ELEMENT STEWARDSHIP ABSTRACT
for

Ulex europaeus

Gorse

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The Nature Conservancy
Element Stewardship Abstract
For *Ulex europaeus*

I. IDENTIFIERS

Common Name: Gorse, Furze, Irish Furze, Whin

General Description:
The following description of Ulex europaeus is adapted from Skipper (1922), Chater (1931), McMinn (1951), Robbins et al. (1951), Pryor and Dana (1952), Yeates (1955), Moss (1959), Hitchcock et al. (1961), Munz and Keck (1973), Rudolf (1974), Amme (1983), and Williams (1983).

Gorse is an evergreen, leguminous shrub. The simple, stiff leaves are spinose or acicular, approximately 5-15 mm long. The typical trifoliolate leaf of the legumes is seen only in the seedling and in plants which grow in rich damp soils. The plant reproduces by both creeping roots or by seeds.

The shiny yellow flowers are solitary or racemose, often clustered at the ends of branches. The pubescent yellow calyx (10-15 mm long) is deeply 2-lipped, the upper lip 2-toothed and the lower lip 3-toothed. The corolla is 15-18 mm long with an ovate banner and oblong, obtuse wings and keel. The wings are larger than the keel. The 10 stamens are monadelphous.

The short, oblong villous fruit pods are 15-18 mm long, many-seeded, and turn brown when ripe. Gorse plants are heavy with ripe seed in coastal California by May. The olive green to brownish seeds are smooth and shining, approximately 2 mm long.

Gorse is an evergreen, leguminous shrub which resembles Scotch broom somewhat in general appearance. It can be easily distinguished from brooms by its prickly nature and profusion of yellow flowers. Although gorse may grow taller elsewhere, individuals in California rarely exceed 3.5 m and more commonly are only 1-2 m high. The short, stout branches are green when young but turn brown with age. They are often densely packed and superficially appear leafless. Their prickly nature is due to well-developed branch spines growing in the axils of the leaves.

II. STEWARDSHIP SUMMARY

III. NATURAL HISTORY

Range:
Gorse is native to central and western Europe, where it has long been cultivated for hedgerows (Rudolf 1974). It has been naturalized in Australia and New Zealand for over 150 years (Moss 1978), where a great deal of research has been done to control its spread (see Gaynor and MacCarter 1981 for a bibliography). It has been reported as an exotic in Costa Rica (D'Arcy 1980) and the Hawaiian Islands (Amme 1983). In North America, it has established itself along the Atlantic Coast from Virginia to Massachusetts (Amme 1983).

There is little published information as to when gorse was introduced to the West Coast. It was originally used as an ornamental (Holloway and Huffaker 1957, Boyd 1984). Seeds from Ireland were brought into Oregon prior to 1894 (Hill 1955). A few plants were brought into Marin County, California, before 1912 as "a bit of ol' Ireland" (Pryor and Dana 1952). Boyd (1984) mentions that it has been established in Mendocino County for 100 years.

By the 1950s, gorse was widespread in western Washington and Oregon and northern California (Hill 1955), covering over 15,000 acres in California (Pryor and Dana 1952) and an estimated 25,000 acres in

southwestern Oregon (Hill 1955). It has been reported in every coastal California county from Santa Cruz to Del Norte (Pryor and Dana 1952, Holloway and Huffaker 1957, McMinn 1951), and sparingly in southern California (Munz and Keck 1973). Boyd (1984) states that much of the gorse is localized, and the "long-standing Mendocino County locality has not expanded its range significantly."

The geographical distribution of gorse depends primarily on temperature (Zabkiewicz 1976). It cannot survive in arid climates, or in continental regions where there are extremes of heat and cold; neither does it grow at great altitude. The mature plant can stand fairly severe frosts. The species also has a preference for habitats sheltered from cold winds. Day length may also affect its latitudinal distribution, as short-day conditions inhibit maturation and prevent thorn formation and flowering (Zabkiewicz 1976).

Gorse invades infertile or disturbed sites, sand dunes, gravel bars, fence rows, overgrazed pastures, logged areas, and burned-over lands (Hill 1955, Moss 1978). It will grow on most soil types (Meeklah 1979), from "good silt soil to plain boulders" (Birdling 1952). It has been recorded as growing well on serpentine soils (Coombe and Frost 1956) and, though rarely, on highly calcareous soils (Chater 1931) in England. In New Zealand, gorse readily invades low fertility pastureland where the organic content of the soil is less than 4% (Matthews 1982).

It is more tolerant of soil acidity than most legumes (Hill 1949). The only restrictions to soil quality seem to be adequate nutrition and availability of trace elements (Meeklah 1979). Although its nutrient requirements are considered low (Zabkiewicz 1976), it can suffer from either magnesium or boron deficiency. Lack of sufficient boron is shown by a yellowing of the needle tips and foliage, slow growth, and delayed maturation (Zabkiewicz 1976).

Optimal growth is at soil pH of 4.5-5.0 (Meeklah 1979). It grows best where abundant soil moisture is available (Dancer et al. 1977) and does better on shady slopes than on sunny slopes (Birdling 1952). According to Boyd (1984), gorse thrives where the water table is very high, although Zabkiewicz (1976) asserts that it does best where there is good drainage. Gorse has nitrogen-fixing bacteria located in nodules on its roots which thrive under aerobic conditions (Zabkiewicz 1976). If the roots are flooded, bacterial metabolism slows down (Zabkiewicz 1976).

Reproduction:
The reputed flowering period varies from author to author (McMinn 1951, Hitchcock et al. 1961, Munz and Keck 1973, Rudolf 1974), but in general may occur between late winter and early fall. In coastal Mendocino County, gorse flowers from late winter to early spring (Amme 1983).

VEGETATIVE REPRODUCTION
Gorse may resprout from stumps. Root systems may be much older than shoot systems because of this resprouting ability (Chater 1931). Such regrowth does not produce flowers until the second year or later, although root cuttings will flower 6 months after rooting (Zabkiewicz 1976). There is one report of a seedless variety of gorse in New Zealand (Miller 1970). Hill (1949) suggests that gorse may be spread by rhizomes.

SEED BIOLOGY
Reproduction by seed is a far more important means of reproduction than is vegetative reproduction and is far more troublesome to control. The seed problem was first emphasized by Moss (1959). The seeds produced are very small, averaging 150,000 seeds/kg (Rudolf 1974) and are produced at the rate of 500-600 seeds/square meter, with counts of up to 20,000 seeds/square meter (Zabkiewicz and Gaskin 1978a, Hartley et al. 1980) in the top 2.5 cm of soil.

The seed has a hard, water-impermeable seed coat that prevents immediate germination (MacCarter and Gaynor 1980). Seeds may remain dormant yet viable in the soil for up to 30 years, with one report of 70 years of dormancy (Zabkiewicz 1976). The fact that fewer seeds germinate and seedling death rate is higher under older plants than in the open (Ivens 1978b, MacCarter and Gaynor 1980) suggests that

germination may be prevented by organic inhibitors leached from older plants (Zabkiewicz 1976), though this may be due to other factors (see below).

Seed dispersal is primarily by ejection from the pod (Moss 1959). Since the seed is considered heavy, it is not wind-dispersed (Chater 1931) and usually lands less than 2 m from the parent plant (Moss 1978). This may account for its localized abundance. In New Zealand, however, travel of seeds has been measured at over 5 m (Moss 1978), a distance too large to be accounted for by pod ejection.

Other possible means of seed dispersal include mud which contains gorse seed clinging to livestock or human feet. Parsons (1958) suggested that birds may play a part in distributing gorse seeds as "patches of the weed are often found under trees where birds have perched." Of more substance is Chater's (1931) observation of active gorse seed collection by ants as well as by the introduced California quail in New Zealand. The effect of quail on gorse seed dispersal has not been studied in California. The seed of gorse growing along streams is spread by water. Subsequent use on roadways of the gravel from these seed-bearing watercourses facilitates its spread (Hill 1949).

Seed germination may take place under suitable conditions at any time of the year. This irregularity is due to the high percentage of impermeable seeds. Light is not essential for germination (Ivens 1978b), but few seeds germinate in the shade of established gorse. When the dense gorse cover is removed, there is a "flush of germination," due to either increased light availability or associated changes in temperature conditions (Ivens 1983). Heat stimulates germination, as Moss (1959) demonstrated by heating gorse to 88 C for 30 minutes. This temperature could be expected to occur 2 cm below the soil surface in a light burn and at about 5 cm in a heavy burn (MacCarter and Gaynor 1980). Short exposures to temperatures above 100 C are lethal (Amme 1983).

Seed mortality may be caused by the gorse seed weevil (Apion ulicis) or two Microlepidoptera (Laspeyresia ulicitana and Coleophora albicosta) (Chater 1931). After germination, seedling death may be due to burial by debris, desiccation, "choking by grasses ... (Agrostis vulgaris, Deschampsia flexuosa or Holcus lanatus)" (Chater 1931), grazing animals, or defoliation below the cotyledons "probably by slugs" (Ivens 1978b).

GROWTH PATTERNS

The surviving seedlings pass through two forms as they mature. The first has a more or less compact, often with an almost rosette-like, habit. The leaves are typically trifoliolate (Boodle 1914) with thin, expanded leaflets. As simple leaves are produced, the plant grows rapidly. The leaves become narrower, smaller, more pointed and eventually, in the second stage, awl-like (Millener 1961). Spines develop in the axils of the leaves. Bienek and Millington (1968) report that spine (thorn) formation was not prevented by altering a variety of environmental factors.

In the second stage, as the foliage spines harden, the leaf cuticle thickens, and thick wax is produced on the leaf surface (Balneaves and Zabkiewicz 1981). Both the cuticle and wax thickness varies seasonally (Balneaves and Zabkiewicz 1981). It takes at least 18 months before a plant has developed sufficiently to produce flowers (Parsons 1958).

Individual plants grow outward, forming a central area of dry, dead vegetation (Anonymous 1974). A single plant can be up to 30 feet in diameter (Boyd 1984). Old bushes are occasionally found to have died or to be dying of old age. Cores suggest that gorse never grows for more than 30 years (Chater 1931).

Since gorse grows in dense, impenetrable thickets (Boyd 1984), the oil in the plant combined with the dead dry matter creates a serious fire hazard (Anonymous 1974).

Because the nitrogen-fixing bacterial metabolism slows down in flooded soils (Zabkiewicz 1976), roots tend to lie within the top few centimeters of the soil, with only the tap root extending to greater depths

(Grubb et al. 1969). These extensive lateral roots are supplemented by a fine mat of adventitious roots which descend from the lower procumbent branches (Chater 1931, MacCarter and Gaynor 1980).

The above-ground shoot system may occur in a variety of growth forms, depending on exposure. The typical form is that of a medium-size shrub, although individuals growing closest to the shore may be matlike (Boyd 1984) or cushion-like (Skipper 1922). This is no doubt the growing branch tips are killed by exposure to wind and salt spray (Skipper 1922, Boyd 1984).

Zabkiewicz (1976) states that adult gorse plants have a relatively low light requirement, and the shading effect of other species has little effect on gorse flowering and seeding. In contrast, Amme (1983) mentions that gorse is relatively intolerant to heavy shade, producing sparse foliage and few flowers. Hackwell (1980) agrees, describing gorse as a "pioneer plant" which grows best in unshaded sites and calling it a "light demanding plant."

PLANT PRODUCTION AND COMMUNITY SUCCESSION

Gorse grows very quickly. 6000 kg/ha of dry matter can be produced in one-year-old stands, and the estimated average annual rate of dry matter production in 7-1/2-year-old stands exceeds 18,000 kg/ha (Egunjobi 1971a). Nitrogen can accumulate at an annual rate of 100-200 kg/ha. This surpasses the production of some well-managed, fertilized pastures (Egunjobi 1971a).

Most of this production, with its high nitrogen content, ends up as litter (Hackwell 1980). The rate of litter accumulation under gorse is higher than any figure recorded for warm temperate species and is near those recorded for tropical rainforests (Egunjobi 1971a). Much of this litter is made up of the lower shaded shoots which have died and is hard and spiny (Grubb et al. 1969). This litter tends to acidify and lower the cation exchange capacity of moderately fertile soils by immobilizing the bases (Grubb et al. 1969, Grubb and Siter 1971, MacCarter and Gaynor 1980).

Observations on soil formation during primary succession show that a certain minimum amount of nitrogen must accumulate in the soil surface before competitive woody species invade communities dominated by legumes (Dancer et al. 1977). Repeated fires reduce the available nitrogen (Zabkiewicz 1976) and prolong the gorse stage of a succession in any area (MacCarter and Gaynor 1980). Undisturbed, the microclimate under gorse can provide favorable conditions for the germination of native shrub seedlings (Hackwell 1980) and the regeneration of indigenous forest occurs more rapidly (Zabkiewicz 1976, Dancer et al. 1977, MacCarter and Gaynor 1980, Hackwell 1980). Often fires are deliberately set to allow the development of exotic forests, as in New Zealand with PINUS RADIATA. This aids in maintaining the gorse population or in producing a community of gorse intermixed with other weedy exotics (MacCarter and Gaynor 1980).

Amme (1983) describes the composition of the gorse community in Mendocino County. In his Holcus lanatus vegetation type, growing on very moist, fine loamy soil, the associated native and exotic plants are Rubus vitifolius, Equisetum stachys, Potentilla palustris, Pteris aquilina, Carex, Juncus, Myrica californica, Plantago lanceolata, Agrostis tenuis, Rosa gymnocarpa, and Anthoxanthum odoratum.

IV. CONDITION

V. MANAGEMENT/MONITORING

Management Requirements:

Gorse may be slow in becoming established and spreading, but where it gains a hold, there are few other plants that will so completely dominate an area (Hill 1955, Anonymous 1974). Besides being a significant fire hazard (Amme 1983), it can successfully outcompete native plants. On San Bruno Mountain in San Mateo County, California, gorse is considered the most difficult exotic species to control, having caused considerable losses to valuable grassland habitat (Reid 1985).

Gorse was nominated to be the subject of an Element Stewardship Abstract by Kate Barrows, former Preserve Manager of The Nature Conservancy's Northern California Coast Range Preserve. Although it is not presently growing within the preserve, it does occur on the coastal bluffs near Ft. Bragg and Mendocino (Barrows 1985), and such proximity may be a cause for concern.

Gorse is a successful invasive species because it can: (1) fix nitrogen; (2) acidify and (at least temporarily) impoverish soils by taking up bases; (3) survive on a variety of soil types; (4) produce copious amounts of heat-tolerant seeds with long-term viability; and (5) regenerate rapidly from seeds and stumps after disturbances such as brush clearing or fires.

Gorse is probably the least recognized yet most unmanageable exotic weed in California. Management efforts must be very long-term in scope in order to be successful, due to the longevity of buried seeds. Burning may be the most adequate means of removing the mature plants. There is debate about the effectiveness of fire in controlling gorse as researchers in New Zealand have seen native species invading and outcompeting gorse on unmanipulated lands. Planting acid-tolerant, fast-growing trees in gorse thickets may eventually shade out gorse without further management efforts.

If plant competition proves ineffective, areas which are burned should be further treated to prevent resprouting and seedling reestablishment. Beyond the use of herbicides for this purpose, goats and possibly chickens may prove effective in controlling gorse.

From a practical viewpoint, methods of weed management are commonly categorized under the following categories: physical, managerial, biological, chemical, and prescribed burning (Watson 1977). Physical methods include both manual and mechanical methods. 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. Prescribed burning includes both broadcast burning or spot treatment with a flame thrower.

The most desirable approach is that of an integrated vegetation management plan. This involves the optimum use of all control strategies to control weeds. 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

Both 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 CONTROL

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 ratio 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). Such activities might be organized to control gorse. Youth groups and civic organizations might also be willing to form work parties (Mountjoy 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.

Hand Pulling: This method may be used to destroy the seedlings and young plants up to 1-1/2 m tall. Seedlings are best pulled 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. Gorse, which has a large tap root, may not be completely removed by hoeing and may resprout afterwards. For plants up to 4 m 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 gorse. This is an important step before many other methods are tried, as it removes the above ground portion of the plant. In addition, for thickly growing, multi-stemmed shrubs such as gorse, 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, as 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.

MECHANICAL CONTROL

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. Site obstacles such as rocks, stumps or logs also reduce efficiency.

Scarification: Various attachments are available for bulldozers and tractors to clear and uproot woody plants. The most basic method is to drag a heavy chain between two bulldozers. Brush rakes or blades may be mounted on the front of the bulldozer and brushland disks or root plows may be pulled behind. These techniques result in varying degrees of soil disturbance and may create erosion problems. The brush rake displaces less soil than a straight blade and is much faster at removing brush. Disks do not remove top soil but they stir and loosen it to depths of up to 16 inches. This is being used on San Bruno Mountain and, when followed by burning, is quite effective at controlling gorse (Reid 1985). Root plows are pulled below the soil surface, cutting off all roots at a set depth and pushing them to the surface. Plants like gorse, which resprout from root fragments, are not permanently controlled by root plowing.

Chopping, Cutting or Mowing: Gorse 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. They reduce potential for biological control through plant competition, and may open up new niches for undesirable vegetation. In addition, wildlife forage is eliminated. Gorse usually requires 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, gorse resprouts from root crowns in greater density if not treated with herbicides (Amme 1983).

MANAGERIAL 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. Once established these may displace the gorse by competing for water or nutrients or by shading out the lower growing plants.

In most cases gorse 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.

Much of the agricultural literature discusses using exotics to outcompete gorse seedlings (Currie 1959, Hartley and Phung 1979, 1982, Ivens and Mlowe 1983), but there has only been one attempt at reseeding with native perennials in California (Amme 1983). The project is ongoing and no results have been published yet. The plant species used are Hordeum californicum, Bromus maritimus, Elymus glaucus, E. virescens, Deschampsia caespitosa var maritima, and Danthonia californica. Costs for such a project are also discussed by Amme (1983).

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. Allelopathic noxious weeds should of course be avoided.

Hill (1949) also mentioned that gorse regrowth may be controlled when it is subject to heavy shade. Planting of fast-growing native shrubs or trees in conjunction with herbicide stump treatment may provide long-lasting control.

Prescribed Grazing: The continued removal of the tops of seedlings and resprouts by grazing animals prevents plant development and seed formation and also gradually weakens the underground parts. Grazing must be continued until the seedbank is eliminated, as the suppressed plants return quickly after livestock is removed and begin to dominate pastures again.

Goat grazing has been shown to be effective in controlling gorse (Hill 1955, Leighton 1978, Hartley et al. 1980). In many areas of California the use of Angora and Spanish goats is showing promise as an effective control for weedy species such as poison oak, scotch broom, blackberries, pampas grass, giant reed, and thistles (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 (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. Angora's 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. Gorse is most readily eaten when seedlings or regrowth is from two to four inches high, a stage when the spines have yet to harden and the foliage is soft and palatable. When faced with mature brush, goats will defoliate twigs and strip off bark, but will leave standing the plant's main superstructure. The remaining branches are too old and tough to tempt them. A period of at least two years of grazing by goats is required before there is any significant reduction in the number of gorse crowns (Hill 1949).

Chickens, surprisingly 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).

BIOLOGICAL CONTROL

The term "biological control" is used here to refer to the use of insects or pathogens to control weeds. 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.

Gorse was the second weedy plant species in the U.S. to have an attempt made at its control by the import of an exotic insect. The gorse weevil (Apion ulicis) was brought into the U.S. in 1953 from France (Holloway and Huffaker 1957) and by 1982 had become established in California and Oregon (Julien 1982). The weevil grub eats the seed within the unopened legume. When the pods open adult weevils are released to feed on the spines and flowers (Cowley 1983), sometimes defoliating large plants.

In California, the weevil has been only partially successful in controlling gorse (Amme 1983). The plant often has enough food reserves in the root and stem to recover rapidly after serious injury (Evans 1942). Additionally, the climate on the northern California coast is too cool. This delays dehiscing of the pods, and the weevil larva dies in the pod (Amme 1983).

Other potential insect enemies of gorse exist but have not been tested for controlling gorse in the U.S. These include: Apion scutellare, Exapioulicis (both listed in Julien 1982), Anarsia spartiella, Depressia costosa, Pseudoterpna pruinata, Laspeyresia ulicitana, Coleophora albicosta (Chater 1931), Agonopterix ulicetella, Rhinocyllus vornicus, Trichosirocalus horridus (Rolston et al. 1981), Tetranychus lintearius, Dictyonota strichnocera (Hill 1983), Anisoplaca ptyoptera (Butler 1979), Coccus hesperidum, and Hemiberlesia rapax (Anonymous 1971).

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 gorse. These reports will be used to update this Element Stewardship Abstract. Management techniques which may encourage the spread of such species-specific agents may be desirable in controlling gorse.

CHEMICAL CONTROL

Detailed information on herbicides is available in such publications as Weed Science Society of America (1983) or USDA (1984), and will not be comprehensively covered 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.

Chemical control of gorse has been well researched in New Zealand. All young seedlings were killed by picloram (Ivens 1979b). Good results were obtained with Tordon applied during the spring and summer months. Larger plants seem to need retreatments, and burned stumps showed a high degree of recovery and regrowth (Ivens 1979b).

There are distinct disadvantages to using picloram. Picloram is persistent in soils, subject to slow degradation by microorganisms (Amme 1983). It leaches with difficulty through soils high in organic matter and lateritic clay soils (Klingman 1975). Picloram also kills other broadleaf plants (Amme 1983) and requires a permit before use.

Hill (1949) reported that 2,4-D was not as effective on gorse as on many other plants. He suggested that ammate gave better gorse control. Yet none of these was capable of totally eliminating gorse. His conclusion was that the application of 2,4-D after a treatment of ammate would destroy seedlings and keep existing live plants under control.

Preest (1980) studied the effect of glyphosate (Roundup) and found it most effective with seedling gorse in early summer. An autumn-winter mortality rise correlated with increasing root-to- shoot ratio as the herbicide is carried to the roots with root regrowth in the fall. Preest speculated that glyphosate is most effective when the wax on the leaf is diminished as the season progresses. Glyphosate is a non-selective herbicide and will kill both grasses and broadleaf plants (Amme 1983). It is a mobile compound and is translocated throughout the plant when applied to the leaves. Klingman (1975) report that glyphosate rapidly degrades in the soil.

Other chemicals used to control gorse include: triclopyr (Naish 1975, McCavish 1980, Balneaves and Zabkiewicz 1981, Hartley and Popay 1982a, Rolston and Devantier 1983); hexazinone (Preest 1980, Balneaves and Zabkiewicz 1981, Rolston and Devantier 1983); ammonium sulfamate (Amme 1983); fosamine ammonium (McCavish 1980);and diquat (Thompson 1975b, Rolston and Talbot 1980). Additional chemicals and their effects on gorse are reviewed by Davenhill (1976), Ivens (1977), Hill (1955), Rolston and Devantier (1983), Thompson (1975b), and Bovey (1971).

The success of herbicide treatment will depend on the timing and frequency of application. Preest (1980) concluded that foliage- absorbed chemicals should not be applied until germination is complete and the plants have at least 4-12 leaves. Ivens (1979b) concluded that, in the absence of burning, cut gorse is best controlled when sprayed in the first season after cutting when shoots are most sensitive. At this time, the longest shoots have reached a length of about 50 cm, and relatively low amounts of the herbicide are sufficient.

Gorse is very difficult to eradicate with a single application of an herbicide (Balneaves 1980).

Compounds other than herbicides have been used to control gorse. Two or more sprayings of salt when the gorse is in full seed may kill it (Hooper 1929), although salt is far less effective than herbicides (Balneaves and Zabkiewicz 1981). Although field trial results have suggested that fewer gorse seedlings establish in pastures treated with lime (Hartley and Popay 1982c), it is not clear whether the lower number of gorse seedlings was due to greater pasture plant competition or a direct effect of lime on gorse seedling emergence and growth (Phung et al. 1984).

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. Growth of Douglas fir and western hemlock was stunted by fosamine ammonium. 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).

Herbicides may be applied non-selectively (as in broadcast treatments) or selectively (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.

In general, when using the broadcast herbicide application method, plants should be sprayed only in full leaf. Results are poor if plants are sprayed when the leaves are developing or 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).

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

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 plant 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 applying high concentrations of herbicides in oil or other penetrating carriers, using backpack sprayers, 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.

PRESCRIBED BURNING

Fire has been frequently used to eliminate gorse thickets, though controlled burns may easily get out of control due to the high flammability of the plants (Amme 1983). Sometimes herbicides are used to desiccate plants prior to burning to ensure a hotter fire, although it would seem unnecessary in most cases. Amme (1983) used two repeated fires in the same area. A year after the first burn, he found that only 24% of the plants were killed by the fire. Of the remaining plants, 21% increased in height and 27% grew to approximately the same height. A second burn was prescribed for the fall one year after the first burn. A follow-up of gorse survival the following year was not reported. His report is very detailed as to climatic conditions on the day of each burn and may be referred to for others interested in doing this. Although fire may stimulate gorse seed germination, it may be a useful tool to exhaust the soil seed bank.

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 is suitable for use during wet weather.

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 desiccate 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, aggressive 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

VI. RESEARCH

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

Gorse is slow to establish itself in an area, and monitoring of its spread is often overlooked. No quantitative monitoring studies of gorse were discovered in the course of researching this ESA. Since it is not considered a major agricultural weed in the U.S., there is apparently little interest or funding available for detailed sampling programs.

Two gorse management programs currently underway have associated monitoring studies to assess the effectiveness of control efforts. Such monitoring is probably qualitative, answering the question, "Does gorse reestablish itself following control treatment?" These two management programs are being conducted by Thomas Reid Associates on San Bruno Mountain in San Mateo County and by the California Department of Parks and Recreation at Jughandle State Reserve in Mendocino County. Analysis of aerial photographs of San Bruno Mountain shows that gorse has spread from 52 acres in 1932 to 334 acres in 1981, a 545% increase (Reid 1985).

We need clearer documentation on how gorse actually influences natural community processes in California.

1. Does gorse acidify soils in California? Does this prevent germination or seedling development of native plant species? How? Are other exotics likely to invade these acidified soils more readily than natives?

2. What are the major means of seed dispersal in California? What is the natural rate of seed mortality before germination? What is the local seed reserve in the soil?

3. What effect does fire have on the resulting species composition of a burned over gorse stand? Are there native plants whose seedlings can quickly outcompete gorse seedlings? Are these available to be artificially distributed after an area is burned? Does fire lead to increased erosion?

4. What effect does lime or salt application have on adult gorse plants? Seedlings?

5. Is gorse intolerant to shading? Can fast-growing trees be planted to shade it out?

6. How effective are goats at controlling gorse?

The extent of the present and potential threat of gorse in California has not been adequately described in the literature. Comments from reviewers are solicited on this. Gorse is a very successful and tenacious plant when it becomes established. It can live on a variety of soils, fix nitrogen and acidify the local soil. It produces copious quantities of seeds that can remain dormant in the soil for several decades. Eradication of the species may only be successful where there are very few individuals. Otherwise, it can only be hoped that its spread can be controlled. The use of fire or mechanical means can be used to initially reduce gorse thickets. Gorse seedling re-establishment may be reduced by fertilizing and oversowing with grasses capable of outcompeting gorse by their rapid growth rate. Goats may prove to be effective at controlling resprouting and seedling establishment. Regrowth from stumps may be controlled by limited application of herbicides. Repeated fires may help exhaust the soil seed bank.

The San Mateo County Department of Parks and Recreation used the Civilian Conservation Corps in 1983 to manually remove gorse on San Bruno Mountain. It took approximately 350 man-hours to remove an acre of densely growing gorse. Subsequent work using a two-man chain saw crew removed gorse from all of the pioneering colonies on the mountain, with a follow up of herbicide treatment to prevent stump and seedling growth. Chaining (dragging a heavy chain between two bulldozers) has produced encouraging results. Use of a heavy duty, bulldozer-mounted rototiller effectively removed several acres of gorse on gentle terrain. Burning alone, or burning followed by crushing or ground scraping was inadequate in controlling regrowth (Reid 1985).

Chemical treatment was also experimented with on the San Bruno Mountain project. Ammate was ineffective in killing cut stumps and young plants. 2,4-D was not effective, but this was probably a result of the season of application (September). Translocatable herbicides should be applied in the early spring when the plants are growing vigorously.

Reid (1985) described all phases and tools of the program to be working well, and he expects 90% recovery of natural habitat within 10 years if intensive management is maintained. He suggested that most exotic weed control programs probably fail because of three factors: (1) lack of a trained biologist(s) coordinating the effort; (2) lack of long-term funding; and (3) lack of persistence and diligence by field personnel (Reid 1985).

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Gorse control at Jughandle State Reserve is relatively recent, and it is too early to assess its effectiveness. Gorse thickets are initially sprayed with glyphosate (Roundup) and allowed to dry for at least four weeks. The thickets are then burned. Subsequent resprouts and seedlings may be either sprayed or burned again. Revegetation with native grasses and shrubs will begin in 1986 (Ryburn 1985).

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VII. ADDITIONAL TOPICS

VIII. INFORMATION SOURCES

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IX. DOCUMENT PREPARATION & MAINTENANCE

Edition Date: 89-03-22

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Herbicide information partly updated: TunyaLee Martin, 8/2001