People, Plants, and Pollinators: The Conservation of Beargrass Ecosystem Diversity in the Western United States

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1. Introduction

Biodiversity conservation often focuses on strategies that aim to protect a species from extinction and to preserve its functional role within an ecosystem. In this chapter we adopt a broader view of conserving biodiversity that calls for conservation of the ecological and social roles of a species within an ecosystem, which we understand to include humans. Viewed as such, biodiversity conservation entails sustaining ecosystem diversity to support both a species and the web of interdependent social and ecological relations in which it is embedded. Hence, if one component of the ecosystem diversity associated with a species is threatened, conservation interventions may be warranted, even if the species itself is not (yet) threatened or endangered. Thus, biodiversity conservation is not only about preventing the extinction of a species, but also about preserving the diversity of its functional roles – both ecological and social – to sustain biocultural diversity.

Conservation strategies based on knowledge about how people affect and interact with the natural disturbance processes that influence ecosystem diversity are more likely to be successful than strategies that focus on only one or the other (e.g., anthropogenic or natural disturbance). Because the niche (both social and ecological) of a species may vary across its range depending on local disturbance regimes and local sociocultural practices, conservation needs and strategies are also likely to vary across its range. For this reason, traditional and local ecological knowledge can make an important contribution to the conservation of ecosystem diversity.

We selected beargrass (*Xerophyllum tenax* (Pursh) Nutt) to illustrate these points. Beargrass is a perennial monocot with distinctive slim, evergreen leaves and a tall flower spike (Fig. 1). Its range lies in the western United States and southwestern Canada, with two disjunct distributions: (1) from the Coast and Sierra Nevada mountain ranges in California north through Oregon's Coast and Cascade mountain range, to the Olympic Peninsula and Cascade Mountains in northwestern Washington; and (2) from the Rocky Mountains in Idaho, Montana, and northwestern Wyoming north to southeastern British Columbia and southwestern Alberta Provinces in Canada (Crane, 1990; Maule, 1959; Vance et al., 2001) (Fig. 2). The coastal portion of this range is influenced by a maritime or mediterranean climate, while the interior portion is continental. Throughout its entire range, beargrass provides food and habitat for several animals and pollinating insects. Beargrass also has cultural and economic value. For centuries the plant has been used by Native Americans, who harvest the leaves for basketry and other uses. In recent decades, beargrass has become an important part of the international floral industry because its leaves are useful for different decorative products.

Fig. 1. Beargrass (*Xerophyllum tenax*). Courtesy Nevada Native Plant Society

Across the range of beargrass many changes are occurring in the frequency, intensity, and severity of natural and anthropogenic disturbances, including fire regimes, timber management, and leaf harvest practices. These changes impact the plant, its pollinators, and the people who use it in an interconnected web of ecosystem relations that are incompletely understood. We suspect that these impacts are – or could be – negative for multiple species and some of the people that are part of the ecosystems where beargrass grows; indeed, they have already been detrimental for some cultural uses of beargrass. Thus, beargrass offers one example of how terrestrial ecosystem conservation strategies might be developed and implemented, taking into consideration both the ecological and social importance of a species within an ecosystem.

Fig. 2. Distribution of beargrass in western North America. Source: Flora of North America

In the next section we introduce beargrass and review some basics of its natural history. We then discuss the ecological and sociocultural roles of beargrass within the ecosystem, with an emphasis on pollination ecology and the traditional cultural and current commercial importance of the plant. We go on to address how natural and anthropogenic disturbances affect beargrass and its ecosystem functions. These sections provide a foundation for the final two sections of the chapter in which we synthesize the information presented to identify and evaluate potential management strategies that could advance the knowledge and practice of ecosystem diversity conservation within the range of beargrass. Our synthesis and analysis are based on a review of the published literature about beargrass.

2. Natural history of beargrass

Beargrass is adapted to a wide range of ecological conditions and can reproduce either sexually or asexually. Habitat conditions affect plant characteristics, which in turn influence its social and ecological roles.

2.1 Botanical overview

Beargrass is not a true grass, but is instead classified as a lily (Liliaceae) (USDA, 2011). The *Xerophyllum* genus has just two members and beargrass is the only one found in the western United States. The congeneric *X. asphodeloides* (L) Nutt, or eastern turkeybeard, is similar to *X. tenax* in form, but is smaller in stature. Eastern turkeybeard grows only in the southeastern United States, where in some places it is classified as threatened or rare. In contrast, beargrass is not listed (USDA, 2011).

The scientific name of beargrass is derived from Greek: *xeros* (dry), and *phyllon* (leaf); and Latin: *tenax* (clinging or tenacious). The prevalent common name is derived from its anecdotal use as a food plant for bears (Crane, 1990). Several alternate common names reflect other roles of beagrass, namely elk grass, soap grass, Indian basket grass, Quip-Quip, and fire lily. As its scientific name suggests, beargrass has morphological adaptations that are typical of drought-tolerant plants, namely a thickened cuticle and stomatal restrictions to the leaf surface that minimize water loss (Rentz, 2003).

Beargrass is an herbaceous, rhizomatous plant with a perennial mass of narrow, long, basally clustered leaves (Hitchcock & Cronquist, 1973). The rhizome is a woody rootstock (Hitchcock & Cronquist, 1973; Maule, 1959). The basal leaves are fibrous and numerous, and grow in clumps (Hitchcock & Cronquist, 1973; Pojar & MacKinnon, 1994). The leaves are 15-100 cm long and 2-10 mm wide at the base, decreasing in width to a thin, stiff, wiry tip (Maule, 1959; Rentz, 2003; Vance et al., 2001).

The plant can reproduce both vegetatively (by sprouting of offshoots from the rhizome) and sexually (by flowering) (Vance et al., 2001). Plants may live for several years, producing vegetative growth and offshoots (Rentz, 2003; Vance et al., 2004). Each shoot arises from a meristematic region located on the upper surface of the rhizome at the leaf base (Crane, 1990). Vegetative reproduction may occur throughout the life span of an individual. An individual plant often dies after flowering, but since offshoots sprout before flowering occurs, a plant is persistant and long-lived (Crane, 1990; Hitchcock & Cronquist, 1973; Laursen, 1984).

In the event of flowering, beargrass produces a single, tall (~1.5 m), and unbranched stalk that bears a terminal inflorescence with 50 to 400 flowers (Munger, 2003; Vance et al., 2001). The onset and length of flowering appear to vary with differences in soil temperatures, aspect, canopy cover, and elevation (Maule, 1959; Rentz, 2003; Vance et al., 2004). The lily-like flowers are small (ca. 1.3 cm) and are whitish (Munger, 2003). Pollen morphology of beargrass and eastern turkeybeard is similar (Takahashi & Kawano, 1989). Floral nectar is not present and the floral scent of beargrass varies. These flowering properties are important, because different pollinating insects are attracted to different flower qualities.

The relative importance of vegetative vs. sexual reproduction in beargrass appears to be associated with environmental factors, but is not well understood. In general, flowering in this species is most often observed in plants growing in open conditions; it becomes less frequent or disappears entirely as forest canopies close and light to the understory is reduced (Crane, 1990; Maule, 1959; Vance et al., 2004).

2.2 Environment

Beargrass grows in a variety of environmental conditions: in open areas such as clearings, meadows, and bogs; on slopes and ridges; and in coniferous forests (Vance et al., 2001). It is a significant component of subalpine meadows, and also frequently occurs as a dominant understory plant in dry, mixed-coniferous forests (Higgins et al., 2004). Beargrass is adapted to harsh environmental conditions; it grows in a variety of soils and forest types. It is associated with soils of low fertility and productivity (Peter & Shebitz, 2006; Vance et al., 2001). The plant is often found on steep sites where the soils are saturated in the spring and well-drained later in the season (Crane, 1990; Higgins et al., 2004; Maule, 1959). The annual precipitation within the range of beargrass is from 48 to 175 cm (19 to 69 inches) (USDA, 2011). The direction of slope (its aspect) may be important for beargrass distribution, due to the influence of aspect on soil temperature and length of the growing season. Topography, hummus content of the soil, and ground cover characteristics may influence soil temperature and thus impact flowering patterns of beargrass.

Beargrass is moderately shade tolerant and can grow in forests with little or no direct sunlight, and on open slopes (Maule, 1959). The amount of overstory shading appears to impact the reproductive strategy of this plant. Flowering is associated with open or filtered light, whereas the plant reproduces by rhizomes in closed overstory conditions (Higgins et al., 2004; Schlosser & Blatner 1997). Overall, beargrass is reported to achieve the highest densities and reproductive success under canopy openings where it grows vigorously and blooms profusely (Crane, 1990).

3. Beargrass ecosystem dynamics

The ecological and social roles of beargrass range from being a food resource for insects and mammals, to being important in the culture of Native Americans, to being at the heart of a multimillion dollar floral greens industry. We describe some of these diverse roles below, recognizing that many of them are not fully understood.

3.1 Ecological roles

3.1.1 Food resource

Beargrass provides food for animals large and small. Bees consume its pollen and, in spring, bears eat the fleshy part of the leaf base (Pojar & MacKinnon, 1994). Likewise, mice and pocket gophers feed on the fleshy leaf bases and rhizomes (Vance et al., 2001). The flowering stalks of beargrass are eaten by elk and deer in summer, and the more tender leaves are eaten by these animals year-round (Crane, 1990; Vance et al., 2001). Since the leaves remain over the winter, they also provide food for mountain goats in cold conditions, when limited resources are available (Vance et al., 2001). Beargrass pollen provides food for a diversity of insects, including at least 29 species of flies, beetles, and bees from at least 14 different families (Vance et al., 2004). Beargrass leaves and flowers also provide habitat, nesting material, and foraging territory for animals, from mice to grizzly bears.

In this chapter our main interest is in the functional role of beargrass as a source of food for the insects that visit its flowers. The process of pollination is essential for the survival of many plants, and therefore, pollen is part of an extensive food web. Pollinating insects include flies (Diptera), beetles (Coleoptera), bees and wasps (Hymenoptera), and butterflies and moths (Lepidoptera). Of these, we focus on the first three because they have been associated with beargrass in published studies. Butterflies are neither known nor expected to pollinate beargrass due to a lack of nectar. Some moths are attracted to nectarless flowers; moth pollination of beargrass is possible, but unknown.

The appearance and presentation of beargrass flowers suggest a generalist rather than a specialist mode of pollination, which means that several insects probably pollinate the plant. Flies, beetles, and bees may not contribute equally to the cross-pollination of beargrass, however (Vance et al., 2004). In a singular study in the Oregon Cascades, flies were the most efficient and effective vectors of beargrass pollen, rapidly moving between flowers and carrying pollen mostly from beargrass (Vance et al., 2004). In contrast, beetles were less efficient, but still effective, cross-pollinators. They spent more time on an inflorescence than did flies, but did move from plant to plant (Vance et al., 2004). Bees were infrequently observed, but carried the most beargrass pollen grains of all insect visitors over two seasons of observation (Vance et al., 2004).

Cheilosia hoodiana, a hoverfly, is one beargrass pollinator. While many fly pollinators consume nectar as their primary reward, flies such as this one feed chiefly on pollen which they require for reproductive success. Many such flies gather pollen and nectar from a wide variety of flower types and shapes (reviewed in Campbell et al., 2007). This implies that beargrass is a non-exclusive host for this hoverfly, which would also pollinate other plants in the beargrass community.

Cosmosalia chrysocoma is a longhorn beetle that pollinates beargrass. The adults fly from June to at least August in the Rocky Mountains and Pacific Coast Range (Craighead, 1923; MacRae & Rice, 2007), actively seeking out flowers and feeding primarily on pollen (reviewed in O'Neill et al., 2008). This species is found on a great diversity of flowers. The life span of most species in this family ranges from one to three years, most of which are spent in the larval stage, feeding on decaying wood. Adult beetles usually emerge, disperse, reproduce, and die within a few days to a few months. The distinctive antennae of this beetle help it locate host trees needed for reproduction.

All bee species are dependent on flowers for meeting larval and adult nutritional needs. Foraging bees may be categorized as specialists (e.g., forage on a single plant species or species in one or several closely related genera), or generalists (foraging across multiple genera and families) (Roulston et al., 2000). Four different families of bees (Andrenidae, Apidae, Halictidae, and Megachilidae) have been reported foraging on beargrass (Vance et al., 2004).

Increased consumption of pollen, protein, and other nutrients may increase the size, survival, longevity, and fecundity of bees, flies, and other pollinating insects (reviewed in Roulston et al., 2000; Vance et al., 2004).

While findings presented in Vance et al. (2004) clearly demonstrate that beargrass is an important food resource to a diverse assemblage of insects, the relative importance of beargrass compared with other plants is difficult to assess. There is currently insufficient evidence to determine whether some insects require beargrass as part of their life history, or whether some pollinators are essential to beargrass reproductive success.

3.1.2 Ecosystem structure

The structural role of beargrass in forested ecosystems is not well documented. However, given its perennial status and growth form, it is probable that beargrass contributes both above- and below-ground structure during different seasons. For example, roots may provide erosion control, particularly in steep habitats (Vance et al., 2001), and also aid in soil stability. The structure around the basal leaves provides habitat for birds, small mammals, and insects. Because the plant is adapted to survive in snow, the spaces among leaves and at the leaf base also likely provide sub-niveal spaces. It may be that some of the pollinators of beargrass – such as bees – use stucture provided by it for nesting and reproducing.

3.1.3 Ecosystem processes

In addition to pollination, an important ecosystem process to which beargrass likely, but indirectly, contributes is decomposition. Some pollinators of beargrass, such as the flower longhorn beetle *(Cosmosalia chrysocoma),* are part of this fundamental process, which breaks down organic matter and makes nutrients available for new life. Although it is not threatened, beetles like this one may be an indicator of forest conditions and processes, since the species assemblages in primary forest habitats differ from those found in second growth.

3.2 Sociocultural roles

Beargrass is a plant that has been valued by people since prehistoric times. It was used by Native Americans in the Northwest primarily for basketry, decorations on regalia, and jewelry, and it continues to be used today for these purposes. More recently, it has gained commercial importance in the floral industry. It is also valued for its aesthetic properties in the wild and in yards and gardens. Finally, beargrass may be useful in ecological restoration, a use that is only now being investigated. Most of the literature documenting its uses references the northwestern rather than the Rocky Mountain portion of its range.

3.2.1 Native American uses

Since prehistoric times, Native American tribes from northern California, Oregon, Washington, Idaho, and British Columbia have harvested beargrass for making baskets of different types (Anderson, 2005; Lobb, 1990; Shebitz, 2005). Plain baskets were used in gathering wild foods such as berries and clams, for storing food and other goods, for carrying water, and for cooking (Lobb, 1990; O'Neale, 1928; Shebitz, 2005). More decorative baskets were used in ceremonies and dances, given as gifts or traded, and used to hold objects of cultural importance. Beargrass was also used to decorate other baskets. Today, Native American basketweavers in the Northwest weave beargrass baskets for sale, gifts, artistic purposes, as a means of carrying on cultural traditions, and as a medium for recording tribal history and expressing tribal identity.

Specific qualities of beargrass are desirable for these traditional uses. Basket weavers prefer long, straight, pliable leaves that are flexible enough to work with, but fibrous enough to withstand the rigor of weaving (Rentz, 2003; Shebitz et al., 2009). The leaves must also be able to lie flat when woven into a design. Leaves having less pigment are favored. Some California basketweavers prefer leaves that have turned white at the tip (Anderson 2005).

The properties of beargrass vary across its range. Certain environmental conditions promote the plant qualities sought for traditional Indian basketry. Plants occurring at high elevations have longer, stronger, more flexible leaves (Hunter, 1988; Rentz, 2003). Plants that grow in partial shade have leaves that remain pliable for longer periods of time, perhaps because they are protected from the sun (Hunter, 1988; Shebitz, 2005). Leaves harvested from plants in areas that recently burned contain less pigment, are easier to pick, and are also relatively strong, thin, and pliable (Anderson, 2005; Hunter, 1988; Rentz, 2003). Because fire improves leaf quality for basketry, harvest often occurs in areas that have recently burned, although the best harvesting is believed to occur three to seven years after a burn (Rentz, 2003; Shebitz et al., 2009). Traditional harvesters seek sites that have environmental conditions conducive to producing high quality beargrass leaves, but accessibility is also important because many harvesters are elderly. Sites near maintained roads are preferred (Hunter, 1988). Although harvesting occurs on public, private, and tribal lands, habitat fragmentation and land conversion have made public lands the most common gathering place today (Lynch & McLain, 2003).

Apart from basketry, beargrass leaves were also traditionally woven into garments and decorations, and were used to make a variety of everyday items (Anderson, 2005; Lobb, 1990; Rentz, 2003). Today they are also used for jewelry, such as necklaces and earrings (Anderson, 2005). The roots were used for medicinal purposes (Vance et al., 2001). Beargrass also played a ceremonial role (for example, at burials) (Peter & Shebitz, 2006). Beargrass often grew as a dominant plant in places where Native Americans went to seek spiritual refuge. In northern California, tribes traditionally ate the tuberous rhizomes of the plant (Anderson, 2005). In addition, it provided forage for game species, such as elk and deer, that were hunted by Native Americans (Shebitz, 2005).

Several researchers have pointed out the links between biodiversity and cultural diversity (see Maffi, 2005 for a review). Biodiversity supports a broad range of cultural practices and adaptations that in turn create demand for, and forest management to support, a broad range of species. In the case of beargrass, forest management to maintain the cultural uses of the plant not only helps preserve associated cultural traditions among Native Americans today; it calls for management to restore beargrass habitat to protect it and associated species assemblages from decline.

3.2.2 Commercial uses

In the 1980s, commercial harvest of beargrass became prominent in the Pacific Northwest and British Columbia (Higgins et al., 2004; Lynch & McLain, 2003). It is used in three forms: fresh, preserved, and dried (Schlosser & Blatner, 1997). Beargrass flowers are used in fresh flower arrangements (Vance et al., 2001). Leaves are used, fresh or dried in floral arrangements, in which they serve as filler (Hansis, 1998). The rich green leaves of beargrass are attractive in floral arrangements but can also be easily dyed, and are long-lasting (Thomas & Schumann, 1993). Although there is a domestic market for beargrass leaves in the United States (especially in the east), most of them are exported for sale on European and Asian markets (Schlosser & Blatner, 1997; Thomas & Schumann, 1993). Since the 1980s, beargrass has become one of the leading nontimber forest product species harvested commercially in the Pacific Northwest. It was believed to be the most widely-harvested floral green species in the Pacific Northwest in the 1990s (Schlosser & Blatner, 1997), and may still be today. Because harvest and trade of nontimber forest products is not well documented or monitored, harvest volumes can only be estimated. Researchers estimated that 200,909 kilograms were harvested from Pacific Northwest forests between 1999 and 2001 (Kramer, 2001), though other estimates are much higher. According to one study, buyers were purchasing and shipping 68,182 to 90,909 kilograms of beargrass leaves per week during the harvest season (Thomas & Schumann, 1993).

Today, commercial beargrass production has become a multi-million dollar industry in the northwestern part of its range. Who participates? Most harvesters are Southeast Asian and Latino immigrants to the Northwest (Hansis, 1998). Despite physical hardships, there are many advantages to working in the floral greens industry. English language skills are not required, advanced skills are not needed, it is unnecessary to provide legal documentation in order to work, and payment is in cash. Many harvesters prefer working in the forest to low-paying jobs in cities, which may be the only alternative, and for some, harvesting may be the only job they can find. Harvesting can also be a way of maintaining family bonds, as it often takes place as a family activity that includes children and elders. The latter might require expensive care if left at home while adults work. Moreover, beargrass harvesting can be done during lapses in employment, serving as a bridge to fill employment gaps until other jobs, such as agricultural and forestry services work, become available. Thus, it provides an important source of supplemental income for many. Beargrass harvesting may also be a primary source of employment; with the decline in jobs in the agriculture and timber sectors in the Northwest since the late 1980s, harvesting beargrass and other nontimber forest product species has provided an alternative employment opportunity in the natural resources sector for workers. Finally, because many immigrants harvest nontimber forest products in their home countries, doing so in the United States provides cultural continuity with the past, and an opportunity to pass on the tradition of gathering to children (Hansis, 1998). Other participants in the market chain include contractors or buyers who purchase beargrass directly from harvesters at buying stations and transport it to processing sheds, wholesalers, and retailers who operate within regional and global market systems (Hansis, 1998; Higgins et al., 2004).

As with traditional cultural uses, commercial-grade beargrass has specific properties that make it valuable. Commercial harvesters seek leaves that are deep green with no yellowing, that retain their color following harvest, that have wide, firm blades, and that are at least 71 centimeters long (Schlosser & Blatner, 1997). Leaf length is the main factor limiting its commercial value. Older, larger beargrass plants are typically those having leaves long enough to harvest, which are generally located in the center of a tussock. Most commercial harvest occurs in spring, summer, and fall, though it is possible to harvest year-round if snow levels permit (Hansis, 1998).

Beargrass leaves that meet commercial standards are usually found in places having partial shade cover from an elevated forest canopy that provides diffused sunlight, that allow for snowfall to the ground, that have low soil compaction, and where the moisture regime is favorable, especially north and east-facing slopes (Schlosser & Blatner, 1997). On the basis of experiments conducted on the west side of the Cascade Range in southern Washington, Higgins et al. (2004) found that as a general guideline, 60 percent forest overstory cover is necessary to produce leaves having the desired color, regardless of forest type. The highest commercial harvest yields are likely to occur from forests having 60 to 90 percent canopy density. Leaf quality is optimal in climax plant communities and during the later stages of forest succession. Beargrass of commercial quality is not present in open canopy areas where recent burns or clearcuts have taken place (Higgins et al., 2004). Therefore, commercial harvest occurs primarily in cool, moist forests at higher elevations (762 to 1,524 meters), where beargrass is the dominant understory species, is abundant enough to make harvesting profitable, and where leaf quality is optimal (Hansis, 1998; Schlosser & Blatner, 1997). On the eastern slope of the Cascade Range and in eastern Oregon and Washington, northern Idaho, and western Montana, these are typically grand fir (*Abies grandis*), subalpine fir (*Abies lasiocarpa*), and mountain hemlock (*Tsuga mertensiana*) forests. Douglas-fir (*Pseudotsuga menziesii*) forests tend not to have commercial grade plants; and beargrass does not usually occur in high enough quantities in western redcedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) forests to be commercially profitable (Schlosser & Blatner, 1997). On the western slope of the Cascade Range and to the west, the forest zones having the highest potential for commercial beargrass production are the Pacific silver fir (*Abies amabilis*) and mountain hemlock forest types; again, Douglas-fir and western hemlock forests are much less favorable (Schlosser et al., 1991). In contrast to traditional uses, we are unaware of specific habitat management interventions undertaken to promote beargrass populations and properties desirable for commercial harvest.

3.2.3 Spiritual/aesthetic values

Beargrass is an aesthetically-pleasing plant – its colorful leaves and prominent, flowering stalk stand out and delight recreationists and nature lovers who visit the natural areas where it occurs. Its appearance also makes it desirable as a cultivated plant in gardens, though it is difficult to propagate beargrass successfully. Seeds gathered in the wild can be cultivated in greenhouses, and seedlings transplanted; but mature plants do not transplant well, and cuttings taken in the wild tend not to establish themselves (Vance et al., 2001; Wick et al., 2008). Some Native American tribal members may also appreciate beargrass for its aesthetic value, and as one component of the larger ecosystem to which they feel a spiritual attachment (Peter & Shebitz, 2006). As noted earlier, open habitat conditions promote flowering. Crane (1990) finds that beargrass achieves its highest densities and blooms profusely in forest openings having a filtered light environment. Flowering diminishes as the forest canopy closes.

3.3 Summary

Our purpose in this section is to demonstrate that beargrass lies at the nexus of a web of ecological and sociocultural relations (Fig. 3). On the one hand, beargrass serves as an important food source for many animals, pollinators, and decomposers, and plays a role in ecosystem structure and processes. On the other hand, it supports a number of cultural uses among tribes throughout its range, and is one of the most economically-valuable plants in the commercial floral industry in the western United States. Its aesthetic and spiritual values are also important. The goods, values, and ecosystem services provided by beargrass all contribute to ecosystem diversity – a diversity that is influenced by both natural and anthropogenic disturbances throughout its range. A description of the key disturbance agents that influence beargrass follows.

4. Disturbance ecology

Disturbances affect beargrass habitat, and in turn, plant structure and ecosystem function. Some dominant disturbance factors that influence beargrass are fire (both naturally occurring and anthropogenic), silvicultural practices, and leaf harvest. Due to limitations of space, we also consider biotic disturbances (insects, pathogens) here, but not abiotic ones (landslides, wind) because we think the former affect more extensive areas, and cause greater alterations across the range of the plant.

Disturbance regimes in the forested plant communities where beargrass grows are changing throughout its range, influencing the ecosystem services the plant provides. Conservation of the ecosystem diversity that beargrass supports will largely depend on managing the natural and anthropogenic disturbances that impact it.

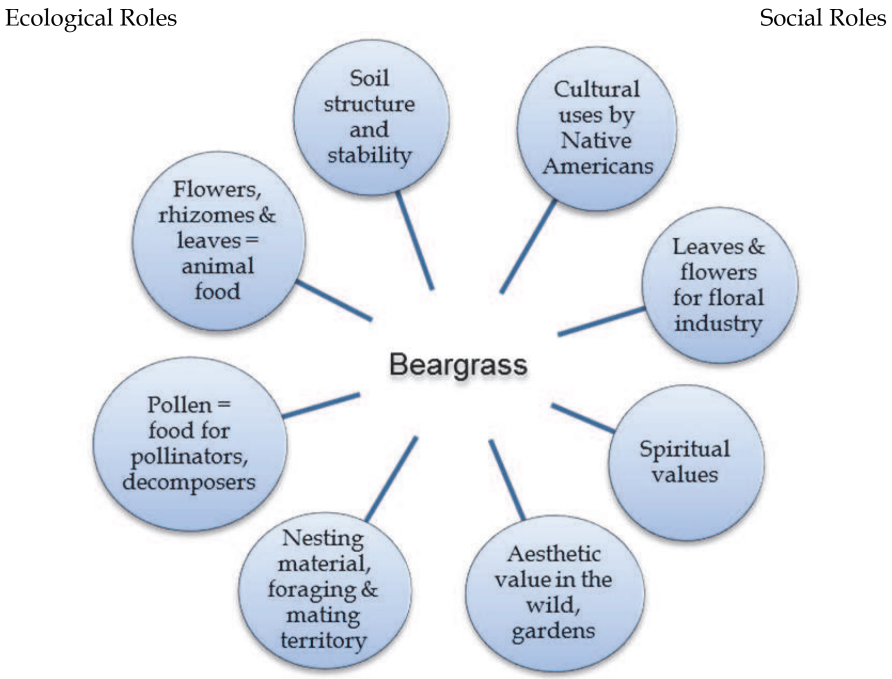

Fig. 3. Ecological and social roles of beargrass

4.1 Fire

4.1.1 Natural ignitions

Wildfire is an important ecological process in shaping plant community structure and function and has been a major natural disturbance in western ecosystems where beargrass grows (Agee, 1993). In forested landscapes of the Pacific Northwest, Rocky Mountains, and Sierra Nevada Range, lightning is the primary natural source of fire ignition (Agee, 1993; Barrett & Arno, 1999; Keeley & Stephenson, 2000). Wildfires generally occur in summer, due to an association with summer lightning storms and the build-up of dry fuel (Bartuszvige & Kennedyre, 2009; Boyd, 1999). Late-season fires (summer to fall) also occur in some areas, such as the eastern Cascades (Wright & Agee, 2004). In northern California, the potential for lightning fires is highest during the period of hot, dry conditions between August and October, especially in inland parts of the region (Agee, 1993).
Within the range of beargrass the extent of wildfire varies, with less than 10 ha (Morrison & Swanson, 1990) to greater than 4000 ha reported in the Oregon Cascades, and from 1 to 800 ha in the Sierra Nevadas. Fire extent in high elevation, subalpine habitat depends largely on the distribution and abundance of forest vegetation, since rock or snow fields may prevent

the spread of fires across patchy forests. At lower elevations, wet forests composed of less-flammable tree species can limit the spread of forest fires. Fire extent is also strongly linked to weather patterns, with the tendency for large fires to coincide with periods of annual and seasonal drought.

Natural fire regimes are tied to climate, elevation, forest community structure, and other environmental factors. Thus, the frequency and severity of wildfires varies across the range of beargrass habitat. In general, naturally occuring fires west of the Cascade Range in the maritime, wetter forest types occur infrequently (100-800 years), but burn extensive areas with high severity fire when they do ignite. Forest types at the upper end of the fire return interval include Pacific silver fir, mountain hemlock, and subalpine fir. Forests of Douglas-fir and western hemlock are at the lower end of the range. In contrast, natural fire regimes in the interior, drier forest types east of the Cascade Range occur frequently (1-50 years) and with low severity. These are forests in which ponderosa pine (*Pinus ponderosa*), grand fir, white fir (*Abies concolor*), and Douglas-fir grow. Interior forests of the Rocky Mountains are influenced by a continental climate. Ponderosa pine, Douglas-fir, western larch (*Larix occidentalis*), and lodgepole pine are common forest species in the Rocky Mountains. In dry, lower elevation forests dominated by ponderosa pine, the natural fire regime is characterized by high-frequency, low intensity fires with fire-return intervals from 5 to 40 years. In contrast, low-frequency, high-intensity (stand-replacing) fires are typical at mesic, higher elevation sites; for example, moist western larch forests are reported to experience comparatively long fire return intervals of ~35 to 200 years (Barrett & Arno, 1999). Natural fire regimes across the range of beargrass thus historically included infrequent, high severity fires in moist and cold regions and more frequent, low severity fires in dry regions. Ecotones between the regions were, perhaps not surprisingly, characterized by mixed-severity fires.

4.1.2 Anthropogenic fire

In historic and prehistoric times Native American tribes in the western United States commonly used fire as an environmental management tool. Evidence for anthropogenic fire in the Pacific Northwest dates to about 3500 years ago (Peter & Shebitz, 2006; Wray & Anderson, 2003); in northern California, the evidence goes back 8,000 years (Rentz, 2003); and in the Sierra Nevada of California, Native American burning is believed to have begun at least 9,000 years ago (Klinger et al., 2008). Burning took place to create habitat conditions favored by desired game species such as elk and deer, enhancing hunting opportunities (Boyd, 1999). It was also used to promote the growth of plants favored as food, medicine, for clothing, and for basketry. In places having high precipitation and long natural fire return intervals, anthropogenic fire made it possible to maintain culturally-important plants in the quantity, and of a quality, needed (Shebitz et al., 2009). Tribes from northern California, Washington's Olympic Peninsula, and others are known to have used fire to maintain beargrass populations for use in basketry (Rentz, 2003; Shebitz et al., 2008, 2009). Following a burn, beargrass re-establishes itself, and new leaves having the leaf qualities desirable for basketry are harvested from the burned clumps. In many parts of its range, beargrass occurs with food plants valued by Native Americans – such as camas (*Camassia quamash*), (a bulb), and berries (*Vaccinium spp.*). Thus, burning promoted an assemblage of desired species (Peter & Shebitz, 2006).

The frequency and severity of burns varied, depending on location and purpose. Fires in beargrass habitat in the Pacific Northwest and California were typically slow moving surface fires that burned with low severity (Rentz, 2003; Shebitz et al., 2009). On the Olympic Peninsula, the Skokomish tribe burned beargrass praries at two to three-year intervals (Shebitz et al., 2009). These fires burned most of the old leaves off of the beargrass plants, and up to 95 percent of their live foliage. New leaves from burned tussocks were harvested one to three years later. In northern California, fire was also used frequently (Rentz, 2003). Elsewhere, anthropogenic burning was less frequent (averaging once every nine years in the northern Rocky Mountains, and every 5 to 15 or 20 years in the Sierra Nevada). In most places, burns were conducted in late summer and fall, though early spring burns took place in the Rockies (Barrett & Arno, 1998).

Whereas Native Americans commonly used fire as a forest management tool, nonnative settlers took the opposite approach: in the mid to late 1800s, they began suppressing both natural and anthropogenic fires (Shebitz et al., 2009). Since the early 1900s, Indian burning in the American West has been severely curtailed and natural fires have been actively suppressed in forest and rangeland ecosystems. Consequently, many praries and savannas in the Pacific Northwest and Rocky Mountains that were not settled by people and instead remained undeveloped have undergone succession to woodlands and forest. One result has been a scarcity of beargrass leaves at traditional gathering sites suitable for use in Native American basketry, and a decline in beargrass in some parts of its range resulting from increases in canopy cover (Peter & Shebitz, 2006; Shebitz, 2005; Shebitz et al., 2008). A century of fire suppression has also meant that today, when natural ignitions do occur, they can cause uncharacteristically severe wildland fires that are difficult to suppress. High intensity fire can kill beargrass by burning the meristematic portion of the rhizome, located near the soil surface, from which growth takes place (Vance et al., 2001).

4.1.3 Effects of fire on beargrass and pollinators

The primary adaptation of beargrass to fire is its ability to sprout from underground rhizomes (Crane, 1990). Shebitz et al. (2009) found that beargrass leaves began resprouting from rhizomes within five months of high-severity fire, and Rentz (2003) reported that plants burned to the ground were once again covered with leaves by the following summer. Fire reduces competition for growing space by shrubs and trees, reduces forest canopy to increase light and soil temperatures, and releases nutrients into the soil, all of which favor beargrass. Increases in beargrass flowering have been observed within one or two years following fire (Maule, 1959; Rentz, 2003). Depending on the season, weather, fuels conditions, forest type, and location of a fire, the severity and extent of a burned area could range from small (a few square meters to a few square hectares) to large (several hundred or thousand hectares).

Anthropogenic fire contrasted to naturally-occurring fire in a number of ways. The effects of interactions between natural fire regimes and the intervals created by human ignitions on ecosystem diversity are unknown, but could be expected to vary directly with the magnitude of alteration from historic frequency and severity. For example, in maritime, or coastal-influenced moist forest ecosystems, frequent anthropogenic burning to favor beargrass and associated species like camas shortened the natural fire return interval and probably reduced the area affected by any one fire. Thus instead of hundreds of hectares burning once every several hundred years, there would have been fewer hectares burned every decade. This would have created and maintained a mosaic of early seral conditions in otherwise mid- to-late-seral forests, which would have increased species diversity and altered fuelbed structure. In contrast, in interior, dry forest types frequent anthropogenic burns would have been more consistent with the natural fire regime. The gradient of potential interaction between natural and anthropogenic fire throughout the range of beargrass implies a variety of effects on genetic, species, and ecosystem diversity, rather than a uniform response to fire.

Fire also affects pollinators. The potential impacts of fire on arthropod communities are variable and can be beneficial or detrimental (reviewed in Swengel, 2001). Beneficial effects include more food for survivors and migrants. Pollinating insects generally rely on sunlight to raise their body temperature enough to fly; thus, the reduced live tree density and canopy cover in burned forests may attract these species (Campbell et al., 2007). Moreover, canopy openings provide an environment in which flowering plants can flourish. These changes improve nectar and pollen rewards associated with a shift from annuals to perennials (Potts et al., 2003). For example, pollen production has been found to be highest in freshly burned sites and to decrease with time (Potts et al., 2003).

The degree of fire-related impact and the potential for insects to rebound are related to a number of characteristics, especially exposure to lethal temperature, the stress experienced in the post-fire environment, the suitability of post-fire vegetation as habitat, and the ability of survivors or colonizers to rebuild their numbers at the site (Swengel 2001). Mobility is important in both fire avoidance (e.g., the ability to reach suitable unburned habitat) and in post-fire recolonization (e.g., the ability to reach burned sites from unburned sites) (Hartely et al., 2007). Thus, ground-dwelling arthropods are slower to return after wildfire than groups adept at flight (reviewed in Swengal, 2001). This suggests that any negative effect of fire on the insect pollinators of beargrass would be lower for mobile species like flies and bees and higher for the larval and adult stages of beetles.

4.2 Timber harvest

Timber harvest is an anthropogenic disturbance across the range of beargrass in the Pacific Northwest and Rocky Mountains (Halpern & Spies, 1995). Specific harvest practices (e.g., harvest method and extent, degree of soil disturbance, management of slash, reforestation efforts, rotation length) have varied over time, depending on land ownership, site conditions, and forest type (Halpern & Spies, 1995), and thus affect forest structure and ecosystem processes differently. In general, harvest activities alter natural successional processes and influence the diversity, abundance, and composition of understory vegetation over both the short and long term (Battles et al., 2001; Halpern & Spies, 1995). The canopy openings, increased light levels, and elevated soil temperatures created through logging could potentially benefit beargrass growth and reproduction (Maule, 1959; Vance et al., 2001). Mechanized harvest could, however, result in compacted or poorly-drained soils that would have a negative impact on beargrass.

The available literature focuses on clearcut harvests, which may adversely affect beargrass. One short-term study of plant cover and composition was conducted in the Oregon Cascades prior to clear-cut logging, after logging but before broadcast burning the slash, and during each of five growing seasons following burns. The study found that beargrass disappeared immediately after clearcut logging, remained absent after burning, and reappeared in trace amounts four years later (Dyrness, 1965). Other studies from Oregon (Halpern & Spies, 1995) and Idaho (Crane, 1990) report an absence of beargrass for decades after clearcutting, though it is not clear what effect post-harvest broadcast burning might have had on the plant. The likely reason for this absence is competition from understory shrub and forb species, which proliferate following a clearcut, creating conditions that make it difficult for beargrass to recover for at least 20 years (Shebitz et al., 2009). Commercial harvest of beargrass from stands that have been clearcut does not usually resume until a closed forest canopy has redeveloped and been in place for a long time (Schlosser & Blatner, 1997).

Studies are scarce on the effects of less-intensive silvicultural treatments, such as shelterwood and group selection, on beargrass. Schlosser & Blatner (1997) report that floral greens harvest, including commercial beargrass harvest, can begin about three to seven years after commercial thinning and other intermediate-level stand treatments, though this may vary some, according to local circumstances. One study has implications for the beetle pollinators of beargrass. O'Neill et al. (2008) investigated the effects of shelterwood logging on wood-boring beetle pollinators living in lodgepole pine forests in Montana and found that logged sites had more adult cerambycids (including *Cosmosalia chrysocoma*, the most abundant beetle pollinator of beargrass [Vance et al., 2004]) than unlogged plots and meadows. Logging-related increases in cerambycid abundance may be attributed to the abundance of decaying wood (larval food) and flowers (adult food) in recently-logged areas (O'Neill et al., 2008). Syrphid flies may increase post-logging for the same reasons (Reemer, 2005).

4.3 Harvesting beargrass

Traditional harvest of beargrass for basketry entails removing the leaves; commercial harvest entails removing the leaves and sometimes the flowers. Done correctly, harvesting leaves and flowers does not kill the parent plant (Thomas & Schumann, 1993). If the rhizome is left intact, it regenerates well after harvest. Beargrass is assumed to recover from harvest within four or five years, based on appearance, although no research confirms this observation (Higgins et al., 2004). It is unclear whether harvesting stimulates the growth of new shoots (Shebitz et al., 2009).

Traditional harvest methods used by Native Americans entail removing the longest plant leaves from the center of a clump of beargrass by gently pulling them, or cutting them at the base (Anderson, 2005; Rentz, 2003; Shebitz, 2005; Shebitz et al., 2009). Because most of the plant remains intact following harvest, traditional harvesting techniques are assumed to have a negligible impact on beargrass.

Commercial harvesters also remove leaves from the center of the beargrass plant, as these are the ones that meet commercial quality standards (Thomas & Schumann, 1993). In general, roughly a dozen long leaves are removed per plant. Harvest takes place by pulling the leaf blade from the sheath, or cutting it with a knife as close to the base as possible to maximize length. Poor training and a tendency to work quickly in order to maximize harvests can cause careless harvesting that damages the plant, or the removal of plant material that does not meet commercial standards, causing waste. If the rhizome is cut or torn out during leaf removal, beargrass can take three years to grow back (Kramer, 2001; Thomas & Schuman, 1993; Vance et al., 2001; Vance et al., 2004). Flowering stalks may also be destroyed in the process of removing leaves. And, some commercial harvesters remove entire plants instead of selectively harvesting the leaves, making regeneration more difficult (Shebitz, 2005; Shebitz et al., 2008). The tendency for commercial harvesters to concentrate in specific places increases harvest impacts.

The effects of commercial harvesting appear to vary by who is doing it. Harvesters who are more place-based and who participate regularly in the nontimber forest products trade are likely to be more concerned about the long-term sustainability of harvesting (Brown, 2001; Hansis, 1998). In contrast, those who are migratory, or who move in and out of the commercial beargrass sector, are more likely to be primarily interested in maximizing short-term gain, and to have less concern for long-term, sustainable harvest practices.

The largely unregulated commercial harvest of beargrass poses a potential threat to the species in parts of its range, and to other uses and values of the plant. For example, some Native Americans in the Pacific Northwest are concerned about declines in the quality and quantity of beargrass, which they attribute in part to the commercial floral industry and to commercial harvesters who do not selectively harvest leaves (Shebitz, 2005; Shebitz et al., 2009). Over the past 20 years, federal and state agencies and private landowners have made attempts to regulate access to beargrass and harvest levels. These efforts have met a number of barriers. The cost of harvest permits varies considerably across federal, state, and private lands, and year to year, and is often too expensive to enable harvesters to make a significant profit (Lynch & McLain, 2003). Permitting rules also change over time and ownership, causing confusion among harvesters. In addition, there is concern that too many people are obtaining permits to harvest in the same locations, creating competition. This situation leads to high levels of illegal harvest, exacerbated by the challenges of enforcing management regulations. Because illegal harvesting is difficult to regulate and monitor, it tends to have a more negative impact on beargrass populations than legal harvesting does.

We are not aware of any studies that directly address the impacts of beargrass harvesting on pollinators. For the most part, harvesting targets leaves, not flowers, so unless flowers are damaged in the harvest process (which sometimes occurs), the most likely impact to pollinators would come from reduced photosynthesis (Vance et al., 2004). The removal of plant leaves compromises the photosynthetic capacity of a plant, reducing its ability to grow and reproduce. If the quality and number of beargrass pollen grains is consequently lowered as a result of leaf harvest, then pollinators would have less food available to them, and would expend more energy obtaining food. It is also possible that insects could be killed by trampling or vehicles used to transport harvesters. Any negative impacts on pollinators could, in turn, affect beargrass by reducing pollination.

4.4 Biotic disturbances

Biotic disturbances – including insects and pathogens – affect light conditions and soil properties within the range of beargrass. Defoliating insects, such as western spruce budworm (*Choristoneura occidentalis*), are native to forest ecosystems throughout the northwest and interior west (Hummel & Agee 2003). Budworm populations are regulated by factors including predators (both vertebrate and invertebrate) and weather. Outbreaks occur when the density of host tree species is favorable and regulating factors are weakened. Repeated budworm defoliation over years can weaken or kill individual trees or extensive groups of trees. Non-native insects, such as the balsam woolly adelgid (*Adelges piceae*), introduced from Europe around 1900, can kill or weaken true fir trees throughout the range of beargrass.

Fungal root diseases in forested habitat cause patches of dead and dying trees, which, upon falling or dying back, create openings in the forest canopy. Trees of all sizes and ages may be killed by these diseases, although susceptibility varies greatly among tree species.

Important pathogens in the Pacific Northwest and Rocky Mountains include laminated root rot (*Phellinus weirii*), armillaria root disease (*Armillaria ostoyae*), and annosus root disease (*Heterobasidion annosum*). In the grand fir zone, they contibute to patchy forest structures associated with small scale mortality (individual trees or groups of trees). These three diseases exist in different combinations and severity throughout the range of the plant. They could impact beargrass pollinators because they increase the availability of dying and dead trees that create habitat for guilds such as wood-boring beetles, hover flies, and wood-nesting bees. Furthermore, the canopy openings caused by root disease may further attract pollinators by providing warmer foraging conditions, and by promoting the flowering of beargrass and other species.

4.5 Summary

This review of beargrass disturbance ecology finds that both anthropogenic and natural disturbances influence beargrass ecosystems. Exactly how these disturbances affect beargrass – either alone or in combination – is understudied. Given the long history of anthropogenic fire within the range of beargrass, and the fact that natural fire return intervals are relatively long in many parts of its range, anthropogenic fire was undoubtedly the dominant disturbance agent affecting beargrass ecosystems prior to around 1900. Indicators are that anthropogenic fire favored beargrass, its habitat, its cultural uses, its flowers, and presumably, associated pollinator communities as well as other species that use it for food, habitat, and nesting material. The effects of other natural disturbances on beargrass – such as landslides, insects, and diseases – were relatively small and localized.

Since 1900, anthropogenic disturbance has continued to play a dominant role in influencing beargrass ecosystems, though the nature of the disturbance has shifted from fire (largely because of suppression policies) to commercial timber harvesting, and in recent decades, to the commercial harvest of beargrass itself. These changes have been less beneficial to beargrass and some of its ecosystem services. Fire suppression has brought about forest succession and the gradual disappearance of open beargrass habitat in parts of its range. Timber harvesting could potentially alter this trend, but the impacts of timber harvest on beargrass are mixed, depending on harvest method. Clearcut timber removal, the most common treatment employed during much of the 20th century, appears to have negative impacts on beargrass. However, partial harvest techniques may enhance beargrass and its associates by creating the forest canopy openings and filtered light conditions it responds to. Long-term studies of the relationship between habitat characteristics, beargrass productivity, and beargrass population dynamics are required before the sustainability of commercial beargrass harvesting can be adequately assessed (Higgins et al., 2004).

5. Management implications

5.1 Overview

We selected beargrass to illustrate how one species can have multiple ecological and sociocultural roles, and to assert the importance of considering the social and ecological relations associated with a species in ecosystem conservation. In doing so, we highlighted how some – but not all – natural and anthropogenic disturbances may affect beargrass and its ecosystem functions and relations over time. Now we consider management implications for ecosystem diversity conservation.

Beargrass still grows across much of the range mapped in the 1950s (Maule, 1959), and is not listed as federally-threatened or endangered in the United States. Nonetheless, the plant has declined in abundance in parts of its range (e.g., on the prairies and wetlands of Washington's Olympic Peninsula), and some of its ecosystem services have been affected by changing disturbance regimes. This trend has negative implications for some of the biocultural diversity associated with beargrass ecosystems. The main values at risk to date are traditional Native American uses and their associated cultural roles, and most likely, commercial harvesting and its socioeconomic importance to harvesters in some locations. Ecosystem processes associated with pollination may also be a concern. It is important to emphasize that it is not merely the presence or absence of the plant in a particular location that puts such values at risk; the reproductive strategy of the plant (flowering or vegetative), plant properties (leaf quality, flower quality, pollen nutrient status), and plant distribution are also vital elements of its functional role.

In order to develop and implement effective management strategies to protect the ecosystem values of a species in places where they are a concern, it is important to understand how natural and anthropogenic disturbances interact to affect them. These interactions may be complex, and will likely vary throughout the range of a species. Thus, best management practices to conserve ecosystem diversity will also vary according to local disturbance regimes, within a regional context. What does this mean for ecosystem management to achieve conservation? One implication is that management needs and approaches will vary throughout the range of a species, because ecosystem values at risk in one location may be less of a concern elsewhere. For example, documented concerns over insufficient beargrass leaves for Indian basketry come from the Northwest, but not the Rocky Mountain portion of its range.

Table 1 summarizes the management considerations associated with beargrass. It indicates the social and ecological values of the plant, the plant properties that support these values, and the values that are currently at risk. It also identifies the environmental conditions that favor plant properties associated with each value that could be managed for in order to protect it. Finally, it lists the natural and anthropogenic disturbances that currently threaten each value. It is apparent from Table 1 that beargrass management, and indeed management to protect the ecosystem diversity associated with many species, is a complex proposition, especially when actions to protect one value may not be optimal for another.

Because management needs and approaches are likely to vary locally within the range of beargrass and other species, there is a role for traditional and local ecological knowledge in addition to western scientific knowledge in contributing to effective ecosystem conservation, especially when a threatened value is sociocultural in nature. We define traditional ecological knowledge as a cumulative body of knowledge about the relationships between people, other living things, and the environment, that is handed down across generations through cultural transmission (Berkes, 1999). It includes knowledge, practices, beliefs, and the range of skills and strategies that people use to respond to the environmental circumstances they find themselves in, and is place-based (Berkes, 1999; Ingold, 2004). Similarly, local ecological knowledge (which is more recent) includes knowledge, practices, beliefs, skills, and strategies that people develop as a result of extensive interactions with, and personal observation of, local ecosystems (Charnley et al., 2007). There are several examples of how traditional and local ecological knowledge can be integrated into biodiversity conservation efforts (see Charnley et al., 2007, 2008 for a review). The most desirable way is to engage the knowledge holders directly, as active participants in conservation efforts, using participatory approaches.

Again, beargrass provides an example to illustrate these points. Based on our earlier discussion of disturbance impacts on beargrass, management interventions to conserve its threatened ecosystem values would likely focus on fire management, silvicultural treatments, and/or regulation of commercial beargrass harvest. We give brief examples of each of these below, including actual or potential roles for traditional and local ecological knowledge.

Ecosystem role	Value at risk?	Associated plant part/properties	Environmental conditions that favor desirable plant properties	Disturbances that may negatively impact value
Social				
Native American basketry	Yes	Leaves: long, thin, pliable, strong, less pigment	- partial canopy/partial shade - recently burned areas	Anthropogenic: - fire suppression - commercial beargrass harvesting - clearcutting and slash burning Natural: - succession to late-seral forest
Commercial floral greens industry	In some parts of range	Leaves: deep green, long, wide, firm, >71 cm in length	- 60-90 percent canopy cover - higher elevation conifer forest in later stages of succession	Anthropogenic: - overharvesting beargrass for commercial purposes - silvicultural practices that create large canopy openings, reducing needed shade (e.g., clearcutting) -prescribed fire Natural: - wildland fire

Ecosystem role	Value at risk?	Associated plant part/properties	Environmental conditions that favor desirable plant properties	Disturbances that may negatively impact value
Aesthetic/spiritual	?	Flowers	- best flowering occurs in open conditions	Anthropogenic: - trampling, commercial harvesting Natural: - processes that favor vegetative state and suppress flowering state
Ecological				
Food	No	Flowers, leaf base and leaves, pollen	- partial canopy, open or diffuse light	Anthropogenic: - fire suppression - overharvesting beargrass Natural: - processes that favor vegetative state (e.g., closed forest canopy) and suppress flowering state
Habitat and soil structure	No	Basal leaves, leaves, and rhizomes	- diffuse light or shade	Anthropogenic: -timber harvest practices that result in soil compaction and plant death
Pollination, decomposition	In some parts of range	Aggregated flowers with nutrient-rich pollen	- partial canopy, open or diffuse light, dead or dying trees that provide substrate for invertebrate pollinators and decomposers like longhorn beetles	Anthropogenic: - fire suppression Natural: - succession to late-seral forest

Table 1. Beargrass management considerations

5.2 Fire management

Beargrass restoration on the Olympic Peninsula of Washington State, where declines in beargrass populations have been observed since the 1980s at least, provides an example in which Native Americans, public land managers, and western scientists are working together to actively integrate traditional ecological knowledge into efforts to restore traditional cultural values associated with beargrass. In 1995 the Olympic National Forest began a restoration project in an area that was historically Skokomish territory to restore beargrass and other shade-intolerant species having cultural importance (Shebitz, 2005). American Indians, forest managers, and University of Washington scientists collaborated to design the project and implement treatments. Land management practices based on traditional ecological knowledge about historical landscape structure and burning techniques (e.g., the season, frequency, and intensity of the burn) were reintroduced. Plots have been set up in several places to monitor the effects of different fire and thinning treatments on beargrass. In the early 2000s, additional management experiments were initiatied on the Olympic National Forest and on the Quinault Indian Reservation to determine if prescribed burns would help reverse the observed declines in beargrass populations occurring on the Olympic Peninsula (Shebitz, 2005; Shebitz et al., 2009).

The short-term results of these experiments indicate that both high- and low-severity fire decrease the percent cover of beargrass by burning its leaves and damaging some meristems. Nevertheless, high-severity fire created conditions favorable for seed germination and seedling establishment, and increased beargrass vegetative reproduction. Shoot production also increased two years later. In the short term, low-severity fire did not affect shoot production or seedling establishment, but the scientists hypothesize that, if done repeatedly, it would likely bring about the greatest increase in beargrass abundance. Frequent fire controls shrub and tree encroachment, limiting competition, and helping beargrass flourish. It also favors leaf properties desirable for basketry (Shebitz et al., 2009). Burning does not promote beargrass properties desired by commercial harvesters, however.

Elsewhere, fuel specialists, timber planners, and cultural resource managers have collaborated with California Indian basketweavers to design prescribed burns that enhance beargrass and other important basketry plants on national forests in northern California (Anderson, 2005; Ortiz, 1993). These projects have been motivated by a desire to restore species having cultural value to tribes, and in the process restore habitat types and associated species that have declined in the absence of fires.

5.3 Silvicultural treatments

A silvicultural system is a planned series of treatments for a forest stand that implies a process for creating target conditions over time. The timing and intensity of treatments in any system that is designed to manage forest ecosystem diversity within the range of beargrass will depend on site-specific conditions as well as key management objectives. Clearcutting is an even-aged system that removes almost all trees, creating a fully exposed microclimate for a new age class of trees to develop under. In the Pacific Northwest, clearcutting predominated for a century (Curtis et al., 1998; Tesch, 1994). The system might provide sufficient light to stimulate flowering in beargrass, but could adversely affect the structural properties of soil and the quantities of dead wood associated with adequate drainage and with pollinator habitat. Clearcutting has also been found to reduce beargrass cover because it leads to increased competition with woody shrubs.

As an alternative, a two-aged, shelterwood system could create the dappled light environment that promotes flowering in beargrass, leaf properties suitable for traditional harvesters, and standing dead and down wood for decomposers. A shelterwood is one in which most trees are harvested, but some are left to shade the new trees establishing underneath. It involves the intentional use of shade, which can give desired species a growth advantage over competing vegetation during the establishment phase of regeneration. Trees retained in a shelterwood system are generally harvested after a new age class is established. In contrast to even-aged or two-aged systems, an uneven-aged system regenerates a forest stand with three or more age classes. This is typically accomplished with some form of selection system. In these systems, mature and immature trees are felled to create or maintain uneven-aged stands. Single tree selection fells individual trees and generally tends to increase the proportion of shade-tolerant species in mixed-species stands. Group selection cuts trees in units and therefore maintains a higher proportion of shade-intolerant species in mixed species stands than individual tree selection. Uneven-aged systems would likely create a shadier environment that inhibited beargrass flowering but produced leaf properties desired by commercial harvesters. They would also tend to promote dead and down wood for decomposers.

We did not find published studies on the effects of different silvicultural systems or intensities of harvest specifically on beargrass. We did, however, discover that long-term data sets exist that could help provide insight. The only study we are aware of that used a participatory approach included Skokomish and Quinault tribal members in management experiments designed to identify management practices effective for restoring cultural uses of beargrass on the Olympic Peninsula (Shebitz et al., 2009). In this study, vegetation and coarse woody debris were manually removed from plots in lowland beargrass habitat as an alternative to burning. Manual clearing caused beargrass cover to decrease, and shoot production and flowering to increase. It did not stimulate seedling establishment, however, needed to sustain beargrass populations.

5.4 Commercial beargrass harvesting

Earlier we noted the difficulty in regulating commercial beargrass harvest. If forest managers were to engage harvesters in the management of local beargrass populations, they might be able to more effectively address the barriers that cause illegal harvesting. Harvesters could also contribute to beargrass management by participating in biological inventory and monitoring of beargrass populations. Many are frequent visitors to forests where they observe plants, ecosystem conditions and processes, and are comfortable navigating the terrain (Charnley et al., 2007). Guidance for involving harvesters in participatory inventory and monitoring of nontimber forest products exists (Lynch et al., 2004). Harvesters could also participate in management experiments or research about the impacts of harvesting on beargrass. One excellent model for engaging harvesters in this type of research again comes from the Olympic Peninsula (Ballard, 2004; Ballard & Huntsinger, 2006), and focuses on another important commercial floral green in the Pacific Northwest – salal (*Gaultheria shallon*). There, harvesters participated in identifying study sites, developing research methods, and gathering and interpreting data about the effects of different harvest intensities on salal regrowth and sustainability, leading to management recommendations. For harvesters to participate in such activities, they must see a benefit. Their interest in sustainable management of plants that contribute to their livelihoods, and in having secure and sustained access to harvest locations that would help them steward the resource, could provide an incentive to participate (Charnley et al., 2007).

6. Conclusions

In this chapter we used beargrass to illustrate a view of biodiversity conservation that focuses on relations among species within an ecosystem. We think single-species conservation approaches have obvious limitations, and that successful conservation strategies must be concerned with the multitude of social and ecological roles a species has within an ecosystem. Such a view implies the need to identify the multiple values and ecosystem services associated with a species (that may or may not itself be threatened or endangered) throughout its range, and to determine which may be at risk and whether conservation interventions are called for. Associated social and ecological values may be at risk because a species has become extirpated locally, changes in species distribution have occurred, or there have been changes in specific properties of the species needed to support the value. It follows that conservation needs, and the nature of management interventions to promote conservation, are likely to vary locally.

We have also contended that conservation interventions will be most effective if they are based on an understanding of the interacting natural and anthropogenic disturbance factors that put a species or its ecosystem values at risk. Again, these are likely to vary locally. Knowledge about how disturbance regimes are changing, and the localized effects of these changes, is important for helping to prioritize management responses.

Where information about how to conserve or restore values at risk is limited, traditional and local ecological knowledge can contribute. Conducting management experiments and monitoring results can be one way for natural resource managers to participate with local knowledge holders to learn what strategies are effective. In this regard, local metrics – preferably those that are important from both an ecological and sociocultural standpoint – are desirable as indicators of conservation success. One example would be abundance of beargrass flowers, which are desirable for pollinators, decomposers, game animals that people hunt, and nature lovers. If different values are at risk in the same locale (such as traditional and commercial uses of beargrass), but different ecological conditions and management interventions are needed to protect these values, it will be necessary to prioritize what values to favor in a particular place. Conservation strategies that address both the sociocultural and ecological values of a species that are important to people will be more likely to receive support, and to succeed, than those that do not.

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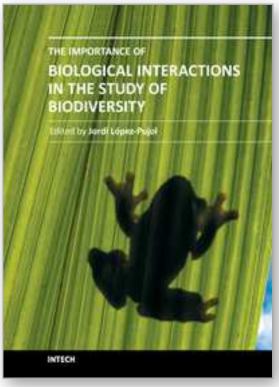

The Importance of Biological Interactions in the Study of Biodiversity
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The term biodiversity defines not only all the variety of life in the Earth but also their complex interactions. Under the current scenario of biodiversity loss, and in order to preserve it, it is essential to achieve a deep understanding on all the aspects related to the biological interactions, including their functioning and significance. This volume contains several contributions (nineteen in total) that illustrate the state of the art of the academic research in the field of biological interactions in its widest sense; that is, not only the interactions between living organisms are considered, but also those between living organisms and abiotic elements of the environment as well as those between living organisms and the humans.