Rare Plants of the Redwood Forest and Forest Management Effects[1]

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Abstract

Coast redwood forests are predominantly a timber managed habitat type, subjected to repeated disturbances and short rotation periods. What does this repeated disturbance mean for rare plants associated with the redwood forests? Rare plant persistence through forest management activities is influenced by many factors. Persistence of rare plants in a managed landscape is not in itself an indication of viability, but may reflect an overall increase, equilibrium, or decline in numbers. Although the persistence of some species can seemingly mimic weedy behavior, it is important to distinguish pioneer species behavior from the weedy behavior of invasive exotics. Individual species will have different responses to disturbance based on their life history and habitat requirements, as well as the type, intensity, and frequency of disturbance. Human disturbance and natural disturbance regimes are frequently and mistakenly viewed as equivalent. In addition, human disturbance regimes commonly create habitat opportunities for invasive exotics that readily out-compete rare plants for habitat. Knowing why rare plants persist in the managed redwood forest is dependent on understanding their distribution, habitat, life history, and sensitivity to disturbance. This paper will examine forest management effects on 10 rare species of the redwood forest.

Introduction

Coast redwood forests are a relic vegetation type closely associated with a narrow ecological region that provides a humid and temperate environment. The redwood forest does not have a unique flora but does have many closely associated species and habitats. There are approximately 1,518 rare plants in California of which 86 percent are herbaceous plants, 12 percent shrubs, and 2 percent trees (CNPS 2003). In the northern redwood forest there are 45 rare vascular plant species that are closely associated with redwoods (Leppig and others in press), and 94 percent are herbaceous plants. The rare flora of the redwood forest is largely herbaceous in nature and diminutive in habit. Redwood forests are predominately a timber managed habitat type with over 80 percent privately owned (primarily industrial timberlands), and are subjected to repeated disturbance events and short rotation periods (Noss 2000). What does this repeated disturbance mean for rare plants associated with the redwood forests?

The redwood forest is subject to both natural and anthropogenic disturbances; however, in the last century the anthropogenic impacts have greatly increased with timber management. Disturbance is defined here as a "relatively" discrete event in

[1] This paper was presented at the Redwood Science Symposium: What does the future hold? March 15-17, 2004, Rohnert Park, California.
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time that is ecologically disruptive at a localized or landscape level and changes resources, substrates, or the physical environment (Imper 2001). Rare species are of particular concern given their greater risk of extinction and potential loss of their economic, medicinal, and ecological function (Kaye and others 1997). This higher risk of extinction coupled with scattered and localized distribution, diminutive habit, and physical immobility of rare plants increases their vulnerability to disturbance. Especially with landscape disturbance regimes such as timber harvesting, which involves large tree felling and yarding, heavy equipment use, and road building.

Forest management activities have been perceived as mimicking "natural" disturbance regimes such as fire, windthrow and flooding by providing forest openings and mineral soil exposure. However, forest management activities are more frequent, and less variable in size and intensity than natural disturbance regimes. Timber harvesting often consists of concentrated impacts over a localized and uniform area, which may not provide the necessary mosaic of undisturbed refugia for native plants, and sources for recolonization (Halpern and Spies 1995).

Timber Harvesting Plans every so often include comments such as: 1) rare species thrive in disturbance regimes; 2) timber harvesting encourages the spread and diversity of native plants; and 3) timber harvesting has little to no significant impacts on rare plants (CDF 2003, CDF 2004). These comments often do not address the fact that not all rare plants belong to one type of disturbance response group (such as early successional), and that while many rare plants may persist through disturbance regimes, they may not all thrive.

It is our premise that forest management activities may do one of two things. They either significantly reduce the viability and persistence of rare species, or they may create rare plant habitat. The heart of this paper is that it is important to differentiate between timber management activities that have negative affects on rare plants and activities that can have positive affects. Another important point is to recognize the difference between rare plants that are truly early successional species and those that are associated with forest understories or openings. Early successional species have evolved with landscape disturbance events such as fire, landslides and flooding. These types of events deforest portions of the landscape and expose mineral soil. Forest openings species are associated with open areas within the forest created by poor soils or small scale disturbances such as tree gaps. The habitat in forest openings has increased light exposure without significant changes to the forest microclimate or soil. Forest understory species have evolved beneath the forest canopy that provides a shady, moist, and sheltered habitat with a well-developed duff layer.

Methods

A subset of ten rare plants associated with the northern redwood forest region (Del Norte, Humboldt and Mendocino counties) were identified for this study, and were selected to include various habitat and life history requirements. The selected rare plants are as follows:

1. Humboldt milk-vetch (*Astragalus agnicidus* Barneby)
2. swamp harebell (*Campanula californica* (Kell.) Heller)
3. coast fawn lily (*Erythronium revolutum* Sm.)

4. thin-lobed horkelia (*Horkelia tenuiloba* (Torr.) Gray)
5. running-pine (*Lycopodium clavatum* L.)
6. leafy-stemmed mitrewort (*Mitella caulescens* Nutt.)
7. North Coast semaphore grass (*Pleuropogon hooverianus* (L. Benson) J.T. Howell)
8. seacoast ragwort (*Senecio bolanderi* (Gray) var. bolanderi)
9. maple-leaved checkerbloom (*Sidalcea malachroides* (H. & A.) Gray)
10. long-beard lichen (*Usnea longissima* Ach.)

These ten rare plants were analyzed in terms of available ecological information and potential forest management impacts. The analysis was conducted through the: 1) utilization of sensitive plant occurrence data in California Natural Diversity Data Base RareFind3 (CNDDB 2003) and California Native Plant Society's Electronic Inventory of Rare and Endangered Plants of California (CNPS 2003); 2) compilation of habitat and life history information provided in literature and flora treatments such as *The Jepson Manual* (Hickman 1993); 3) review of reports such as Timber Harvesting Plans, sensitive plant surveys, and sensitive plant monitoring and annual summaries; and 4) field observations of the authors.

Results

The subsequent two tables summarize the ecology *(table 1)* and responses to disturbance *(table 2)* of these ten redwood forest rare plants.

Table 1— *Ecological information on selected redwood forest rare plants.*

Scientific name	Life form / natural history	Habitat/ distribution	Light requirement/ shade tolerance	Moisture/ hydrology	Soil disturbance/ compaction	Reproduction/ dispersal/ seed bank
Astragalus agnicidus **Humboldt milk-vetch**	Perennial herb to sub-shrub Early successional species and short-lived 5 to 10 years (Bencie 1995) Low tolerance of vegetation competition/canopy closure (Golec 2004) Temporal habitat, reliance on seed banks (Pickart and others 1992) Invasive exotics compete for habitat (Golec 2004) Sensitive to herbicides, even Imazapyr registered not to affect legumes, (Lundby 2003) Browsing commonly noted by rodents and other vertebrates (Pickart and others 1992, Golec 2004) All life stages present indication of population stability, alternately absence of seedlings an indication of a declining population (Pickart and others 1992)	Openings in redwood forest tanoak forest, and mixed evergreen forest, often disturbed sites and ridgelines with south to west aspects Outer North Coast Ranges in southern Humboldt County and northern Mendocino County (Hickman 1993) Belongs to small distinct taxonomical group of species (four species distinctive from the European and Asian species) that are all rare or highly localized (Barneby 1957) Closely associated with redwood region, limited distribution (CNDDB 2003)	Full to partial light Shade intolerant (Enberg 1990) Full light exposure affects seed coat permeability (Pickart and others 1992)	Xeric Susceptible to damping off	Tolerant to disturbance (Pickart and others 1992, Golec 2004) Plants more robust in habit on uncompacted soils (Golec 2004)	Pollinated commonly by bumble bees (*Bombus* sp.) with occasional visits from honey bees (*Apis mellifera* L.) and syrphid flies (Bencie 1997) Insect visitation is necessary for successful fruit set (Bencie 1997) Limited and clumped seed dispersal via dehiscence of legume (Bencie 1997) Seed caching by rodents Seeds have impermeable seed coat like many members of this family that allows for long term viability in the soil (Baker 1989) Highest density of seed found in the first 3 inches soil (Bencie 1995) Scarification and stratification of seed needed for good germination (Enberg 1990)
Campanula californica **swamp harebell**	Short-lived perennial herb Weak stemmed and shallowly rooted species with clambering habit via stiffly recurved hairs along leaf margins and stem Forest openings species	Wet seeps & swales, marshes and swamps, and seasonally wet forest openings Northern Central Coast and the southern North Coast (Hickman 1993) Closely associated with redwood region, limited distribution (CNDDB 2003)	Full to partial light Shade intolerant	Mesic to hydric	Tolerant of soil disturbance if light and hydrology habitat requirements are met Not tolerant of soil compaction	Many small seeds in capsule, dehiscing through basal pores (Hickman 1996)

Scientific name	Life form / natural history	Habitat/ distribution	Light requirement/ shade tolerance	Moisture/ hydrology	Soil disturbance/ compaction	Reproduction/ dispersal/ seed bank
Erythronium revolutum **coast fawn lily**	Perennial bulbiferous herb with retractable bulbs Dormant during summer Forest understory species Slow establisher and long-lived with moderate tolerance of vegetation competition (Parsons 2003)	Mesic sites in redwood and mixed evergreen forests (such as north aspects), and margins of streams, swamps, and bogs North Coast and the Outer North Coast Ranges to British Columbia (Hickman 1993) Horticulturally valuable species and over collected	Full to partial light Shade tolerant	Mesic Frequently associated with wetlands, facultative wetland plant (Reed 1988)	Not tolerant to soil disturbance and compaction, many liliaceous species sensitive to soil compaction (Imper 2003) Requires excellent drainage and modification of compacted or other water-holding soils may be necessary (Hickman 1993)	"Bulb-building" and flowering takes 5-7 years from seed germination (Schmidt 1980)
Horkelia tenuiloba **thin-lobed horkelia**	Short-lived perennial herb Forest openings species	Forest openings, chaparral, grasslands, and seasonal wetlands, often sandy soils Central and southern North Coast, the central and southern Outer North Coast Ranges, and the northwestern San Francisco Bay Area (Hickman 1993)	Full to partial light	Xeric to seasonally hydric	Tolerant to soil disturbance but not compaction Requires excellent drainage and modification of compacted or other water-holding soils may be necessary (Hickman 1993)	Fruit an achene (Hickman 1993)
Lycopodium clavatum **running-pine**	Perennial and evergreen rhizomatous herb with shallow root system Slow establisher and long-lived Forest understory species ~80 years following disturbance needed to allow for higher levels of frequency to develop as well as for clonal expansion or a substantial increase in cover to occur (Nauertz 1999) Mats can range from very young to hundreds of years old (Golec 2001)	Mesic sites in coniferous forests and margins of marshes and swamps North Coast, extending to Alaska, Montana, eastern North America, the Caribbean, South America, Eurasia, Africa, and Asia (Hickman 1993) Closely associated with redwood region (CNDDB 2003) Special forest product (Nauertz 1999) with many uses, and over collected.	Partial light Shade tolerant Optimum canopy closure around 60% (Golec 2001, Nauertz 2002)	Mesic to hydric Not strongly associated with wetlands, facultative wetland plant (Reed 1988) Moisture and light limiting environmental factors (Golec 2001) Correlated with large woody debris that retain water and well-developed organic layer (Golec 2001)	Not tolerant, sensitive to soil disturbance and compaction (Golec 2001, Nauertz 2004) Adventitious roots enable travel over compacted soils (Nauertz 2004)	Reproduces sexually by spores and vegetatively by rhizomes Vegetative reproduction most commonly observed, and sexual reproduction rarely observed (Nauertz 2002) Spores dispersed by wind Spore germination and gametophyte formation takes place below soil and in the dark (Whitter 1988) Alternation of generations (gametophyte/sporophyte) cycle may take up to 20 years (Nauertz 2002)

Scientific name	Life form / natural history	Habitat/ distribution	Light requirement/ shade tolerance	Moisture/ hydrology	Soil disturbance/ compaction	Reproduction/ dispersal/ seed bank
Lycopodium clavatum **running-pine**				Sensitive to warmer temperatures and drier forest conditions (Nauertz 2004)		
Mitella caulescens **leafy-stemmed mitrewort**	Perennial rhizomatous herb with shallow root system Forest understory species	Mesic sites in mixed evergreen forest, redwood forest, and montane coniferous forests (commonly along riparian corridors), and meadows North Coast, Klamath Ranges to British Columbia, Montana (Hickman 1993)	Partial light Shade tolerant	Mesic to hydric Sensitive to desiccation	Not tolerant of soil disturbance and compaction Tolerant of soil deposition with high water	Capsule with many small seeds (Hickman 1993)
Pleuropogon hooverianus **North Coast semaphore grass**	Tall perennial rhizomatous bunchgrass Dormant during summer Forest openings species Threatened by herbicides, mowing, conifer encroachment (Showers 2002) Potentially threatened by invasive such as annual ryegrass (*Lolium multiflorum* Lam.), Harding grass (*Phalaris aquatica* L.) and pennyroyal (*Mentha pulegium* L.)	Seasonally wet to wet openings in redwood/mixed evergreen forest and oak woodland, and grasslands Southern North Coast and the northern Central Coast (Hickman 1993) Closely associated with redwood region (CNDDB 2003)	Full to partial light Shade tolerant	Mesic to hydric, often seasonally wet sites	Not tolerant of soil disturbance and compaction	Does not have a large persistent seed bank (Showers 2002)
Senecio bolanderi **var.** ***bolanderi*** **seacoast ragwort**	Perennial rhizomatous herb Forest understory to opening species Low tolerance to vegetation competition	Coastal scrub and coastal coniferous forest (includes redwood forest) and along streams North Coast, extending to Washington (Hickman 1993) Closely associated with redwood region (CNDDB 2003)	Full to partial light Shade tolerant	Mesic	Not tolerant of soil disturbance or compaction	Fruit with pappus of thin, minutely barbed deciduous bristles (Hickman 1993), possibly animal dispersed

Scientific name	Life form / natural history	Habitat/ distribution	Light requirement/ shade tolerance	Moisture/ hydrology	Soil disturbance/ compaction	Reproduction/ dispersal/ seed bank
Sidalcea malachroides **maple-leaved checkerbloom**	Perennial, rhizomatous and gynodioecious sub-shrub Forest openings species Small populations appear to have lower viability perhaps influenced in part by plant being functionally diociecous (Leppig 2004) Not tolerant of direct impacts that crush or uproot plants (Lundby 2003) Invasive exotics compete for habitat (Golec 2004)	Coastal scrub and prairie, and openings in coastal coniferous and mixed evergreen forests, often disturbed sites. North Coast, the Outer North Coast Ranges, northern and central Central Coast, San Francisco Bay Area, northern Outer South Coast Ranges, and western Oregon (Hickman 1993) Closely associated with redwood region (CNDDB 2003)	Full to partial light Shade intolerant	Mesic Sensitive to desiccation with total canopy removal (Golec 2004)	Tolerant of soil disturbance, but more robust on uncompacted soils	Fruit:5–10 segmented and indehiscent, generally with one seed per fruit segment (Hickman 1993) Heavy weevil predation of seeds
Usnea longissima **long-beard lichen**	Epiphytic lichen Long-lived, slow establisher Sensitive to air pollution and timber harvesting (Keon 2001, Bittman 2003) Dependent and pendant on older conifers, hardwoods and snags, presence correlated with stand age (Keon 2001) Most effective strategy for conservation of pendant lichens is the protection of gaps, wolf trees and old-growth remnant trees (Neitlich and McCune 1997) Encourage forest management practices to retain groups of occupied trees, and set-aside high quality populations (Bittman 2003)	North Coast Coniferous Forest, Broadleaved Upland Forest, grows in the “redwood zone” on a variety of trees (CNDDB 2003) San Francisco Bay Area northward to Humboldt County in the North Coast Ranges (Hale and Cole1988); AK to CA, western Cascades (McCune and Geiser 1997) Closely associated with redwood region, and currently no extant occurrences south of Sonoma Co. (Bittman 2003) Declining throughout Europe, Pacific Northwest may contain the best remaining populations of this species (Keon 2001)	Full light, generally high in the canopy	Moist microclimate	N/A	Disperses almost exclusively by vegetative fragmentation, fertile individuals very rare (Keon 2001) Wind dispersed and dispersal limited (Keon 2001) Retention of remnant trees containing species can enhance dispersal within regenerating stands (Keon 2001)

Table 2—*Positive and negative disturbance impacts to selected redwood forest rare plants.*

Scientific name	Positive disturbance impacts	Negative disturbance impacts
Astragalus agnicidus **Humboldt milk-vetch**	Canopy removal increases light and improves habitat Reduced vegetation competition and shading Seed scarification via soil disturbance and sun exposure/temperature Creation of seasonal road bank and fill habitat Potential dispersal through mechanical soil movement such as seasonal road grading	Plants crushed or uprooted Soil disturbance buries seed bank too deeply for germination (> 3") Heavy slash deposition obstructs light to herbaceous layer limiting germination/growth Displacement and loss of habitat with introduction and proliferation of invasive exotics Canopy closure with reforestation creates unsuitable habitat Mortality from herbicide application
Campanula californica **swamp harebell**	Partial canopy removal increases light and improves habitat Seasonal road drainage creates mesic to hydric habitat	Plants crushed or uprooted Desiccation from changes in hydrology and full light exposure, Heavy slash deposition obstructs light to herbaceous layer limiting germination/growth Displacement and loss of habitat with introduction and proliferation of invasive exotics Mortality with soil compaction Mortality from herbicide application
Erythronium revolutum **coast fawn lily**	Partial canopy removal increases light and improves habitat	Plants crushed or uprooted Desiccation from canopy removal and full light exposure Heavy slash deposition obstructs light to herbaceous layer limiting germination/growth Mortality with soil disturbance or compaction Mortality from herbicide application
Horkelia tenuiloba **thin-lobed horkelia**	Canopy removal increases light and improves habitat Reduced vegetation competition and shading	Plants crushed or uprooted Heavy slash deposition obstructs light to herbaceous layer limiting germination/growth Displacement and loss of habitat with introduction and proliferation of invasive exotics Mortality with soil compaction Mortality from herbicide application

Scientific name	Positive disturbance impacts	Negative disturbance impacts
Lycopodium clavatum **running-pine**	Partial canopy removal increases light and shading	Plants crushed or uprooted Greater then 50% canopy removal decreases habitat quality through desiccation and full light exposure Dense canopy closure with reforestation creates unsuitable habitat Frequent disturbance inhibits establishment Mortality from herbicide application
Mitella caulescens **leafy-stemmed mitrewort**	Partial canopy removal increases light and improves habitat	Plants crushed or uprooted Desiccation from changes in hydrology and full light exposure, Heavy slash deposition obstructs light to herbaceous layer limiting germination/growth Mortality with soil disturbance or compaction Mortality from herbicide application
Pleuropogon hooverianus **North Coast semaphore grass**	Canopy removal increases light and improves habitat Seasonal road drainage creates mesic to hydric habitat	Plants crushed or uprooted Desiccation from changes in hydrology Heavy slash deposition obstructs light to herbaceous layer limiting germination/growth Displacement and loss of habitat with introduction and proliferation of invasive exotics Canopy closure with reforestation creates unsuitable habitat Mortality from herbicide application
Senecio bolanderi **var.** ***bolanderi*** **seacoast ragwort**	Partial canopy removal increases light and improves habitat	Plants crushed or uprooted Heavy slash deposition obstructs light to herbaceous layer limiting germination/growth Desiccation from changes in canopy removal and full light exposure Mortality from herbicide application
Sidalcea malachroides **maple-leaved checkerbloom**	Canopy removal increases light and improves habitat Reduced vegetation competition and shading Creation of seasonal road bank and fill habitat Seed bank germination with soil disturbance and sun exposure/temperature Dispersal with mechanical soil movement such as seasonal road grading	Plants crushed or uprooted Heavy slash deposition obstructs light to herbaceous layer limiting germination/growth Desiccation from changes in canopy removal and full light exposure Dense canopy closure with reforestation creates unsuitable habitat Displacement and loss of habitat with introduction and proliferation of invasive exotics Mortality from herbicide application

Scientific name	Positive disturbance impacts	Negative disturbance impacts
Usnea longissima **long-beard lichen**	Partial canopy removal (non-host tree) increases light and improves habitat	Loss of habitat with removal of host tree or snag Mortality from broad scale herbicide application and smoke from prescribed burning

Discussion

The results indicate the response of these ten redwood forest rare plants to disturbance is correlated to the ecology and life history of the species. Important ecological results were: 1) forest understory species were dependent on shade and the moist forest microclimate, and were sensitive to soil disturbance and compaction (running-pine, coast fawn lily, and seacoast ragwort); 2) early successional species in some cases but not all increased with canopy removal and soil disturbance but not soil compaction (Humboldt milk-vetch and maple-leaved checkerbloom); and 3) forest openings species benefit with full light exposure but not necessarily with soil disturbance and compaction (North Coast semaphore, swamp harebell, and thin-lobed horkelia). Potential impacts to these species as a result of disturbance associated with timber management activities are strongly weighted toward having negative effects. Direct impacts (crushing or uprooting plants), heavy slash deposition (obstruction of light to herbaceous layer), and herbicide application are the primary negative impacts. Other secondary impacts are changes in hydrology or forest microclimate, soil disturbance and compaction, and introduction and proliferation of invasive exotics. The primary positive impacts were increase in light exposure with canopy removal, and augmentation of habitat and hydrology associated with seasonal roads. Overall, the most significant conclusion from the results is the paucity of comprehensive and published ecological data on redwood forest rare plants, and their response to disturbance regimes such as timber harvesting.

Clearly many rare plants are dependent on environmental factors like hydrology and amount of light exposure. Swamp harebell and North Coast semaphore grass need partial to full light exposure and at least seasonal hydric conditions. Thin-lobed horkelia benefits from full light exposure. Long-beard lichen requires full sun but is dependent on large tree structure, and may require decades to recover from canopy removal (Halpern and Spies 1995). Forest understory species such as leafy-stemmed mitrewort, coast fawn lily, running-pine, and seacoast ragwort are dependent on the shady and moist forest microclimate, and generally are affected by management activities that significantly alter these forest attributes. Swamp harebell and running-pine are shallowly rooted and are more sensitive to soil disturbance, compaction, and changes in hydrology (Halpern and Spies 1995). Humboldt milk-vetch and maple-leaved checkerbloom are early successional in nature, and these species' habitat requirements were the most compatible with timber harvesting activities such as canopy removal and exposure of mineral soil.

Persistence of rare plants in a managed landscape is not in itself an indication of viability, but may reflect an overall increase, equilibrium, or decline in numbers over time. Rare plant persistence is influenced by many factors as well as how management impacts affect these factors singularly or cumulatively. These factors can be abiotic or biotic in nature. Abiotic factors include topography, aspect, shade and light exposure, hydrology, forest microclimate, and soil type, chemistry and structure. Biotic factors include population size, number of reproductive plants, seed set, dispersal and seed banking, canopy cover, vegetation competition, invasive non-native displacement, organic layer and large woody debris, predation, pollinators and microbial relationships such as such as mycorrhizae and nitrogen fixation.

Rare plant persistence in a managed forest is also influenced by the species rate of establishment (fast vs. slow). The establishment of a reproducing individual can take one season or years. For example, Humboldt milk-vetch and maple-leaved checkerbloom have much faster rates of establishment than coast fawn lily and running-pine. Under appropriate habitat conditions, Humboldt milk-vetch and maple-leaved checkerbloom can develop into robust reproducing plants within several years unlike coast fawn lily that takes over five years to flower (Schmidt 1980). Running-pine has a lengthy and complex maturation. The spores of running-pine first develop into a subterranean gametophyte prior to developing into the familiar mat-forming sporophyte, and this maturation of the gametophyte can take over 10 years and is mycorrhizal dependent (Leppig 2004). In addition, slow establishers like lilies [fairy bells (*Disporum* spp.), western trillium (*Trillium ovatum* Pursh), and single-flowered clintonia (Clintonia uniflora (Schultes) Kunth)] and orchids [rattlesnake plantain (*Goodyera oblongiflora* Raf.), heart-leaved twayblade (*Listera cordata* (L.) R.Br.), and western coralroot (*Corallorhiza mertensiana* Bong.)] are more susceptible to local extirpation (Halpern and Spies 1995, Jules 1997). Bryophytes and lichens such as long-beard lichen are often lacking in younger stands due to slow growth rates as well as dependency on large tree structure, moist microclimatic requirements, and limited dispersal (Halpern and Spies 1995)

Timber management activities can alter factors influential in the persistence of rare plants. Alteration of these factors can result in direct, indirect, and cumulative impacts to rare plants. Whether negative or positive and to what degree, is based on the type, intensity, size and frequency of disturbance, and the individual species habitat and life history requirements. Potential direct impacts ("take") can result from timber felling and yarding, road construction and maintenance, log decking, and other staging area activities. Indirect impacts can include canopy alteration (change in shade and light exposure), change of hydrology, disruption of symbiosis (such as mycotropic or mycorrhizal relationships), disturbance of root systems, burial of seeds below germination depths, exposure of mineral soil, reduction of vegetation competition, and slash accumulation. Lastly, cumulative impacts can result with frequent disturbance regimes (especially with slow establishing species), selective pressure toward a certain type of habitat or taxa, and increase habitat opportunities for invasive exotics.

To avoid negative impacts and ensure positive effects to rare plants within timber managed landscapes, it is important to understand the specific niche requirements. Understanding specific niche requirements increases the probability of finding rare species and effectively mitigating impacts (Sholars 2004). However, distribution of a rare plant and its dispersal mechanisms are equally important. Not all plants are limited by available habitat; dispersal limitation and regional speciation can be stronger factors for determining occurrence. Understanding rare plant distribution, habitat, and life history requires developing good inventory and ecological data collection methods. Rare plants distribution is often determined by forest managers solely through the use of electronic databases such as CNDDB RareFind or CNPS's Electronic Inventory of Rare and Endangered Plants of California. The problem is that these are positive occurrence databases that contain only known locations of species that have been observed and documented. Absence of data in these sources does not mean that a rare species is not present (Jirak 1998). Known occurrence data needs to be used by forest managers in conjunction with inventories and monitoring in order to better manage the forest and not contribute to the further decline of rare plants.

Although the persistence of some species can seemingly mimic weedy behavior, it is important to distinguish pioneer species (early successional) behavior from the weedy behavior of invasive exotics. Pioneer species will have different responses to impacts from disturbance based on their early successional role. Humboldt milk-vetch likely evolved and benefited with fire disturbance events, as indicated by observations of increased seedling expression at burned sites (Golec 2004). Slash is, however detrimental to its establishment and growth. Prior to fire suppression, forest fires were significant disturbance events in generating large forest openings and exposure of mineral soil. Fire history of the redwood forest shows surface fires created frequent disturbances in coast redwood forests of Mendocino County prior to the early 20th century. Average fire frequency varied between 6 and 20 years in one study (Brown and Baxter 2003). With fire suppression timber harvesting has for the most part replaced these prehistoric disturbance events in generating forest openings and exposing mineral soil.

Lastly, invasive exotics are often introduced or proliferate with repeated disturbance. Invasive non-native species are a worldwide threat to biodiversity, and this threat is second only to direct habitat loss and fragmentation. Their effects are severe, complex, and extensive to the environment, and include displacement of native plants and animals. Rare plants are particularly vulnerable to invasive exotics and every rare plant can be readily displaced by invasive exotics such as the early successional species purple pampas grass (*Cortaderia jubata* (Lemoine) Stapf), or the shade tolerant forest understory species English ivy (*Hedera helix* L.). In addition to natural dispersal through wind, water and wildlife, the spread of non-native invasive plants on forest lands are often facilitated by heavy equipment and vehicle traffic, road construction and maintenance, erosion control seeding and mulching, and vegetation and soil disturbance associated with management activities. Some of the problematic non-native and invasive plants associated with redwood forests are bull thistle (*Cirsium vulgare* (Savi) Ten.), purple pampas grass, Scotch broom (*Cytisus scoparius* (L.) Link), French broom (*Genista monspessulana* (L.) L. Johnson), English ivy and Himalayan blackberry (*Rubus discolor* Weihe & Nees).

Conclusions

The concept of "disturbance" as used in forest ecology is subjective, often complex, and oversimplified. Many rare plants are not necessarily benefited by disturbance from forest management activities. Forest management activities may create what appears to be potential habitat; however, census and monitoring data do not always indicate an increase in rare plants. This may be due to unapparent niche requirements, poor viability (such as small populations, or pollination and dispersal limitations), and proliferation of invasive non-native plants.

To ensure the persistence of rare plants, forest managers need to take into account the distribution, habitat, and life history of each individual rare plant in their management area. A great deal of positive effect can take place given care to both the direct and indirect impacts of management activities. With increased knowledge of the biology and ecology of rare species, forest management activities can have a positive effect on rare plant viability and survival. Without this knowledge and the interest in fostering rare plant conservation, forest management activities are sure to continue to play a role in the increase of rare plant extirpation and extinction.

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