture to penetrate bark and enter the vascular system. This method gives good root kill, especially in the fall when vascular fluids are moving toward the roots. This method may be easier to use with small diameter stems than the two previous techniques.

4) Herbicide pellets: Pelletized or granular herbicides are scattered at the bases of unwanted plants. Subsequent rainfall dissolves the pellets and leaches the herbicide down to the root system. Optimal time for treatment is towards the end of the rainy season to prevent leaching beyond the root zone. Green (1976) reported successful control of large broom clumps with hand applied granules of picloram.

Summary:
Scotch broom: Scotch broom is most common in the San Francisco Bay counties and in the central Sierran foothills. In addition to its natural dispersal means, its range is probably still being extended by gardeners and horticulturalists. Resistance to the control of broom has come from these people in the past. Control of adult plants should begin with removal of at least the above ground portion either by hand, machine or fire. As broom stumps may resprout, it is best to remove a majority of the root system. Stumps may be treated chemically if root removal is not possible. Seeding with native species in areas where broom has been removed may lessen the chances of survivorship of subsequent broom seedlings. There is yet promise for adequate biological control as there are several broom-feeding insects from Europe, which have not been introduced.

French broom: Even though French broom is the most widespread broom species in California, little quantitative information is available on its biology and ecology. Parallels may exist with Cytisus scoparius.

Control of adult plants should begin with removal of at least the above ground portion either by hand, machine or fire. As broom stumps may resprout, it is best to remove a majority of the root system. Stumps may be treated chemically if root removal is not possible. Seeding with native species in areas where broom has been removed may lessen the chances of survivorship of subsequent broom seedlings. Biological control of French broom has not been studied.

VI. RESEARCH

Management Research Programs:
No quantitative monitoring studies of any of the weedy brooms were discovered in this research. Qualitative monitoring of control efforts are being conducted along with management programs at San Bruno Mountain, the Northern California Coast Range Preserve, Mt. Tamalpais State Park, Angel Island State Park, Siskiyou Wilderness State Park, Jughandle State Reserve and in El Dorado County (see "Management Programs - Comments" for more information").

It would be useful to more thoroughly document the conditions under which broom initially establishes itself. If it is true that broom is shade intolerant and can be displaced by taller growing species, why has broom spread so quickly throughout California? Is initial establishment due to soil disturbance, overgrazing, improper fire management or some other factor?

Broom seeds buried more than 10 cm deep do not germinate. Is it possible to burn a broom stand and then disk the debris in an attempt to bury all broom seeds? The seeds would still be viable and ready to grow rapidly with future soil disturbance, but the rapid establishment of a dense native vegetative cover may adequately prevent seedling emergence.

John Cliezewitz of the University of California at Davis, Dept. of Pathology [(916)752-0309] is studying a fungi which may prove to be pathogenic to Scotch broom. As of May 1985 he was still waiting for his plants to size up to begin his experiments.

French broom was recently observed to be in poor health in one location on the Golden Gate National Recreation Area and samples were sent to the University of California at Berkeley to determine the cause. Results are still pending, but it may be due to a fungus which uses French broom as a host (Nackley 1985).

Rosemary Lein is just beginning research at the University of California, Berkeley to study native lupine moths to determine whether or not they would be useful in controllilng different species in the Leguminosae (Fabaceae), specifically the brooms (Nackley 1895).

The California Dept. of Parks and Recreation is attempting to control broom in several of their parks (Ryburn 1985). The topographic relief in Mt. Tamalpais State Park is severely limiting the success of broom control at any great distance from roadways. Roadway spraying of broom with Roundup may be the most feasible method. Broom control is more manageable in areas with less rugged terrain.

Mechanical removal and use of picloram (Tordon) over the last five years on Angel Island have been ineffective. Picloram was sprayed on the broom plants but "flashed-back" into surrounding vegetation, creating undesired damage. However, a pilot study using Roundup has produced good results on Angel Island. Use of Roundup at Sinkyone Wilderness State Park has also been effective. At Sinkyone the herbicide sprayer is mounted on a horse to reach distant infestations.

Broom control at Jughandle State Reserve is conducted simultaneously with gorse control. Thickets are sprayed with Roundup to dessicate the plants and then burned. There is a small amount of resprouting which can be subsequently controlled with more Roundup.

Contact: Marla Ryburn or David Boyd
State Park Resource Ecologist
California Dept. of Parks and Recreation
333 Cleveland, Suite 110
Santa Rosa, Ca
(707) 576-2185, 576-2310

Thomas Reid Associates, working with the County of San Mateo, is managing both broom and gorse on San Bruno Mountain (Reid 1985). Thickets are mechanically disked and then burned. This promotes and seed germination and exhausts the seed bank. Seedlings and resprouts are spot treated with two applications of Roundup. All phases and tools of the program are working well and native species are returning. Ninety percent restoration of the habitat is expected within ten years,
but management should be continued long beyond that.

Contact: Thomas Reid or Victoria Harris
Thomas Reid Associates
P.O. Box 872
Palo Alto, CA 94302

The California Native Plant Society encourages volunteers to participate in "broom-bashing" parties (Nackley 1985). These control efforts rely on manual removal of plants and use no herbicides. No quantitative evidence was available to determine the effectiveness of these efforts.

Contact: Bonnie Nackley
California Native Plant Society
Marin Chapter
P.O. Box 146, Lagunitas, CA 94938
(415) 488-9638

Manual removal of broom is being done at the Northern California Coast Range Preserve and repeated treatments may eliminate it there (Barrows 1985).

Contact: Bruce Bingham
Preserve Manager
Northern California Coast Range Preserve
42101 Wilderness Rd.
Branscomb, CA 95417
(707) 984-6653

Nona Dennis of ESA-Madrone has written a management plan for a coastal resort in Mendocino County near Fort Bragg, which includes suggestions for monitoring and controlling broom. No results are yet available.

Contact: Nona Dennis
Vice President
Esa-Madrone
23 Pamaron Way
Novato, CA 94947
(415) 883-0484

The El Dorado County government is managing broom throughout the county.

Foliage spraying with 2,4-D or Roundup is used, but must be repeated from year to year. Mechanical means are avoided as they are believed to disturb the soil and create an excellent seed bed for broom seedlings (Delfino 1985).

Other people to contact regarding broom management programs in California include Bob Hubbell (916/644-2345) of the Mt. Danaher Research Station, Jackson State Forest (located in the northern Coast Range), who is presently engaged in a broom removal project; Gary Strachen (408/649-2862) of the Monterey Central Coast Region of California Parks and Recreation Department who is in charge of managing Scotch broom in Mt. Diablo State Park; and Ralph Carhart who works for CalTrans and has been instrumental in assuring that CalTrans no longer plants broom along rights of way.

VII. ADDITIONAL TOPICS

VIII. INFORMATION SOURCES

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IX. DOCUMENT PREPARATION & MAINTENANCE

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